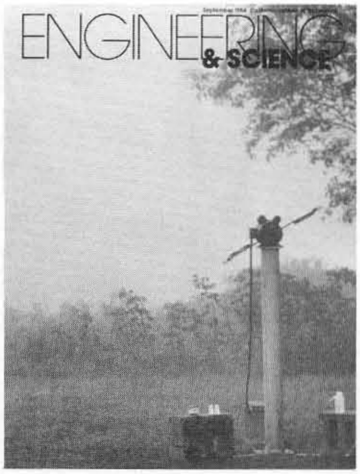
September 1984 California Institute of Technology

ENGINEERING & SCIENCE

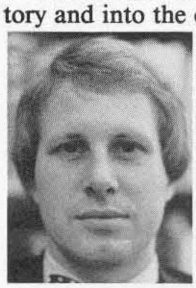
In This Issue



In a Fog

On the cover — Caltech's rotating arm collector (RAC) gets set to capture fogwater droplets for a study of the acidity of fog. The scene is Albany, New York, which, despite the Northeast's reputation for dirty air, had the cleanest fog of all the sites studied by Michael Hoffmann and his research group.

Hoffmann got into fog when he came to Caltech as associate professor of environmental engineering science in 1980 after five years at the University of Minnesota. He describes himself as an applied chemical kineticist and had previously worked — in the laboratory — on the reactions of sulfur dioxide in aqueous systems. On looking around for a problem appropriate to southern California, an aqueous system that immediately suggested itself was fog, a project that took him out of the laboratory and into the clouds.



One of Hoffmann's most important findings was that air quality in southern California is directly related to relative humidity, or the presence of fog along the coast. His detailed studies of the chemical composition of fogwater have shown that it can be 100 times more acidic than southern California's acid rain and potentially more hazardous. "Acid Fog," Hoffmann's account of some of his findings, which begins on page 5, was adapted from his Seminar Day talk last May. Hoffmann is a graduate of Northwestern (1968) and earned his PhD in chemistry from Brown in 1974.

On the Spot

Rochus (Robbie) Vogt has been Caltech's provost and vice president for a little over a year and a half, a post he was perhaps destined by his ancestry to hold: His surname in German means literally "provost," among other things, all harking back to the chief administrator of a castle in medieval times.

Before submitting to this fate, Vogt had been a member of the physics faculty since 1962, most recently as the R. Stanton Avery Distinguished Service Professor (since 1982) and as chairman of the Division of Physics, Mathematics and Astronomy (1978-83). He arrived at Caltech by way of the University of Chicago, Antarctica, and Germany. In a series of interviews this summer Vogt discussed how he got here from there and what he thinks of his new job. "Caltech's Vogt," based on those interviews, begins on page 12.

New Look

Jacquelyn Bonner, editor of *E&S* for the past five years, decided last spring that the constant hassle of deadlines was perhaps not the most enjoyable thing in life and that working half time would be preferable. Caltech will still keep some of the benefit of her valued editorial expertise, however. She will continue as senior editor on the Publications staff but, along with her husband, Institute Registrar Lyman Bonner, who is also going on half time, will spend part of her days in less demanding pursuits.

Jackie has worked at Caltech for 22 years, since 1965 with *E&S*. She became associate editor in 1968 and managing editor in 1971, and when Ed Hutchings, the magazine's longtime editor, retired five years ago, Jackie was his obvious successor. Ed's 31-year-old identification with *E&S* was a tough act to follow, but Jackie followed his tradition admirably well with a good show of her own.

Jane Dietrich, who has been on the *E&S* staff for the past five years, is the new editor. The September issue was put together with the editorial assistance of Neil Saccamano and other members of the Public Relations staff. Dennis Meredith, director of the News Bureau, and Sylvia McBride in the Division of Engineering and Applied Science contributed articles.

For the first time, all the type for this issue was set on the phototypesetter at Caltech's Booth Computing Center with the invaluable help of Kim Border, associate professor of economics.

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ENGINEERING & SCIENCE

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SCIENCE/SCOPE

Artificial intelligence, the programming that lets computers "think" almost like humans, is the focus of a new advanced technology center at Hughes Aircraft Company. The facility brings research and development efforts under one roof. Scientists and engineers will work closely with universities throughout the country to develop software and equipment. Finished systems will be able to make far more complex decisions than the simple "yes" or "no" decisions that traditional software programs require. Projects will include self-controlled systems and image understanding - both of which can be used in such applications as geological surveys from space, manufacturing technology, and defense.

Satellite Business Systems will add two space craft to its constellation of four to provide U.S. businesses with voice, facsimile, teleconference, and high-speed data services. Like their predecessors, SBS-5 and SBS-6 will operate in the K'band frequency range. In addition to the standard 10 channels of 43'MHz each found on earlier versions, the new spacecraft will carry four transponders with bandwidths of 110'MHz each. This feature nearly doubles the telecommunications capacity of SBS-1. The new satellites will allow SBS to serve Alaska and Hawaii for the first time. They are designed with a 10-year operational life instead of the current seven. The new spacecraft are based on the Hughes HS'376 model. This versatile drum-shaped satellite, with 30 versions sold, is the world's most popular commercial communications satellite.

Development times for semicustom very large-scale integrated (VLSI) circuits have been cut from greater than one year to 20 weeks at an ultramodern computer-aided training and design center at the Hughes facility in Newport Beach, California. Utilizing advanced design automation software, a comprehensive library of predesigned logic functions (called Macros), and preprocessed wafers, the new facility is helping engineers design chips with 2,000 to 8,000 gates and with as many as 180 pins. New 3-micron dual-layer metal HCMOS processes are applied to both standard cell products and state-of-the-art gate arrays. Skilled design engineers and education specialists at the Newport Design Center provide training and technical support for IC designers throughout the company.

Hybrid integrated optical receivers have been developed by Hughes research scientists for transmitting microwave-modulated optical signals over fiber-optic links. The receivers are part of an effort to find inexpensive links for such applications as phased-array antennas, satellite ground stations, radars, and communications systems. Each receiver consists of a high-speed gallium arsenide Schottky photodiode developed at Hughes and a low-noise amplifier using commercial gallium arsenide field-effect transistors. These receivers are designed to operate at a modulation frequency of 3 GHz with a 1 GHz bandwidth. Their advantages over discrete components include better sensitivity, lower noise, and the elimination of ripples in the frequency response caused by impedance mismatch between detectors and commercial amplifiers.

Hughes needs graduates with degrees in EE, ME, physics, computer science, and electronics technology. To find out how to become involved in any one of 1,500 high-technology projects, ranging from submicron microelectronics to advanced large-scale electronics systems, contact Corporate College Relations Office, Hughes Aircraft Company, P.O. Box 1042, Dept. C2/B178-SS, El Segundo, CA 90245. Equal opportunity employer. U.S. citizenship required.

For more information write to: P.O. Box 11205, Marina del Rey, CA 90295

HUGHES
AIRCRAFT COMPANY

Acid Fog

by Michael Hoffmann

VIRTUALLY ALL the world's air pollution episodes or disasters are known to have been associated with heavy fog conditions. During the five days in December of 1952, for instance, when thick fog virtually deprived London of light at noon, the death rate rose dramatically from the normal daily average of 250 to approximately 1,000 per day. As the fog dissipated and was removed, its effects began to diminish. By the time the death rate finally returned to normal three months later, the fog had claimed 12,000 excess deaths.

Pollution episodes of the same order of magnitude on a per capita basis have occurred in the Meuse Valley of Belgium near Liege and, in the U.S., in Donora, Pennsylvania. These episodes have usually only been considered extreme and rare examples of the damage possible from acidic fog and associated air pollutants. Our research at Caltech has indicated that on occasion the concentrations of acid in fog in certain areas of southern California do not differ greatly from those calculated for the London fog of 1952.

Over the years, the public has become more aware of the concept and reality of acidic deposition, primarily through the phenomenon of acid rain. Acid fog is now also fairly well known, and some may even be informed that acid snow has been observed. Yet while the publicity given to acid deposition phenomena may be relatively recent, the phenomena themselves most definitely are not. In a landmark textbook, *Air and Rain*, which was published in 1872, Robert Angus Smith not only presented at length his own research on acid rain in Brit-

Thick fog blankets London in December 1952, turning noon into night. During the five-day siege of fog the death rate quadrupled.

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ain and Europe but discussed previous studies on the acidity of fog dating from as long ago as 1811. So although we at Caltech have contributed significantly to understanding the processes that lead to the acidification of fogs and clouds and subsequent production of acid rain, we have in fact rediscovered phenomena that were familiar to scientists at the beginning of the 19th century.

Our rediscovery has proceeded by studying the acid concentrations of fog, or low-lying clouds, in southern California. Clouds, we now know, are very active environments for the conversion of sulfur dioxide to sulfuric acid. For many years, though, the primary pathway for oxidation of SO_2 to H_2SO_4 was thought to be in the gas phase. At first, an active form of oxygen and, later, ozone were believed to be involved in the gas-phase reactions; eventually, we settled on the hydroxyl radical — a very reactive species generated in photochemical environments when sunlight is present. But as it turns out, none of the known rates of gas-phase reactions can predict the observed atmospheric conversion rates of SO_2 to H_2SO_4 or other products, such as ammonium sulfate or ammonium bisulfate. Based on our current research, it is apparent that reactions occurring in clouds and aquated haze aerosol can account for much of the rapid conversion seen in urban and even rural atmospheres.

The acidification phenomenon begins primarily when the combustion of fossil fuels produces SO_2 and NO_x. Normally unreactive, nitrogen and oxygen combine through high-temperature combustion to form NO, which is subsequently oxidized to NO_2. These gases are discharged into the atmosphere and dispersed by turbulent mixing and advection. Though the gas-phase reactions are not extremely fast under ambient conditions, the SO_2 and NO_x in the atmosphere can be oxidized to produce H_2SO_4 and HNO_3 gases. Nitric acid remains in the gas phase. But once the concentration of the gaseous sulfuric acid reaches a sufficiently high level, homogeneous nucleation occurs and particles or droplets of pure sulfuric acid form. Some of these sub-micron droplets of H_2SO_4 will be neutralized by ammonia gas derived primarily from agricultural activities. If the acidic particles are large enough, they can settle to the earth by sedimentation; otherwise, this dry form of deposition is accomplished through turbulent transport to the surface.

The fastest production of sulfuric acid occurs in clouds. Absorbed by clouds, the fairly soluble SO_2 is dissolved into the liquid phase and, as a result of chemical reactions taking place within this assemblage of liquid water droplets, it is transformed into H_2SO_4 (that is, H^+, HSO_4^-, and SO_4^{2-} in the aqueous phase). As similar pathways are open for the conversion of the nitrogen oxides to nitric acid, clouds will accumulate predominantly these two acids. And when precipitation occurs, of course, the acids are brought back down to earth.

Besides acid rain's wet and dry forms of deposition, we have recently discovered a mode of precipitation that has not previously been taken into account. We call this phenomenon "occult" precipitation. As the clouds and fogs move through the environment, the acidic droplets are deposited on trees — which are very good fogwater collectors — and, through them, drip down to the earth. In coastal regions, it turns out, vegetation can receive up to 50 percent of its total moisture during the year from the occult precipitation of impacted cloudwater and fogwater.

To get an idea of the acidity of rainfall, we have to know its pH — which is defined as the negative logarithm of hydrogen ion activity (that is, concentration). A pH of 7 — a concentration of 10^{-7} molar — is considered neutral, so that any pH lower than 7 should ordinarily indicate notable acidity. But this value does not take into account the equilibrium between carbon dioxide as a gas naturally present in the atmosphere and carbon dioxide in the aqueous phase. When dissolved in water, aquated carbon dioxide dissociates to give a proton and bicarbonate with a resultant pH of 5.6 for the above atmospheric concentration. Rainfall has always, of course, been acidic; but the pH values of acid rain are much less than the anticipated "clean" background level of 5.6.

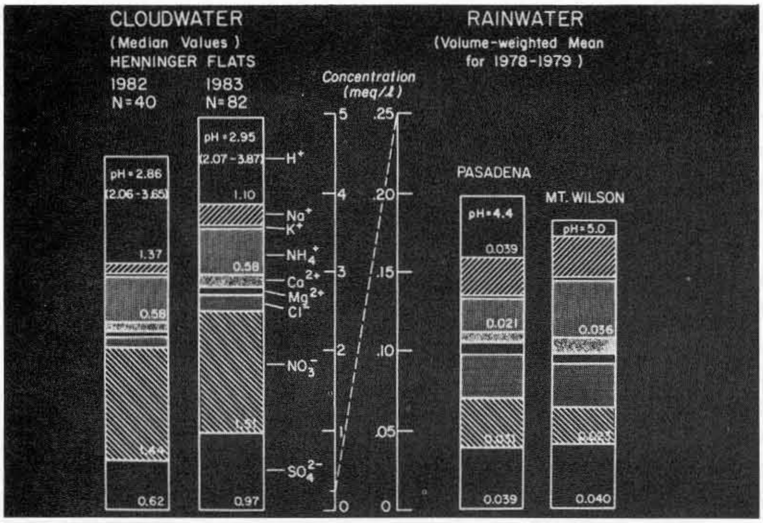
Public attention has focused on the northeastern part of the United States as the area where the most severe acid precipitation is taking place. Rainfall in the New England states typically has a pH of 4, while 4.2 would be a low value for Florida, for instance. And though measurements of the pH of rainfall in southern California have gone as low as 2.9, the acidity of the region's rain is, on the average, one-third less than in the northeast. A typical value for Pasadena in 1979- 1980 was 4.8; in Riverside in the eastern part of the Los Angeles basin, where there are bases — such as soil dust, and ammonia from cattle feedlots and other agricultural activities — that can neutralize some of the acidity in the droplet phase, the pH was about 5.2; and at Big Bear in the San Bernardino Mountains, the value was determined to be 5.65 in 1979.

The severity of acid deposition in southern California cannot be assessed, however, only on the basis of the average pH of rainfall. Our research on the acidity of fog in this area indicates that the field of acid deposition must be widened to include phenomena whose acidity may be 100 times that of acid rain.

An important finding in southern California was that air quality — the visibility and sulfate loading of the atmosphere — is directly related to relative humidity or, under certain circumstances, to the presence of fog along the coast. When the fog burns off in the morning, visibility in the afternoon is quite low and particulate sulfate concentrations in the atmosphere are quite high. On days of high relative humidity, generally when it's greater than 50 percent, a haze aerosol occurs. An aerosol is usually called smog, but it's actually a precursor of fog since it contains aquated particles that cause light scattering and visibility reduction.

As our data strongly indicated a correlation between fog and sulfate pollution in the

Views of the San Gabriel Mountains from the roof of Keck Laboratory compare a typical clear winter day (top) with the familiar summer smog (bottom). The smog is actually a haze aerosol that occurs on days of high relative humidity.



The chemical composition of cloudwater at Henninger Flats in the San Gabriel Mountains is compared above with that of rainwater in Pasadena and on Mount Wilson.

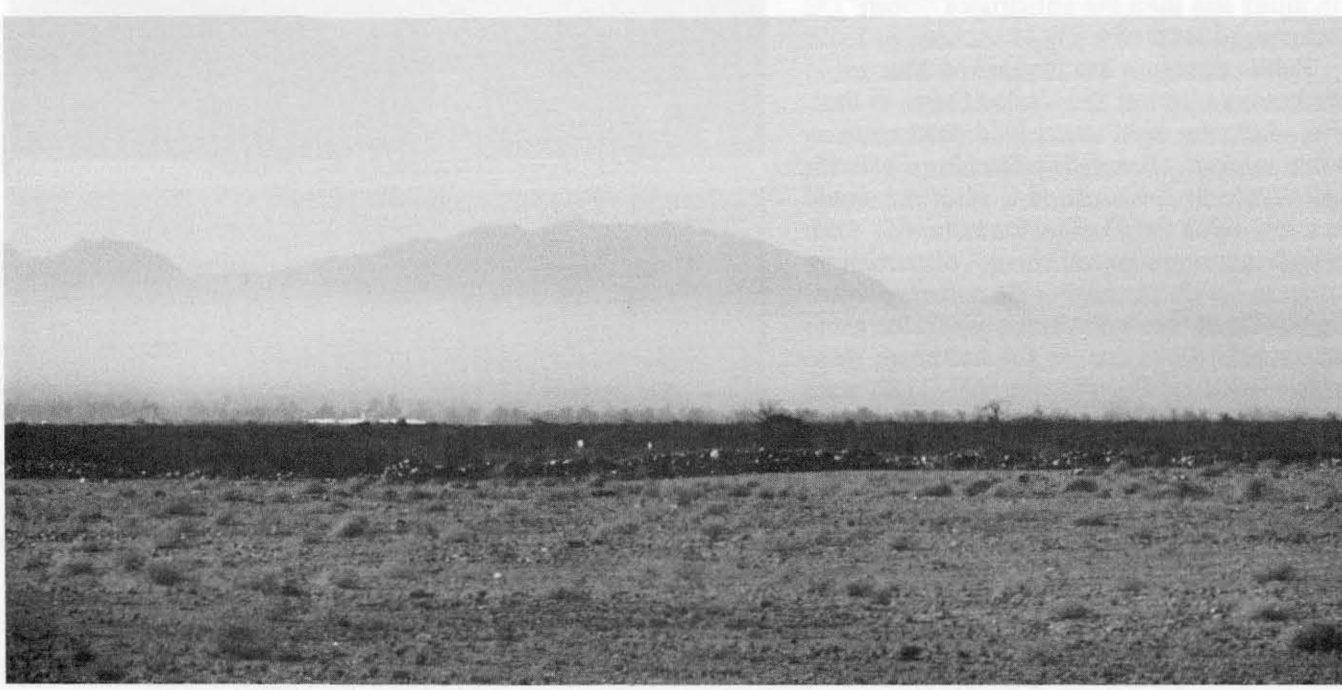
southern California atmosphere, we suspected that the aquated droplets of both fog and haze aerosol would comprise a very active environment for the conversion of SO_2 to H_2SO_4. The situation in fogs and clouds is very similar. For a cloud droplet or a fogwater droplet to form, there has to be a condensation nucleus. The condensation nucleus can be soil dust, sea salt aerosol along the coast, fly ash from power plants, or secondary or haze aerosol. Under the appropriate conditions of relative humidity and temperature, water will then condense on the particles' surface and either a cloud or a fog, when the cloud is at the ground, will be formed.

The chemical composition of the fog will, to some extent, be a direct function of the chemical composition of the condensation nucleus from which it was formed. Part of that nucleus will be soluble, and those soluble chemical components will go into the aqueous phase. In the atmosphere certain gases will partition into the aqueous phase and undergo various chemical reactions. Among the many organic and inorganic reactions taking place in this droplet phase and contributing to the acidification of fogs and clouds, the ones that particularly interest us produce sulfuric, nitric, and sulfonic acids.

The acidification process starts with sulfuric acid, nitric acid, NO_x, SO_2 in the gas phase, aldehydes, ammonia, and water. First, gas-to-particle conversions occur to form solid or liquid particles, which then deliquesce. Next, light-scattering haze aerosol droplets form with particle diameters near 0.5 microns (10^{-6} meters). These droplets may be quite acidic, containing nitrate, sulfate, sulfonates, ammonium ion, and free acidity. Given proper conditions, what is called activation then occurs and fogwater or cloudwater droplets are produced. The measurements we've made at different stages in this process show that, on a volume basis, the haze droplets are much more acidic than the fogwater or cloudwater droplets, which in turn tend to be more acidic than the much larger rainwater droplets.

We have called this interdependence between smog and fog the smog-fog-smog cycle. As the temperature drops rapidly in the evening after a warm day when a large amount of water has evaporated, the relative

Fog also comes in on little cat feet near Riverside near the foot of the San Bernardino Mountains.



humidity increases, water condenses on the haze aerosol droplets, and acidic chemical components are introduced into the aqueous phase. During the course of the fog the gaseous components are dissolved and diluted, more acidity is produced in the droplet phase, and, as once again the temperature goes back up and the relative humidity goes back down, the droplets begin to evaporate. The acidity of the droplets affected by evaporation at this stage in the cycle is very high. Eventually, a haze aerosol reappears, providing the seed for the production of smog on the subsequent day. Until a new primary meteorological condition comes in to break it up, the cycle of smog and fog will continue.

To obtain the cloudwater and fogwater for our measurements, we developed a device called a rotating arm collector (RAC). The collector looks like a propeller or helicopter blade with sampling bottles firmly attached to the periphery blades. Rotating at a velocity of roughly 1,800 rpm, the collector's blades sweep out a cylinder of air and capture fogwater droplets by inertial impaction. While the smaller particles or unactivated condensation nuclei in the fog follow the fluid mechanical streamlines around the rotating blade, the larger fogwater droplets, due to their inertia, strike the leading edge of the blade and are forced inside. Once inside, they hit a tube or cylinder and are pushed outward by centrifugal force into the sampling bottles. In side-by-side comparisons with cloudwater collectors designed at other universities, the Caltech collector has proven to be a superior collection device under a wide range of operating conditions.

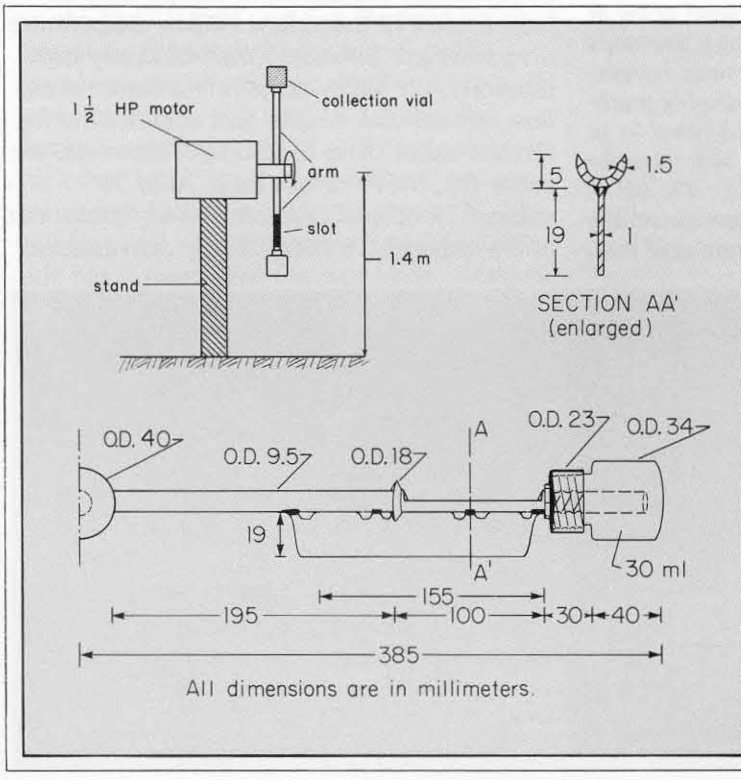
Our collector has a droplet size cut of roughly 10 to 20 microns. Fogwater droplets have a mass median diameter of 20 microns, and none are found smaller than 2 microns in diameter. In most fogs, however, the droplets are less than 50 microns. So although the collector accumulates only a certain fraction of the smaller fogwater droplets in the range of interest of 2 to 100 microns, it collects those greater than 15 microns with close to 100 percent efficiency.

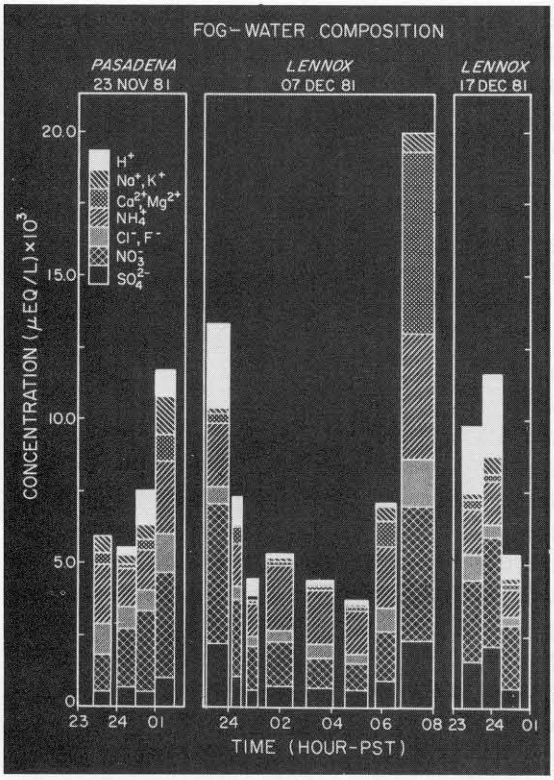
In the field, we use a laser optical particle counter to determine the droplet size distribution and the number of fog droplets present. To measure the amount of water in the atmosphere, or what is called the liquid water content, we use a laser transmissometer, which measures the attenuation of a 9.2- micron laser beam over a 10-meter path length. A cyclone separator enables us to filter out of the fog the unactivated condensation nuclei so that we can determine their chemical composition. We also determine the composition of the haze aerosol before and after the fog, measure all the gases in the gas phase, and then do all the chemical analyses to understand what occurs within a fog or cloud environment over the course of time.

When plotted as a function of time, concentrations of major chemical components — typically sulfate, nitrate, chloride, formaldehyde, ammonium ion, calcium, magnesium, sodium, potassium, and hydrogen ion — generally follow a concave profile. At the beginning of the fog, the concentrations are high; as the fog develops, the liquid water content rises, the droplets are diluted, and the acidity drops; and, then, as evaporation takes place, the relative humidity decreases, the temperature goes up, and there is a concentration effect. As a consequence, the pH value of a fog varies as a function of time.

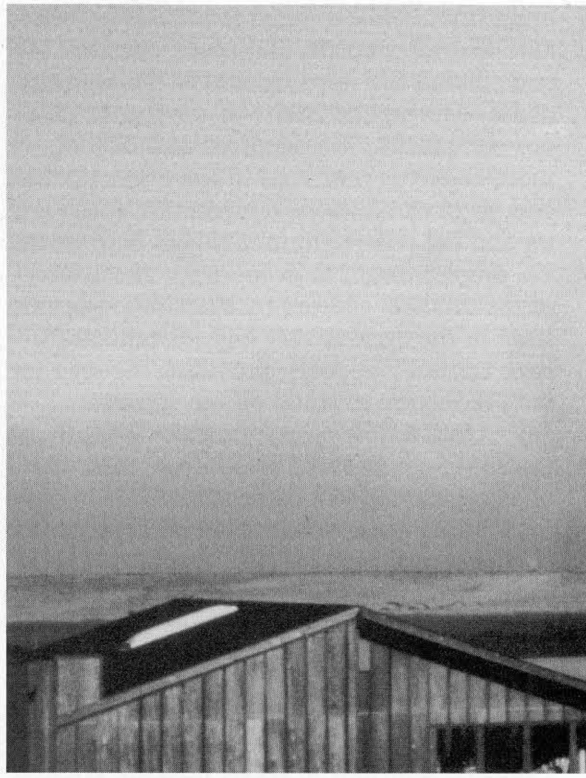
Most fogs follow this concave concentration-versus-time profile; not every fog, however, follows the symmetrical pattern described previously. Fogs in the Central Valley of California, for example, are seldom as acidic at the end as they are at the beginning. They usually last for longer periods of time (the longest, known as Tule fogs, can persist for up to 20 days) but undergo a gen-

Caltech's rotating arm collector is shown in the diagram below at top left; half of the arm is enlarged below it, and at top right is a cross section through the arm of the slot in which the fogwater droplets are collected.





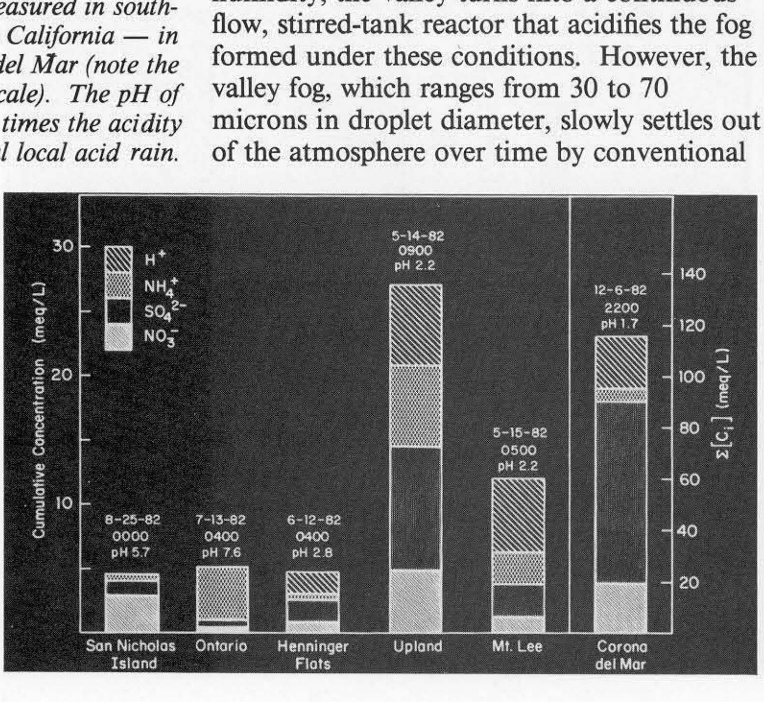
A fog system developed over time presents a concave profile — high concentrations at the beginning, going down as the liquid water in fog dilutes them, and rising again as evaporation occurs. Lennox is near the Los Angeles International Airport and was one of the first sites studied.

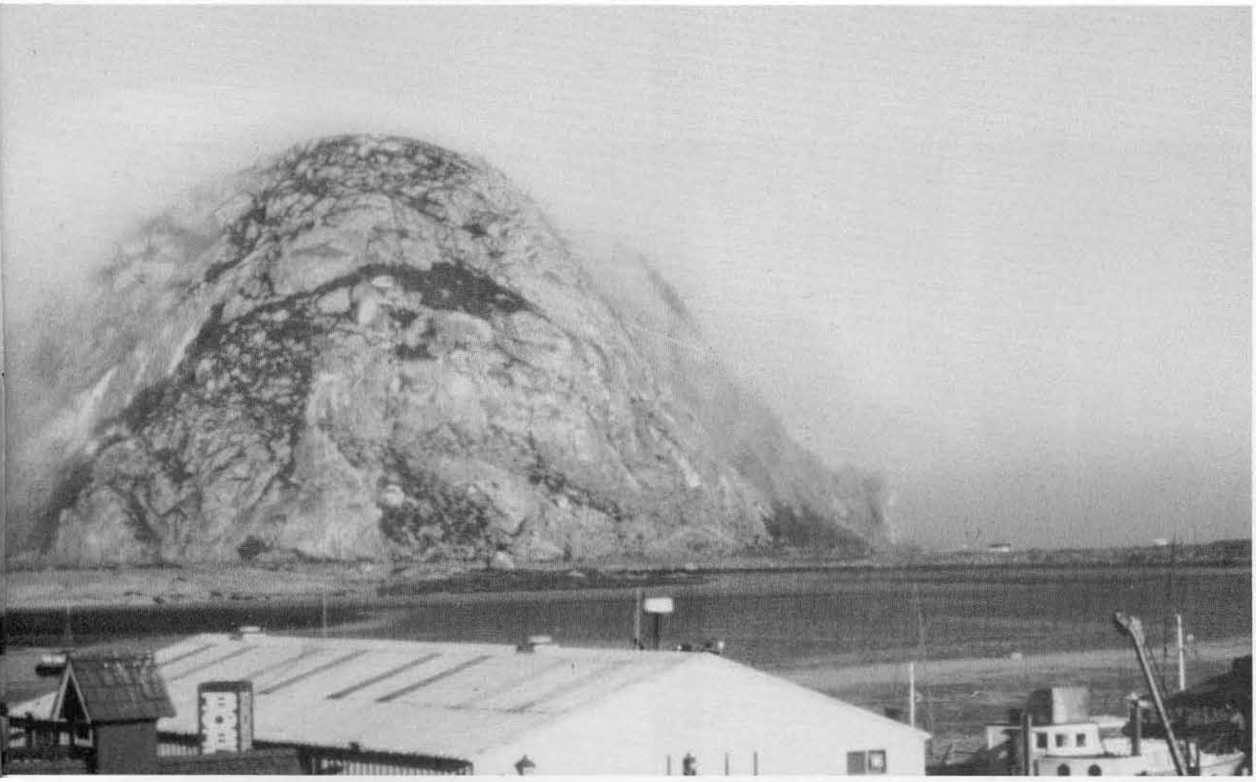


eral decline in acidic concentration. The reason for this is that a certain portion of the fogwater droplets reach the earth by deposition. Oil recovery operations in Kern County release sulfur dioxide and nitrogen oxides that are converted to sulfate and nitrate. In addition to these ions, ammonia and hydrogen ion dominate the chemical composition of haze aerosol in the valley. When temperature inversions are associated with relatively high humidity, the valley turns into a continuous-flow, stirred-tank reactor that acidifies the fog formed under these conditions. However, the valley fog, which ranges from 30 to 70 microns in droplet diameter, slowly settles out of the atmosphere over time by conventional sedimentation. This results in an overall removal of acidity from the atmosphere during the course of a fog event in the Central Valley.

The measurements of fog we've taken in southern California show a pH in the domain of roughly 3 to less than 2. Since acidity is a function of time in any fog event, the pH values used to compare a number of locations must have been obtained at approximately the same point in time during the course of a fog. The most extreme event observed in southern California was a relatively light, evaporating fog at Corona del Mar, during which the pH reached a low of 1.7 — an acidity equivalent to that of some common toilet bowl cleaners. This fog was about 1,000 times more acidic than the typical acid rain in southern California and about 10,000 times more acidic than relatively pure rainfall. Its nitrate concentrations were quite high; they were found to be roughly three times the sulfate. This ratio seems to hold for the Los Angeles area as a whole. Mt. Lee (known for the Hollywood sign), though not as highly concentrated as Corona del Mar, was also quite acidic: pH 2.2. Upland had relatively low pH values and slightly higher concentrations, resulting in an acidity approximately 100 times higher than typical acid rain. And at Henninger Flats in the San Gabriel Mountains, the cloudwater main-

Observations of the major constituents of fog at several sites are compared with the most extreme acidity measured in southern California — in Corona del Mar (note the different scale). The pH of 1.7 is 1,000 times the acidity of typical local acid rain.





Fog forms as a density-stratified flow over Morro Rock. Morro Bay was found to have relatively clean fog.

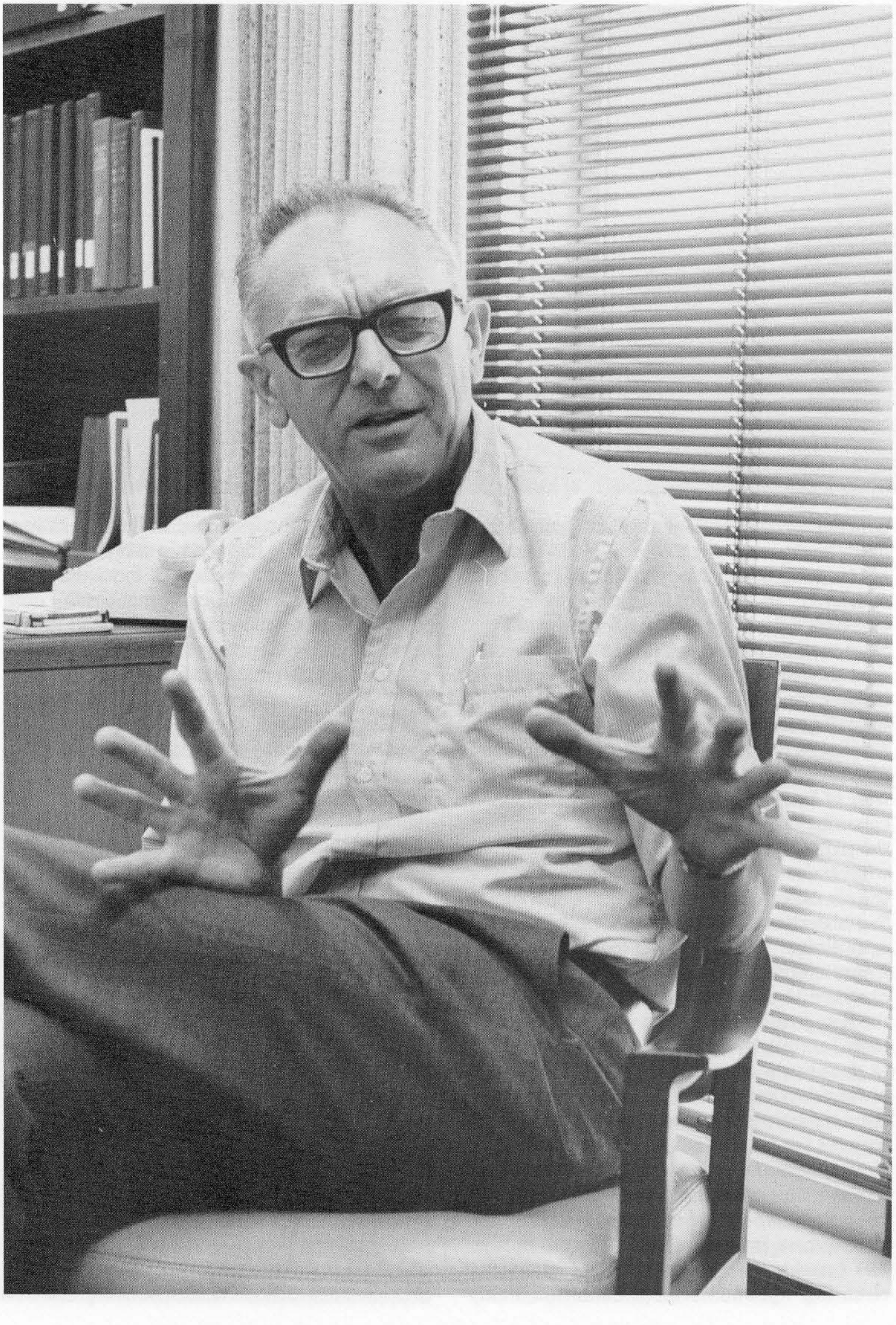
tained an average pH of approximately 2.8 over three years.

Acid fog is not the only kind of fog we've measured. In Ontario, California, we observed a basic fog of pH 7.6 downwind from a cattle feedlot, where the hydrolysis of urea to yield ammonia and carbon dioxide helps to neutralize potential acidity. But such basic fogs--and their requisite conditions--are anomalies in southern California. One midnight on San Nicolas Island, 60 miles due west of Los Angeles, we found a relatively clean fog of pH 5.7; by the end of the night, the pH had dropped to 3. An analysis of the wind trajectories indicated that on that day the air mass was coming straight down the Santa Barbara Channel over the offshore oil operations. As a result, the fog that night had a very different chemical signature from fogs observed in either the Los Angeles basin or the San Joaquin Valley (that is, sulfate dominated nitrate by a ratio of two to one).

Relatively clean fogs have also been observed. Despite the tendency to think of the northeast as being relatively dirty, that region's fog was found to be comparatively clean at ground level. In fact, one of the cleanest sites we have studied was in Albany, New York, where the acid concentrations were a mere fraction of what they are in the Los Angeles area. Morro Bay had relatively clean fog, while in northern California, Point Reyes showed the influence of the San Francisco air mass: its fog was routinely acidic, but did not contain levels and concentrations of acidity as high as in fog farther south.

Through the phenomenon of occult precipitation, acid fog may take its toll on southern California's environment in unsuspected ways. The extensive damage suffered by trees on the San Gabriel and San Bernardino mountain slopes may be a partial consequence of the intercepted cloudwater in a pH range of 2 to 3. It's hard to say that this damage is directly due to acid deposition; on the other hand, it's hard to believe that an entire tree bathed in water of about pH 2.5 will fare well. Recent research at UC Riverside has documented the damaging effects of water at this pH on a variety of plant surfaces.

Although we have made significant advances in our understanding of aqueous-phase atmospheric chemistry over the last three years, much research lies ahead. The complexity of the acidic deposition problem is enormous, and no easy solution is readily apparent. In a few more years we hope to have greater insight into the chemistry and physics of cloud acidification. At that point there may be a more fundamental basis for implementing specific pollution control strategies to reduce the inherent problem of acidic deposition and, in particular, acid fog. □



Caltech's Vogt

Vogt,...overseer, bailiff, steward, warden; prefect, magistrate, governor, administrator; provost, constable, beadle...
Cassell's German & English Dictionary

As VOYAGER 1, its planetary missions completed, heads out toward the edge of the solar system, it grows more and more exciting to the cosmic ray scientists, whose project's major phase is yet to come. When the spacecraft crosses the heliopause sometime in the 1990s, its cosmic ray experiment will send back the first scientific data on the low-energy galactic rays that inhabit interstellar space. Rochus (Robbie) Vogt, however, who has been involved with the Voyager mission since its beginning and who was principal investigator on the cosmic ray experiment, will be denied participation in the excitement of the new discoveries. Vogt resigned from the Voyager team July 1; being Caltech's provost left him no time for honest participation in the Voyager work.

"Voyager was a very personal thing for me," says Vogt. "For a long time it was what I lived and bled for." Although perhaps the most painful, this was only the latest in a series of renunciations. After being named vice president and provost in January 1983, he resigned as chairman of the Division of Physics, Mathematics and Astronomy, and as principal investigator of Caltech's high energy astrophysics program. "In the last year all remaining connections with the research program I've developed have been severed," he says. "I am now a person without any roots."

Rootlessness has been a leitmotiv of Vogt's life. But what roots he has are at Caltech now, and the passionate commitment those roots seem to demand explains his willingness to give up his research to take on the provostship, to become the president's "hired gun," as Vogt himself puts it. He doesn't like the phrase, but most of the Caltech community would agree that it's an apt description of a difficult job.

"Caltech is what I am sworn to," he says. "I clearly have a greater loyalty to Caltech than to anyone. I am uncompromising when it comes to the well-being of Caltech." He feels Caltech is his home. He rates it even higher than a country, and he feels strongly that he owes it something.

Vogt sees the provost as part of a team with the president; they work together on all issues, but "Murph's the boss." Because of their particular backgrounds, "we will have a different kind of division of responsibilities than a different president and a different provost would have." His own strength, he thinks, is in planning, solving problems, getting things done, and he feels "very comfortable in dealing with organizational systems. In fact, it's very difficult to keep me out of these things — fortunately or unfortunately for Caltech," he adds.

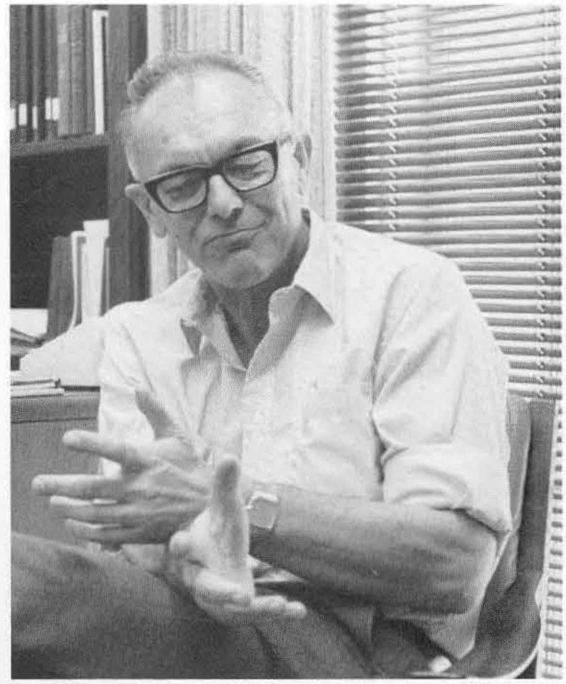
This provost isn't just the chief academic officer in a very narrow sense, according to Vogt's view, although, because of the absence of a layer of deans between the provost and the division heads, he does consider himself accountable to the faculty ("which is healthy though uncomfortable"). But, rather, the Vogtian provost is the chief operating officer, responsible for managing the day-to-day affairs of the Institute. And that means *all* the Institute affairs. "I will do whatever needs to be done for Caltech, no matter in what area." For example, he's deeply concerned about the well-being of the non-academic staff and considers them inextricably connected to Caltech's academic life. He considers himself ultimately responsible for students too and thinks they should have some input into the decisions he makes ("but they'll have to compete for my time like anyone else"). He doesn't want to meddle in other vice presidents' tasks, but "when it comes to policy matters, basic issues, these are as much my concern as anybody else's," and he will not hesitate to step into someone else's arena. But he freely admits that this vigorous, all-encompassing concern for Caltech's affairs has often made him a headache, or at least an "inconvenience" to others.

Vogt has already had a few headaches of his own as provost, the most visible of which have involved Caltech's Jet Propulsion Laboratory — first, faculty dissatisfaction over Caltech's association with the Army's Arroyo Center, and now the still simmering controversy over the presumed "Star Wars" aspects of the Talon Gold project. But JPL is an important part of Caltech, says Vogt, and probably no one at Caltech more typifies the integral connection between the two than Vogt himself, who, in addition to his long association with Voyager and cosmic ray experiments on other NASA projects (OGO, IMP, HEAO, ISEE), was the first Chief Scientist at JPL when that post was created in 1977.

He thinks there can be no doubt that the campus and JPL mutually enhance each other. JPL has benefited intellectually from its integration with Caltech to become one of the most, if not *the* most, outstanding of the national laboratories; the campus gains the management and engineering capacity to undertake larger, more ambitious projects. "The existence of JPL forces the campus community to be less parochial, to consider larger issues," Vogt says, a situation that he considers positive, even when it causes headaches. Although some differences ("JPL is hierarchical; the campus is anarchical") may strain the relationship, he feels that adjustments on both sides are worth the effort to keep it harmonious. "It's like a marriage — you have to work hard at it. And it's perfectly normal to have to do so."

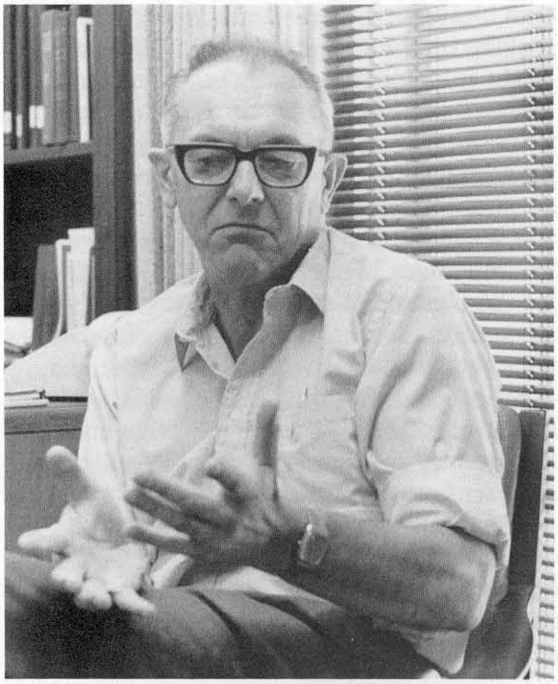
Such problems will most certainly involve making some unpopular decisions, but Vogt has the reputation of a man unafraid to make them. And although the style of a hired gun is, unavoidably, not universally regarded as positive, Vogt's candor about himself and his position can be disarming. "I am what I am," he says. "They get what they see."

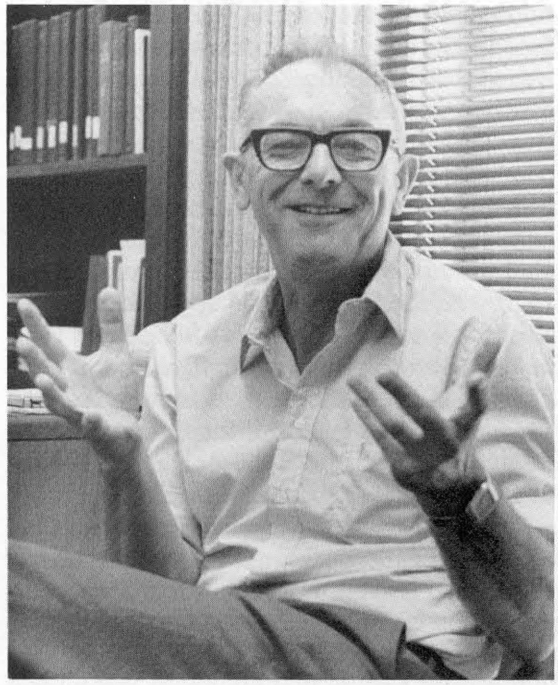
What they see is a strong personality, an intense and volatile man, quick to express what he thinks, which is not always what they want to hear. This intensity has laid his health low at least once, and since 1973 he hasn't smoked and has been a regular morn-



ing runner on the Caltech track, now more for mental than for physical relaxation. "Sometimes when I run I manage the luxury not to think; sometimes I do think and decide how I'm going to handle the difficult problems of the day." He doesn't appreciate distraction during this hour for himself. Although he figures he can run away from most people who importune him on the track, "in the shower — there's the danger. Some people are very good at roping you in. They ask you an innocent question and then you are stuck." But despite a driven schedule, most of the rest of the time Vogt is extremely willing to be accessible to the Caltech community and to address problems that need to be solved — "just don't get the idea that I'm sitting up here lonely." He has always had plenty to do.

Vogt was born into a "culturally privileged environment" in southern Germany, an environment that was about to vanish completely with Hitler's rise to power. His childhood and education devastated by the Nazi regime, he spent the early postwar years working first on a farm and then as a worker in the steel mills. It was the latter experience that motivated him to attend the Technical University of Karlsruhe to become a steel industry engineer. Instead, he discovered physics there — and chess. After a profitable year of hustling chess games for money ("I was no Bobby Fischer, but I was damned good") and *not* attending physics lectures, his professor gave him the choice of going cold





turkey on chess or quitting physics. Vogt still collects chess pieces and reads chess books, but he hasn't played a serious game since.

His English name also comes from his German student days. Vogt was christened "Robbie" by an American officer in Karlsruhe, charged, among other things, with inspecting university labs "to make sure we weren't making nuclear weapons. They thought the Germans were very ingenious; they were wrong; we were not that good." As student government representative, it fell on Vogt to argue with the man and get him to "stop bugging us." Oddly enough, this turned into friendship; Vogt moved in with the American family, and the problem arose of what to call him, since no one could pronounce his given name. "It came down to Rocky or Robbie, and it was my good fortune that he chose Robbie." The name stuck. No matter where he went thereafter, there was always someone who had known him as Robbie. He seems quite comfortable with the name, though it still, decades later, puzzles his German relatives.

The University of Heidelberg followed Karlsruhe. But his American friends urged him to apply for a Fulbright fellowship, which took him to the University of Chicago in 1953, where he became involved in astrophysics and cosmic rays under Peter Meyer and John Simpson. His Fulbright was extended another two years, one of which he spent at sea and in Antarctica as the only physicist with Admiral Richard Byrd's Expedition Deepfreeze in preparation for the International Geophysical Year. Thereafter he dutifully returned to Germany because he was legally required to leave the United States (and also because he thought the Chicago PhD qualifying exams might be too hard), only to run into the derision of his German professor, who thought he must be crazy for blowing his chance to get away from Germany. Physics in Germany was a mess then, Vogt says. Laboratories were poorly equipped, students had to share basic instruments in around-the- clock shifts, and components had to be bought from the American GIs on the black market.

So he came back — with a little help from Byrd, who got him legal immigrant status under what was known as the "Basque sheepherders act," which admitted without the usual obstacles anyone who had a skill that didn't exist in the United States. As the only physicist on Byrd's previous expedition, Vogt had a unique skill to train the science crew of the next Antarctic expedition. After a short stint exercising this skill at the naval school in Providence, Rhode Island, he returned to Chicago, where apparently the qualifying exams were not so hard after all, and finished his PhD.

"And then they kicked me out," Vogt states. Chicago had a rigorous law against inbreeding and forced its graduates to move on. "They were absolutely right; otherwise the apron strings would never have been cut. I wanted to stay, desperately. It was a beautiful laboratory, the leading laboratory in the field in the country." But as soon as Vogt was exposed to Caltech, where he came as assistant professor in 1962, it was perfectly clear that it was right for him. "It was like coming home; I felt immediately comfortable and this has never changed. It was the right family for me to join." Vogt became associate professor of physics in 1965, professor in 1970, and the R. Stanton Avery Distinguished Service Professor in 1982. Since 1978 he had been chairman of the Division of Physics, Mathematics and Astronomy and was also acting director of the Owens Valley Radio Observatory in 1980-81. From 1975 to 1977 he was chairman of the faculty.

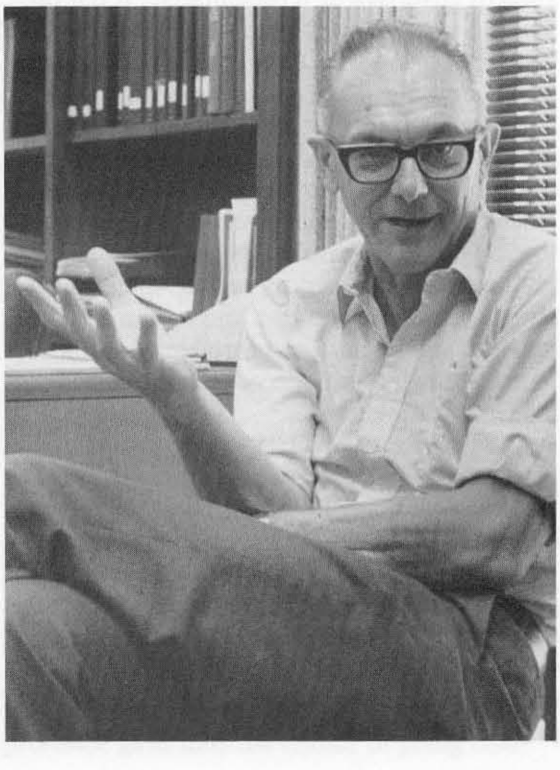
He credits Bob Bacher, who was then chairman of the Division of Physics, Mathematics and Astronomy, with the vision to gamble on cosmic ray research back in the early 1960s, although Bacher told him later that it wasn't really that big a risk; if it hadn't been successful, he could always have thrown Vogt out. Bacher became provost the year Vogt arrived. The following year Vogt lured Ed Stone out from Chicago to join the cosmic ray team, and this began their lifelong research association. Stone succeeded Vogt as division chairman and as head of the high energy astrophysics program in 1983.

Work was being done on cosmic rays at Caltech then under Victor Neher, but the new approach to the measurement of the elemental and isotopic composition of high-energy radiation had its origins at Chicago. Under Vogt and Stone, Caltech's Space Radiation Lab evolved into a recognized leader in the field and "we have even won a few against our home laboratory when we have competed for the same space missions." The two also initiated Caltech's gamma ray research project.

Although Vogt's devotion to Caltech is unquestionable, he's still "inordinately fond of the University of Chicago. It shaped my basic outlook on life and my scientific style." Actually, when he first arrived in the U.S. with a Fulbright fellowship, he had a choice between Chicago and Caltech and elected the former out of suspicion that the cultural transition for a European would be too drastic in California. He now considers the nine years in Chicago sort of a halfway house in preparation for his ultimate destination.

Vogt's first Fulbright year and his introduction to the U.S. began with what he calls a "cultural brainwashing program" at Syracuse University, where he spent three months soaking up the American way of life with Fulbright students from many other countries. "It was marvelous. My assignment was to read *The New York Times* and then show up for a discussion with professors and ask them questions about what I didn't understand about American politics, American economics, and so on." His enormous admiration for the United States began at this time — for its constitution and its protection of individual rights, in stark contrast to what he had experienced in Europe. He has a deep-felt horror of totalitarianism in all forms and sees this country as having the strength and common sense to resist it.

He remembers during his first year at Chicago watching the Army-McCarthy hearings on television and sensing the fear among his colleagues that a totalitarian system was evolving. But ultimately, of course, it did not. "I was impressed with how the country solved its problems; the system took care of itself." Vogt has never become a U.S. citizen because of frustration with the petty, bureaucratic requirements. He often refers to himself as an "undesirable alien" or a "displaced person" but doesn't really feel German any more either. "I feel like a misfit there now because I no longer belong. If I have to choose any country I belong to, it's this one." He may soon belong legitimately. Since some members of the Caltech community think it

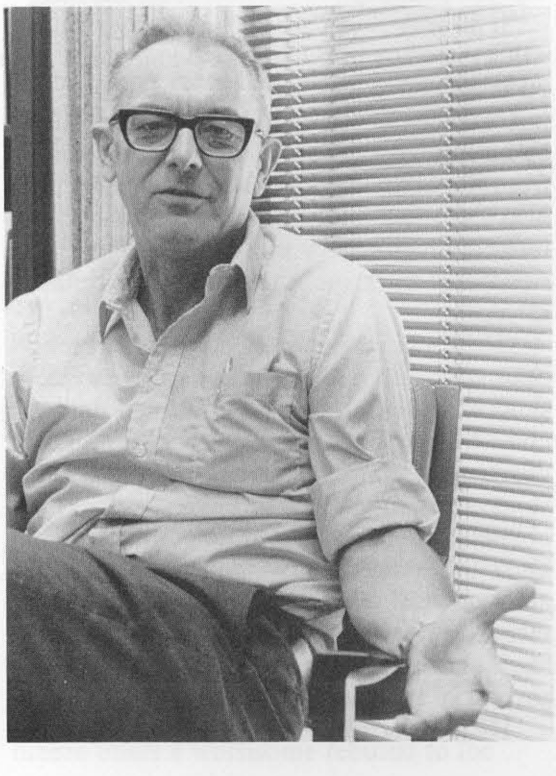


may be an advantage if their provost lost his "undesirable alien" status, efforts are being made to secure Vogt's citizenship.

Besides the exposure to American culture at Syracuse, there was also the opportunity to encounter other cultures as well. In postwar Europe, for example, it would have been impossible for a German boy and a French girl to get acquainted, but Vogt met his wife Micheline, a Fulbright scholar from France, at Syracuse. Their wedding announcement quoted Senator Fulbright's reason for promoting the scholarship program: "...they might be able to find a way to reconcile their countries' differences without resorting to armed conflict."

The Vogts have recently moved into the newly conceived and newly renovated provost's residence near the campus. "It's a marvelous house, but I feel like a visitor there." Vogt feels somewhat uncomfortable being both a renter (of Caltech's property) and a landlord (of his old house); but he and his wife have not yet decided whether to sell their house — "since I might quit or get fired" and because they identify closely with the home in which they raised their children. The Vogts' older daughter, Michèle, is a senior at Occidental College, majoring in geology. Nicole is a freshman at Caltech.

Vogt considers the students at Caltech "the lifeblood of the research program because they keep us intellectually young and alive. They add an element of brilliance to the enterprise, which is invaluable. They give as well as receive." Caltech's special distinction lies, he feels, in filling the needs of its very select student body, in providing a unique quality of education and research. This is its reason to exist, and there is no reason to try to convert it into a small copy of a traditional university. He believes in the Caltech conceived by Hale, Millikan, and the early trustees — an institution focusing on science and engineering. "I think it was a damned good idea and still has a place.



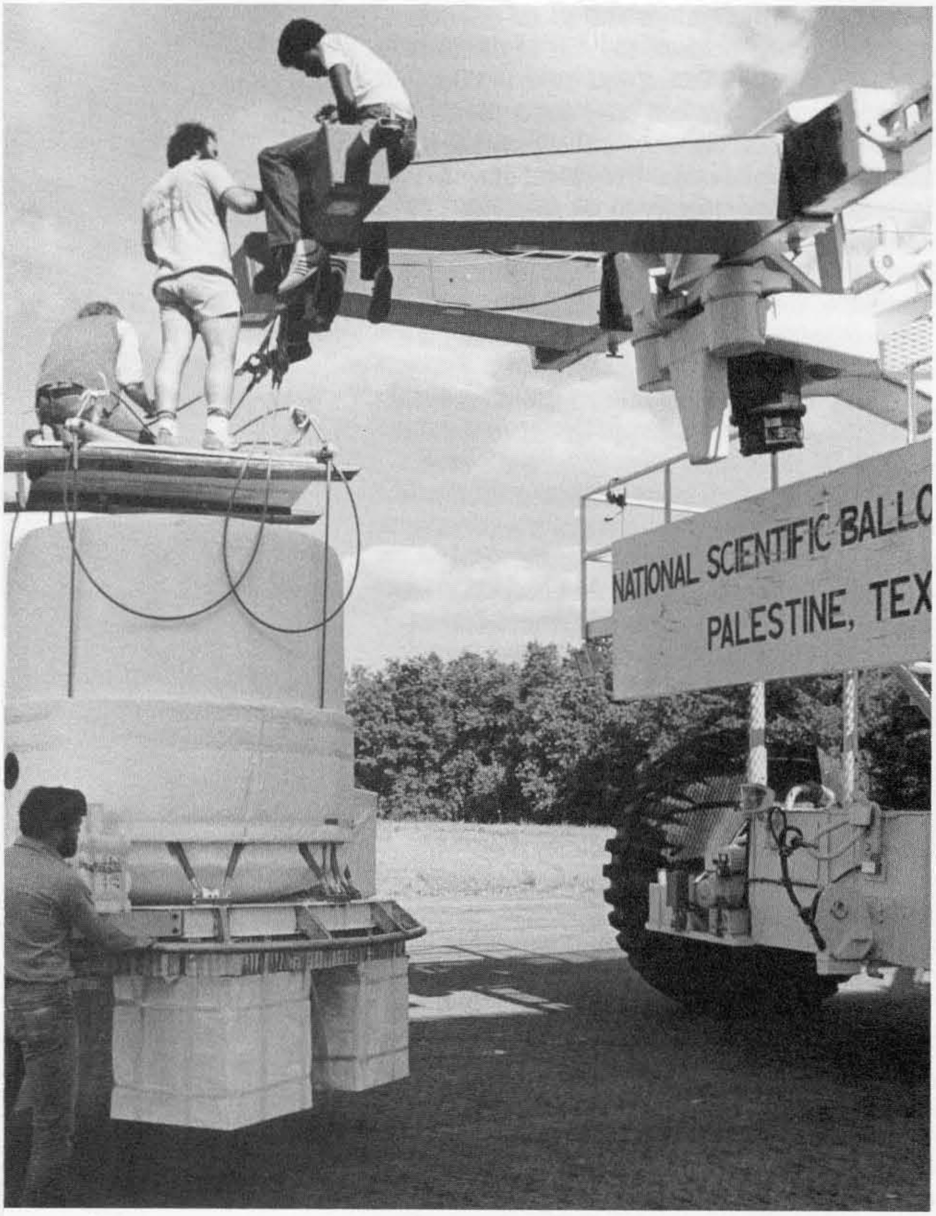
"Of course, in order to educate a good scientist or engineer, the humanities and social sciences are essential. And to have people in the humanities and social sciences as good in their fields as the rest of the Institute faculty are in theirs, you have to take them seriously. We can have good people in these disciplines, but only if they can have satisfactory professional lives here, and that includes the opportunity to do research. Even if it is not our primary goal to do research in these areas, we ought to maintain a capable, strong, and valuable faculty with the professional opportunities to pursue their scholarly goals.

"Hale had a vision; Millikan implemented it. *We* have to have a vision to create the Caltech of 50 years from now. There are two aspects to one's job in the administration: You've got to take care of today's problems, and you've got to assure the future. The decisions I make today should affect Caltech then; if now I make expedient, short-sighted decisions, then there will be no effect on the future except that I leave it a mediocre place."

Vogt feels strongly that there will be a need in the future for the "unique aspects of excellence and quality which an institution like Caltech contributes to society, and we owe it to future generations to lay the groundwork so this need can be met."

As for his own future, Vogt figures he is much too young to retire ultimately as provost. But since he has cut all his research roots, passed everything on to others, he can't just pick up where he left off. "If I went back in, my colleagues would have to feel sorry for me, because I'm out of touch. It would be bad to embarrass people that way. So it's clear I will have to enter a totally new area." He admits to some idle thoughts about what that might be but plans to worry about it when the time comes. □ — *JD*

Cosmic Heist



A 60-ton crane called Tiny Tim prepares to hoist HEIST for the first leg of its journey to intercept cosmic rays in the troposphere.

THE LARGE, METAL BUILDING might be expected to house tractors, considering that it sits up a forest road amidst the fields of rural east Texas. However, its three-story steel doors open to reveal, not farm machinery, but several strange white agglomerations of boxes and cylinders, each suspended from the ceiling by heavy cables.

Scattered among these large, awkward-looking shapes is an assortment of computers, terminals, tools, spare parts, and workbenches. The afternoon of May 12, 1984, sees a half-dozen scientists, engineers, and technicians at work checking out one of these packages, an ungainly six-foot-high cylinder festooned with assorted boxes and wires. The only bits of color on it are four small, orange Caltech pennants on its steel cable harness.

If all goes well on May 12, these pennants will soon wave in the thin, cold air more than 20 miles above the earth; the 2,600- pound instrument called HEIST will be borne aloft by an immense 17-million-cubic-foot balloon from the National Scientific Balloon Facility near Palestine, Texas. HEIST's mission: to intercept high-energy particles that have ricocheted throughout the galaxy for millions of years.

These particles may be the ashes of long-dead stars, expelled in the convulsive explosions called supernovae that marked their end. Or else, the particles may be cold space dust caught up in the shock wave from a supernova as it sweeps through space. This high-energy stardust — more commonly known as cosmic rays — consists of the atomic nuclei of elements from hydrogen through uranium, accelerated to velocities ranging from a few percent to more than 99 percent of the speed of light.

HEIST, for High Energy Isotope Spec-

by Dennis Meredith

trometer Telescope, represents a brand new approach to detecting and sorting out the fine differences among heavier, high-energy particles — ranging between neon and iron, at energies up to a few billion electron volts. So far, May 12 looks like an excellent day for the first test.

The Balloon Facility meteorologists have declared that the low-level evening winds may be just right for the balloon launch; and that the upper-level winds are unlikely to carry the balloon too far in its planned two-day mission — either south toward the Gulf of Mexico or to the east or west. Indeed, certain periods of the spring and fall are called turnaround periods, when the high-altitude winds are more likely to dither back and forth with relatively little net movement to blow a balloon too far from its launch point.

A forklift eases into the hangar, and its operator gingerly maneuvers the machine's prongs beneath HEIST's harness. The prongs rise, lifting the package so that it can be detached from the suspending cables. As the forklift retreats slowly out the door with its cargo, the Caltech scientists and engineers carefully shepherd it along. Perched atop the ponderous instrument are the project leader, Senior Scientist Stephen Schindler, and Marty Gould of Caltech's Central Engineering Services, which was responsible for most of the mechanical work of building HEIST. Also manning the launch are William Althouse, technical manager of Caltech's Space Radiation Laboratory (SRL); Senior Research Associate Richard Mewaldt; HEIST technician Wallace Campbell; and Caltech graduate students Koon Lau, Eric Christian, and Eric Grove.

The forklift stops and waits. A sultry breeze offers a worrisome rebuttal to the meteorologists' prediction of calm. After a few minutes the roar of a large engine is heard through the trees, and into view comes what looks like a giant child's Erector set toy. Rolling smoothly toward the hangar is an odd- looking, 60-ton crane called Tiny Tim, from which HEIST will be launched. Tiny Tim rolls up to the forklift, and lowers a pair of red steel jaws into place above the instrument. The jaws are clamped shut on a crossbar at the top of HEIST's harness, and, revving its engine, Tiny Tim lifts HEIST easily off the forklift.

Another small forklift approaches, carrying the only means HEIST will have of controlling its flight — two 500-pound boxes of fine steel shot to be used as ballast. Dribbled out the bottom of the boxes via radio-controlled valves, the shot will lighten the payload to maintain altitude during crucial nighttime flight, when cooler air reduces the balloon's buoyancy.

The ballast attached beneath it, HEIST begins its journey toward the launching pad. The Caltech scientists grin as they walk beside Tiny Tim, steadying its load. After all, this is the culmination of some five years of painstaking work. The procession, consisting of the gangling Tiny Tim holding HEIST, the excited scientists, and various cars and trucks reaches the launch pad, a 2,000-foot-diameter paved circle carved from the forest.

The scientists begin to check out HEIST and its telemetry system. A hundred feet above them floats a small test balloon tethered near the launch pad. Its string slants downward at a 45- degree angle to the ground, telling of a steady breeze aloft. The balloon technicians attach the parachute, which will lower HEIST safely to earth, to the top of the payload harness. They also carefully lay out a ground cloth from Tiny Tim to the edge of the launch pad and sweep it; even a stray twig could ruin the whole launch, should it pierce the balloon.

Checkout is nearly complete, and the time has come to make the irrevocable decision to deploy the balloon. Once pulled from its large crate, the balloon cannot be repacked without increasing the danger that its delicate skin may be inadvertently pierced. A car makes its way across the pad with two balloon facility staff members. They bring bad news. Their instruments say winds near the ground are too high; the launch is scratched for that day.

The news is particularly vexing because

the weather is becoming increasingly unstable, and if HEIST does not fly during the next few days, it may miss the optimum turnaround season and perhaps be postponed until the fall. The workmen fold the ground cloth away, and trundle HEIST back to its hangar, leaving it hanging overnight from Tiny Tim's jaws in hopes of another chance; Schindler and his colleagues can only hope tomorrow's weather will be calmer.

They take the announcement in their stride, however; such problems are typical of any radical new instrument, and they have met many since the project was begun in 1979. It was then that the scientists, working at SRL with Professor of Physics Edward Stone, began casting about for a new approach to capturing cosmic rays. They were particularly interested in sorting out the fine differences in isotopes of heavy, high-energy cosmic rays. Isotopes are the nuclei of those elements that possess identical chemical properties, but which differ in their masses because of differing numbers of neutrons in their nuclei. The group, working with Stone and Rochus Vogt, now Caltech provost, had already developed the first low-energy isotope spectrometer, which was launched on NASA's ISEE-3 spacecraft in 1978.

The isotopes of heavier particles, in particular, possess unique information about the history of cosmic rays. For instance, the abundance of certain radioactive isotopes of cobalt, nickel, and iron can give scientists a measure of the time between their birth in the furnaces of stars and their acceleration. This is because these isotopes decay only as atoms with orbital electrons, and not as stripped nuclei traveling at high speeds. Still other radioactive isotopes of aluminum, chlorine, calcium, manganese, or iron can function as cosmic ray "clocks" to measure how long the cosmic rays had been rattling about the galaxy after being blasted to high energies by exploding stars.

To distinguish among these isotopes, the instrument had to resolve extraordinarily fine differences in mass, as little as a few tenths of a percent. The scientists also wanted a detector that had enough mass to slow the high-energy particles that range up to about 2.5 billion electron volts. At these high energies, they could be sure of a clearer picture of the cosmic rays streaming through the galaxy; high-energy particles are less likely to be affected on their voyage into the solar system by the solar wind — the low-energy stream of particles constantly billowing out from the sun.

And finally, the new instrument had to operate reliably while being lofted into the harsh reaches of the upper atmosphere beneath a balloon, and to survive being parachuted back to earth. The instrument was to be balloon-borne, because even in the rocket age balloons remain the ideal way to test large experiments in the upper atmosphere — at a small fraction of the cost of a rocket launch. The balloons can float for days in the upper atmosphere, acting as stable platforms for instrument packages that can be easily recovered near the launch point. So the Texas Balloon Facility is in considerable demand, sending some 60 flights aloft each year, carrying a wide variety of instruments for cosmic ray studies; gamma and X-ray studies; optical, ultraviolet, and infrared astronomy; atmospheric research; studies of the earth's magnetosphere; and attempts to capture micrometeorites.

It was Senior Research Associate Andrew Buffington who made the calculations that showed the way for Caltech's balloon experiment. His studies showed that a stack of sodium iodide disks — long used as the basis of gamma ray cameras in the medical imaging technique of positron emission tomography — could provide enough mass to slow the high-energy particles. At the same time, the number of fragmenting particles would be kept to a reasonable level in such an instrument. Thus, large sodium iodide crystals could serve as the basis for a scintillation counter, which, combined with other detectors, could resolve the isotopes.

Scintillation counters consist of materials whose molecules are excited by the impact of high-energy particles. After the particle has passed, these excitations relax, producing faint flashes of light that can be detected by photomultiplier tubes surrounding the material. The scientists and engineers designed HEIST as a stack of 12 circular plates of sodium iodide, each 0.5 meters in diameter and two centimeters thick. Surrounding each of these highly polished disks would be six photomultiplier tubes, each sending its signals to an onboard computer.

But HEIST needed to do much more than simply sense when a cosmic ray particle plowed through it. In order to resolve the minute mass differences among isotopes, it had to tell the researchers precisely at what angle and position the particle traveled, so that they could correct for the variations in thickness of material seen by the particle.

HEIST's design allowed for this fine measurement. By comparing the respective strength of signals from different photomultipliers aimed at a given disk, the scientists could tell just where a cosmic ray passed through the disk. By comparing signals from several disks, the scientists could trace the particle's path precisely.

New high-precision electronic circuits had to be developed by Caltech engineers William Althouse and John South to measure accurately the 108 different signals generated in the detectors. To function properly, the circuits had to be small in size, draw little power to minimize consumption of onboard battery power, and be inexpensive enough to produce in large quantities. The final result fitted on a thin printed circuit board less than two inches square and used less than one watt of power.

To calculate the particles' energies, the scientists had to know how fast they streamed through the instrument, a capability supplied by Danish space scientist Ib Rasmussen. Working with the Caltech scientists, he developed a pair of Cerenkov radiation detectors to be installed above and below the sodium iodide crystals, like the bread of a sandwich.

Cerenkov radiation is the tiny flash of light produced when a charged particle plunges through a material at greater than the speed of light *in that material.* The radiation is a sort of electromagnetic shock wave generated along the particle's wake. (Of course, nothing can exceed the speed of light in a vacuum, but light travels more slowly through matter. For example, particles can travel up to 1½ times faster through glass than can light.)

HEIST's Cerenkov detectors consisted of three kinds of material — above the sodium iodide was a slab of light, foamed glass called an "aerogel" and below, a layer of Teflon and one of plastic. A particle from space would pass at higher speed through the aerogel, then would be slowed by the sodium iodide, and finally would plow through the Teflon and plastic. By comparing the intensity of flashes produced in the two Cerenkov detectors, the scientists could figure out the extent of the particle's slowing, and by combining this with the energy loss measurement in the sodium iodide, could determine the particle's mass and the energy it began with.

To insure that no data would be lost, HEIST would record all its data onboard, as well as transmit it via radio to the ground. The two onboard recorders would be nothing more elaborate than commercial videocassette recorders, each of which has about 10 times the storage capacity of commonly used magnetic tapes. And overseeing the flight would be a microprocessor similar to those found in

Technicians lay out a clean ground cloth from Tiny Tim to the edge of the launch pad for the empty balloon to lie on. Even a twig could pierce the balloon's delicate skin.

The unwieldy, giant balloon is hauled out of its crate and laid along the ground cloth (left); then the filling begins and the balloon swells into shape.

home computers. The microprocessor and its associated circuitry was developed specifically for use on HEIST by Steen Laursen of the Danish Space Research Institute.

To Harshaw Chemical Co. of Solon, Ohio, went the job of fashioning the sodium iodide plates. It was a challenge for the company; the crystals had to be polished to optical quality, much higher than had ever been attempted. Rasmussen made the aerogel Cerenkov detector. The major task of building the mechanical portion of HEIST fell to Caltech's Central Engineering Services. CES engineers were already well known for their ability to build instruments to the exacting demands of science, and within its no-frills budgets. HEIST would prove to be one more feather in their cap.

HEIST's birth was accompanied by its share of challenges and adventures. In trying to polish the disks, Harshaw fractured two of the crystals as they learned the new techniques necessary. Once the crystals were finished, the concept of HEIST was tested by bombarding them with precise particle beams at UC Berkeley's Bevalac accelerator. The tests provided confidence that HEIST would be able to resolve the isotopes, and the Caltech scientists and engineers began to build the full instrument. As the CES engineers had long known, scientific instruments often present unique engineering problems, which demand unique solutions.

At one point in HEIST's gestation, CES manager Norm Keidel found himself managing a rather peculiar fishing expedition with Schindler. Buffington and Schindler had developed a cooling system for HEIST that relied on water boiling off into space to carry heat away from the instruments. To test the cooling system chamber under extreme conditions of pressure, the engineers had to lower the system into at least 35 feet of water. Keidel and Schindler ended up bobbing about in a borrowed rowboat off a San Pedro pier, monitoring the unit below. They successfully made the critical tests, development forged ahead, and by early 1984 HEIST was ready.

On May 13, 1984, Tiny Tim again sits on the launching pad holding HEIST aloft as the Caltech scientists and engineers run their final checks. Again the parachute is attached; again a mild, muggy breeze jeopardizes the launch. But the breeze dies, and the weather turns perfect. HEIST's instruments function perfectly too, but when the balloon technicians run their tests of the ballast system, they discover a new surprise. One of the hoppers has to be soundly thumped before it will release a smooth flow of steel shot, perhaps because the shot has become packed too tightly. Since nobody will be available to

thump the hopper at 20 miles above the earth, the technicians decide it best to replace the hopper. It isn't the first time a hopper has ever proven balky, but the Caltech scientists hope it's the last for this mission.

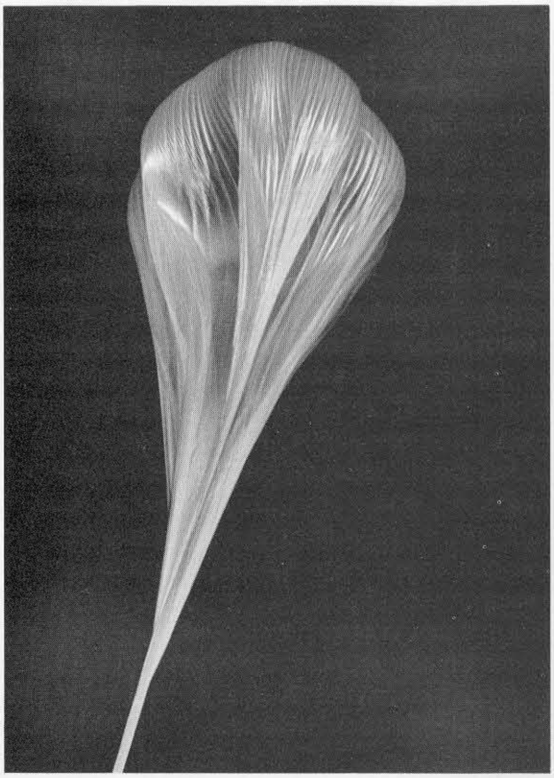
At 6:00 pm, Schindler gives his go-ahead, and so do the meteorologists. Above, the NASA chase plane circles, ready to control the ballast and eventually, to trigger the release of the payload to parachute to earth. A small truck carrying a large wooden crate makes its way toward Tiny Tim, and the balloon, now a huge wad of silvery plastic, is payed out of the crate along the ground cloth. The balloon is attached to the top of HEIST's parachute. Soon a large truck fitted with huge red cylinders arrives with the helium. The workers thread two large filler nozzles into the plastic ducts in the body of the balloon. They hold the nozzles aloft; the balloon is ready to be inflated. The valves on the truck are opened.

With a powerful hiss, the filling begins. The balloon begins to take shape, as the flow of helium creates a swelling, silvery bulb. The growing balloon is held down at one end by a roller attached to a truck, which inches toward Tiny Tim as the balloon swells and rises higher. After 30 minutes, the hissing suddenly stops. The balloon has been filled with about $10,000 worth of helium, but it remains only partially expanded. Not until it reaches the upper reaches of the atmosphere will the near vacuum allow it to blossom to its full 300-foot diameter.

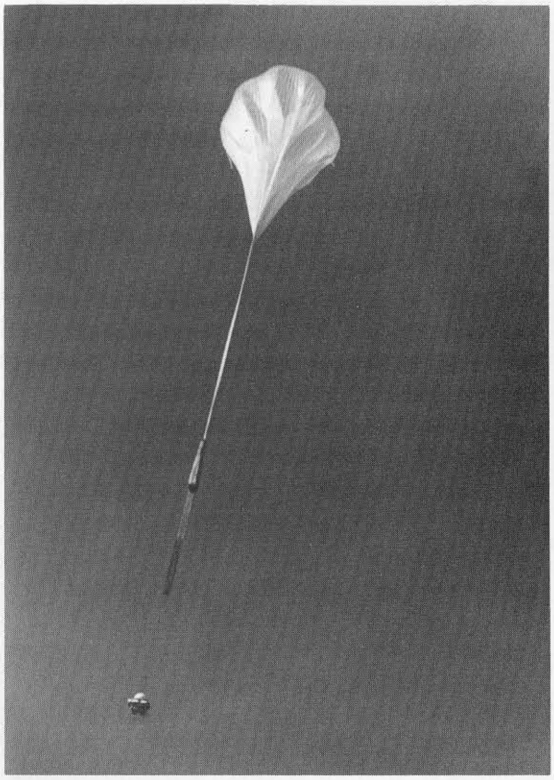
Abruptly, the roller flips back, and like a gigantic shimmering jellyfish, the balloon undulates violently upward to its full 500-foot height, towering over Tiny Tim. The crane starts forward, and with a loud click opens its jaws and scoots away. Without hesitation, the balloon vaults into the cloudless, blue sky, bearing its 3,600-lb. payload smoothly upward at 600 to 700 feet per minute. It is 7:18 p.m., Central Daylight Time on May 13. Schindler crouches at the edge of the launching pad, coolly watching the balloon rise, his ear to a walkie-talkie. HEIST has survived the launch beautifully. After brief congratulations, the scientists return to the hangar to begin the constant two-day vigil over the instruments.

Watching the monitors and printouts, they

Only partially inflated, the balloon is ready for launch.



The balloon sails upward at 600 to 700 feet per minute, bearing HEIST into the troposphere.



follow HEIST's progress as it rises through the critical region of the troposphere, where -70° centigrade cold slows its ascent. The instrument is turned on about one hour into the flight, and a tuning up process is begun. After about two hours, however, the balloon breaks through into the warmer -20° stratosphere, and rises quickly to its maximum altitude of 120,500 feet.

The third hour into the flight, as HEIST drifts northwest toward Fort Worth, the scientists complete the tuneup and continue recording data, which stream in at a high rate. During the entire flight, the instrument will gather some 450,000 impacts from cosmic rays. In fact, so heavy is the data flow that the scientists issue a series of radio commands to HEIST to raise the threshhold at which it triggers, in order to catch only the most interesting particles — the heavier ones. They fear that the high data rate may exhaust the capacity of the onboard tape recorders, and if the balloon drifts out of telemetry range, useful data may be lost.

After meandering over Fort Worth for several hours, HEIST drifts south by southwest over central Texas. Eventually, a line of thunderstorms approaches from the south, threatening the landing. So, at 12:04 p.m. on May 15, after 38 hours at its operating altitude, the chase plane triggers the balloon's release, and HEIST parachutes to earth. The landing — on the treeless, wide-open spaces belonging to a cooperative farmer — is as successful as the flight. The instruments and even the fragile sodium iodide plates are undamaged.

The scientists have now begun analyzing the data, which at first look appear excellent. Next summer, at an International Cosmic Ray Conference, they will report on this first successful test flight.

The story of HEIST, however, has only just begun. Next year, the instrument will be recalibrated at the Bevalac accelerator and possibly fitted with another more sensitive Cerenkov counter that will allow HEIST to measure the isotopes of lighter elements, including beryllium, carbon, and oxygen. If all goes as planned, 1986 may see an enhanced HEIST again rise into the stratosphere.

Ultimately, the Caltech researchers hope that the new technology of HEIST will lead to a version to be launched aboard the Space Shuttle or on a space platform. There the much longer exposure times would allow the gathering of data that would add a useful volume to the exotic chronicle of cosmic ray physics.

But whatever future success this remarkable device experiences will be traced back to that first triumphant flight high over Texas in the spring of 1984.□

Books

T.S. Eliot
A Study in Character and Style

by Ronald Bush

Oxford University Press $25.00

LITERARY BIOGRAPHY has held an accepted, if not always prominent, place in professional literary studies ever since Samuel Johnson combined biographical and aesthetic considerations to compose his model of the genre, *Lives of the Poets.* But even for some humanists whose credo would include an article on the reciprocal influence of a writer's life and art, an inquiry into this relationship in the case of T.S. Eliot may still seem somewhat incongruous. A powerful force in the development of both modern poetry and modern literary criticism, Eliot has often been understood as calling for a strict separation between the personality of the author, with his or her unique qualities and concerns, and any of the voices that may inhabit the poetry. It is no surprise that the work of a writer who could define great art as impersonal art should seem to require exceptional treatment.

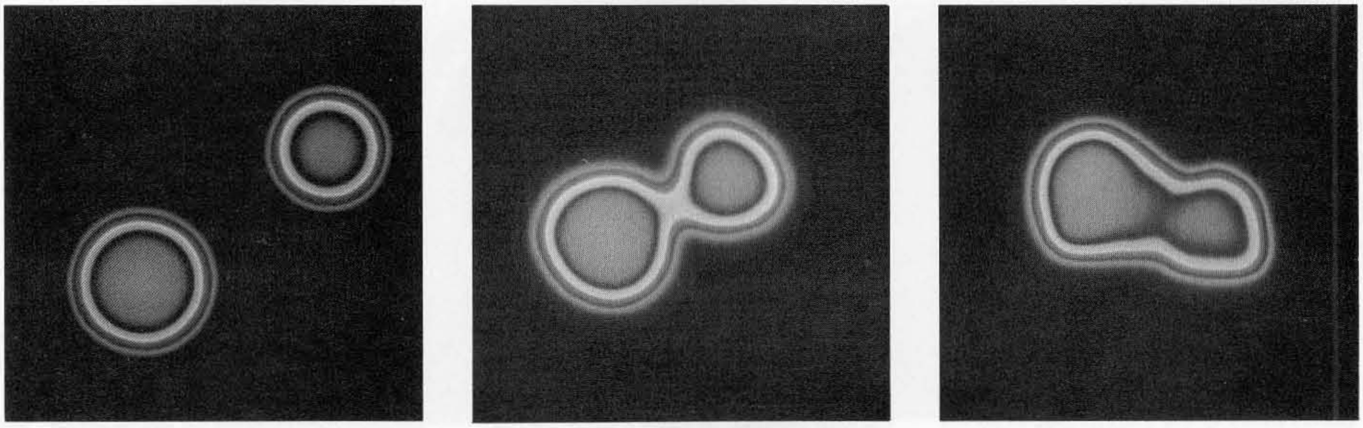
The latest book by Ronald Bush, associate professor of literature at Caltech, shows, however, how our understanding of poetry can be broadened by just such an account of the poet's career. The study moves effortlessly through a wide range of material, much of it unpublished, to demonstrate that the poet's genius carried out what his character demanded. Familiar with such diverse poets as Dante and the 19th-century French *Symbolistes* whose figures hover around Eliot's poetry, with Eliot's own literary criticism, lectures, and early drafts of his poems, as well as with a wealth of biographical documents, Bush uses his scholarship to persuade us that, in the words of one of Eliot's poems dreaming of life's harmony, the end is in the beginning. For Bush, the poetry Eliot wrote throughout his life, despite its variety and conflict, essentially develops a potential present from the outset in the tensions in his personality — tensions that have to do with exactly the degree to which feeling and form, personal or impersonal considerations, would predominate in Eliot's life and art. Bush conceives of the poetry as progressing from a precarious balance in Eliot's early period between romantic honesty and classical order, between internal monologue and an encompassing mythology, to a tilt in favor of impersonal form, after 1922 and Eliot's breakdown and conversion to Anglicanism. But long before the poet began to think of this struggle as presenting a stylistic choice between self-dramatization in the lyrical monologue and self- effacement through the music and incantation of highly structured verse, the man had already endured this strife within himself.

Bush's account of Eliot's life, narrated as counterpoint to the poems throughout the chronological study, may fairly be called a ghost story, a story of the demons haunting Eliot's psyche and shaping the emotional logic of his poetry. It begins with the fateful effects on the young Eliot of the ancestral spirit presiding over his New England Unitarian family: his paternal grandfather, a minister of Puritan descent whose devotion to duty, self-denial, and self-improvement and whose distrust of emotional expression and the value of the self were held up by the family as exemplary and were unavoidably internalized by Eliot. The spirit of the Eliot family nourished his ambition but deprived him of the satisfaction of success. The source of a continual oscillation between a rebellious exploration of the emotional life and a recoil from such indulgence, this demon left Eliot in a state of despondency which could only lead, Bush contends, to despair or to God. The despair, deepened by his unhappy marriage to Vivien Haigh-Wood, another ghost in Eliot's life, would lead to his breakdown and to his poetic monument to desolation, *The Waste Land.* The stillness and peace of the contemplative, religious life would require a disciplining and suppression of insistent personality in the musical structure of *Four Quartets,* when a middle-aged Eliot would include in his meditations the ghost of his past self among the shades crowding around him.

Although Eliot's personal struggles provide Bush with his framework for interpreting the poetry, the biographical plot is not deterministic in any simple sense. Bush is too skillful a literary critic, too sensitive to the linguistic intricacies of the poems, to allow them to become merely corroborating biographical documents. Whether a poem dramatizes the mind's remarkably agile feints, its approaches and evasions of unconscious fears or desires, or presents a controlled vision of spiritual fulfillment, Bush remains primarily concerned with how the diction, syntax, prosody, rhetoric, and network of literary allusions and ancient myths interact to create perhaps the finest specimens of modern poetry.

T.S. Eliot once said that no biography, however full and intimate, could rival the ability of poetry to render the undertones of personal emotion, the personal drama and struggle. While this may be true, Bush's literary biography goes a long way toward deepening our understanding of the poetry and its emotional power. □ — *Neil Saccamano*

Research in Progress



Nuclear Bumps

When two large *nuclei* (heavy ions), each carrying its collection of *nucleons* (neutrons and protons) collide in a particle accelerator, classical and quantum mechanics also meet. The motion of the *nucleons* within each nucleus is governed by quantum mechanical nuclear forces, but the trajectories of the *nuclei*, whether head-on or just grazing, can be viewed as governed by classical physics. Steven Koonin, professor of theoretical physics, studies what happens at this interface of physical laws in low-energy, heavy ion collisions, calculating models of the "semi-classical" phenomena that result.

These collisions, and how the resulting system shares its excitation energy and reaches equilibrium, can be investigated in the laboratory under various conditions involving nuclei of different sizes bombarding each other at various speeds and colliding at different angles. When the nuclei collide more or less head-on, they fuse briefly, for about 10^{-17} seconds, forming a single "compound" nucleus before decaying, often into two large pieces. (This is not the same as thermonuclear fusion of light nuclei.)

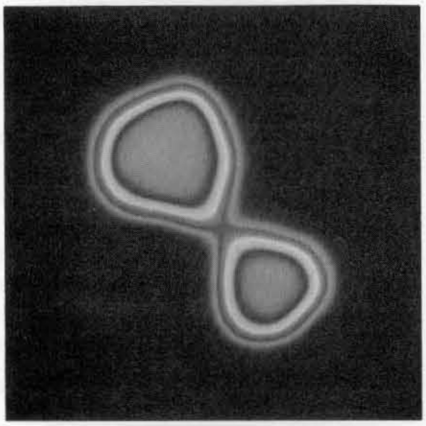
When the nuclei merely sideswipe each other, however, instead of meeting in a direct hit, an entirely different set of phenomena results. In these events, called deep-inelastic collisions, the combined nucleus appears to lose most of its energy but still retains a memory of its original components, breaking up into two fragments closely resembling them, give or take a few nucleons. Because of these interesting, contradictory phenomena (the energy loss is indicative of a violent collision while the memory suggests the opposite), deep-inelastic collisions are of particular interest to Koonin and his colleagues.

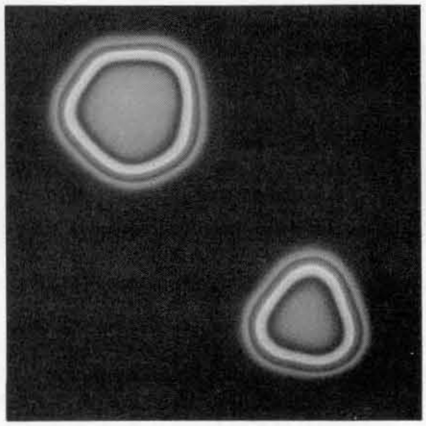
Koonin performed the massive calculations modeling these collisions on a Cray-1 computer. The model is derived from the independent particle model (also called the shell model) of the nucleus, which holds that, under weakly excited conditions, all the nucleons move in orbits affected by the average force generated by other particles. In other words, the interior of the nucleus can be considered roughly homogeneous, with the nucleons moving freely about and not hitting each other. This theoretical picture correlates closely with experimental observations. The computer calculations can follow the development of the wave function (or, essentially, the motion) of each nucleon from the beginning of the collision to its final state and so can predict the average properties of the products of the collision — numbers of neutrons and protons, spin, and degree of excitation.

Since the mechanisms that change these different properties operate at different rates, Koonin applied a time-dependent generalization of the shell model (time-dependent Hartree-Fock method) to track the average properties experienced by each nucleon as the system moves toward a new equilibrium. The project has been under way for six years and is now largely finished. Koonin's models describe heavy ion collisions with surprising accuracy and have become a standard tool in the field; researchers can apply a computer program to predict what will result from a particular collision reaction. He and his colleagues have also made heavy ion collisions visible by converting their theoretical models into computer-animated "movies," which show the nuclei merging on contact, bobbling around in a single distorting shape, and, depending on the original angle of impact, oozing apart like a droplet of honey into separate fragments.

Now, says Koonin, he and his students are "cleaning up the corners" and pursuing various sidelines. One of the clean-up operations is to extend the calculations to account for fluctuations; the models agree with the average properties of the fragments but not with the observed fluctuations. J. Bradley Marston, BS '84, elaborated these calculations in his senior thesis and is continuing work on the problem.

Another direction of extension is to develop a description of collisions at higher energies. The independent particle model holds only for weakly and moderately excited conditions. Under more highly excited conditions collisions between the nucleons inside the nucleus become more important and must be considered in the model. This creates a much more complicated problem — but an interesting one, as new accelerators capable of higher energies make experimental observations of such nuclear collisions possible. □ — *JD*





These frames from a computer-graphic movie show a peripheral collision between two heavy nuclei, ^{86}Kr and ^{139}La, at a total energy of 505 MeV. In the first frame they are moving toward each other. They fuse temporarily into a single, rapidly rotating system and then break apart again almost immediately.

Hispanic Politics

By official count California's Hispanic community currently represents 19.2 percent of the state population and is probably larger. This percentage has been increasing and will likely continue to do so — a demographic shift that will have long-term effects on the politics and policies of the state. To try to define and anticipate some of these effects, a group of faculty and students in political science are undertaking a comparative study of the Hispanic and other minority populations in California.

Bruce Cain, associate professor of political science, is principal investigator on the two-year project. He and his team will be collecting both published statistics and survey data on community leaders (in businesses and unions as well as in politics) and will conduct an extensive poll of the larger public. They will try to determine from what kinds of backgrounds these leaders emerge, what their attitudes are about specific issues, and how they may differ from other minority leaders and within the Latino national groups. They will look into voting patterns — who sponsored and who lobbied for what bills. And they're interested in how representative the political elites are of the attitudes of their constituents — for example, whether political leaders feel the same way about bilingualism as the Hispanic community at large.

On the economic side they want to know what areas of business Latinos have entered, how active they are in unions, and how the business community has adapted to the growth of the Latino population. Questions on the surveys of business and political leaders will be coordinated with questions on the statewide attitude survey of the larger Latino public.

Associate Professor Rod Kiewiet and Douglas Rivers, assistant professor of political science, will design and supervise the statewide poll — an extremely ambitious attempt to examine minority attitudes on a broad range of issues. Unique and difficult sampling procedures will be necessary to capture the characteristics of urban and rural populations, as well as regional, national, and generational variations.

In additional to learning about what Latinos *think* about particular issues, the Caltech group wants to know how they participate in and influence the political process; for example, what issues they organize around (such as the Simpson-Mazzoli bill, bilingualism, agricultural labor, social services), what kind of political action committees and grass roots organizations arise, and where political funds come from.

While the study concentrates on Hispanics, it will also be a comparative study of California's other large ethnic groups — Asians and blacks. Other studies have concentrated on a single group and have been conducted from "inside." Cain believes his comparative approach from a disinterested perspective will make a significant contribution to understanding the political dynamics of California's minorities — not only how they differ or are similar to each other, but also what their attitudes are toward each other and what the possibilities of tension and coalition are.

For example, Cain expects to find that the Asian community is less concerned than Hispanics about mass public issues, such as social services, and more likely to organize around local problems, such as zoning, local

Senior Michael Chwe (right, foreground) presents his report taken from census data on Asian Americans to a meeting of the political science group involved in the comparative study of Hispanic and other minority populations in California. Associate Professors Bruce Cain (left), principal investigator on the project, and Rod Kiewiet sit across the table.

taxes, and education. Asian political candidates also often do not come from specifically Asian communities, while Hispanic politicians almost invariably represent Hispanic areas. The researchers hope to be able to explain some of these differences. They also want to compare the strength of ethnic identification and the perception of discrimination among California's major ethnic groups.

Cain has already begun interviewing Latino leaders. Students will conduct interviews for the mass survey in September; the researchers intend to avoid the national election with their poll so as not to get caught up in polarized or uncharacteristic results. Students working under the grant for the study (from the Seaver Institute) and on SURF (Summer Undergraduate Research Fellowships) have spent the past summer compiling statistics and will also eventually be involved in coding and computer processing all the data. Cain, Kiewiet, and Rivers plan to hold a conference at the conclusion of the study and invite national leaders to react to the position papers that emerge from the research.□ *--JD*

Give It a Whirl

THE CIVIL ENGINEERING profession as a whole is paying increasing attention to the use of centrifuges for modeling studies. At Caltech, for example, Ronald F. Scott, professor of civil engineering, has been operating an unusual and versatile centrifuge for soil studies for a number of years. It is one of the first in the United States to be used for geotechnical research.

Because of the size of full-scale civil engineering structures, it is almost impossible to conduct full-size tests. The available alternatives are theoretically based computer solutions and the centrifuge, which affords the opportunity of checking computer calculations. The Caltech machine has an acceleration range of from 1 to 175g at the 40-inch radius of the basket, with a payload capacity of 10,000g per pound. A variety of computer-driven accessories supply engineering information and store it in a digital data acquisition system.

Examination of the qualities and behavior of the surface soils of the moon and Mars between 1960 and 1980 prompted Scott's proposal to the National Science Foundation in 1974 to obtain a centrifuge for scientific experimentation. He wanted to study granular materials at increased gravitational acceleration under a variety of conditions, and with a range of tools.

Since it was obtained and installed, the centrifuge has had diverse uses, most of which have been aimed at establishing model-to-prototype relationships in engineering research and design. One of the important engineering problems, particularly for offshore structures, concerns the load-bearing and deflection performance of piles. Exact correspondence of model with prototype is difficult, however, because of the size of the prototype projects involved, the inability to obtain the exact soil profile in the field, and possible scaling inconsistencies. Nevertheless, model pile studies are beginning to bridge the computational gap in studies of offshore structures. Though early testing was done by static loading of the pile, research at Caltech, funded by the American Petroleum Institute, initiated the first dynamic studies — application of an electromagnetic shaking device to a pile. Subsequent tests employed a variety of apparatus designed to shake different models.

Other tests made use of a special bucket constructed and donated by Chevron Oil Field Company for mounting on the arm of the centrifuge in order to model a prototype of up to 175 feet in length and 50 inches in diameter. In 1977-78, Scott conducted large-scale pile tests using the Chevron bucket in the centrifuge to study pile behavior in a fine-grained silt soil from an offshore location. The results were interesting enough to prompt further study — this time on a model of a large offshore concrete platform — in the same clayey silt. The model platform (10 cm in diameter, representing a 10-meter diameter prototype) was subjected to vertical and inclined concentric and eccentric cyclic loads. These experiments were accompanied by a computational study using the finite element method, which transforms the governing differential equations to a matrix equation that is solved on the computer.

Then, in 1981 a consulting firm, Earth Technology, Inc., of Long Beach, John Ting (now of the University of Toronto), and Scott, with NSF funding, cooperated on the most extensive pile study to date. Full-scale piles were driven and tested at Seal Beach, California, with Caltech structural shaking machines. Model pile tests were performed on the same soil in the centrifuge. The researchers achieved good correspondence between the two tests.

The variety of uses of the Caltech centrifuge is underlined by a review of some of the experiments conducted. In 1975, K. Tagaya of Mitsubishi used it to begin the first systematic study of anchors embedded in sand or clay at various depths and in different configurations. These anchors were to be applied as possible support systems for offshore guyed oil towers.

In 1976 Hsi-ping Liu, a postdoctoral fellow in the Division of Geological and Planetary Sciences, became interested in the use of the centrifuge for geophysical modeling. He experimented in the centrifuge by fracturing a simulated rock block at high acceleration and recorded the vibrations, later continuing the work on the Boeing Company centrifuge in Seattle with an artificial block of sandstone. This block was tested at 400g until a precut plane displaced, simulating a geological fault rupture that produces an earthquake. Small transducers recorded the seismic waves the rupture generated. A little later, in 1979, the Southern California Gas Company became interested in a site for liquefied natural gas tanks and wanted to examine the mechanism of fault rupture in soil overlying a fault in bedrock. After a soil layer was placed in the Caltech centrifuge, a fault was generated by a hydraulic mechanism with the centrifuge in flight and a high-speed movie camera recording the motion of marked layers of soil. At the same time accelerometers recorded accelerations in the container and soil. This testing was done with a variety of soils, thicknesses, and speeds of fault initiation. The work was done in cooperation with Dames and Moore, a geotechnical consulting firm.

Another application of the centrifuge in engineering studies has involved dynamic earth pressures on retaining walls during seismic shaking through a study completed in 1982 by Alexander Ortiz. The focus was on reinforced cantilever concrete walls like those along freeway construction. By simulating a Richter magnitude 5.5 earthquake through a hydraulically operated apparatus, a corresponding prototype earthquake of several seconds duration and 0.5g peak acceleration was developed.

Behnam Hushmand (PhD 1983) made studies of the behavior of footings and foundations under seismic and other dynamic loading. Model footings and rigid structures on soil were rotated in the centrifuge at elevated g's. Impulsive loading was accomplished by means of small explosions generated by toy pistol caps exploded electrically. In addition, an air-driven shaking machine using two counter-rotating unbalanced disks, which generated a vibrating force at speeds to 40,000 rpm, was applied to the model structures.

A last example of recent centrifuge application is in the developing area of plate tectonics. H. Nataf, a visiting associate in geophysics, undertook geophysical research in the Caltech centrifuge on the motions of the hot viscous mantle underlying the crustal plates. This study of the stability of convection patterns used a custom-built, thermally controlled, fluid-filled cell, in which the illumination of the convecting unstable fluid by a split beam of light reveals the patterns of fluid motion. By filming these occurrences at elevated g's in the centrifuge, Nataf has been able to note convection patterns, material property interactions, temperature gradients, and associated shear stresses.

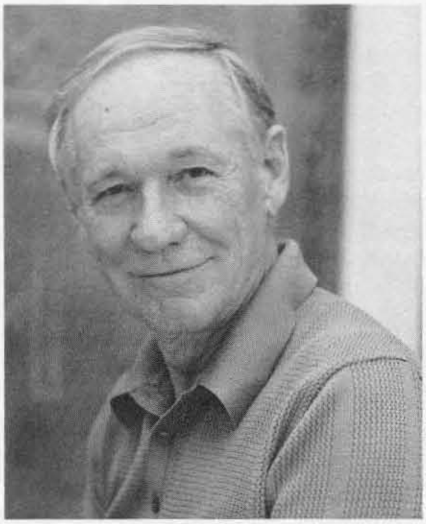
A key element in all the research conducted since 1977 has been John R. Lee, research engineer with the centrifuge. He makes the equipment, keeps the electronics working, and assists the students in running the machine.

The future holds many challenges for new applications of the centrifuge. Likewise, the addition of more centrifuges in this country and throughout the world may result in the formation of an international body specializing in the compilation of centrifuge studies. Such an organization could serve as the focal point for worldwide information on progress in the field. A journal published by such a group could give scientists access to the information on the subject more directly.

Government funding has proved invaluable in centrifuge studies, as has industry support. Future cooperation with a given industry, such as the oil industry, or by joint government/industry studies, will promote the solution of engineering problems common to an increasingly industrialized world.
□ *--Sylvia McBride*

Ronald Scott adjusts the earthquake basket of the centrifuge. A model of, say, a dam, set into the basket, can be shaken like a model earthquake (compressed into .2 seconds), reflected in the mirror angled above the basket, and filmed by a high-speed movie camera that uses 100 feet of film in 3 to 4 seconds.

Retirements — 1984



Herschel K. Mitchell

HERSCHEL MITCHELL came to Caltech as a senior research fellow in 1946 along with George Beadle. His research at that time concerned biochemical genetics, as did Beadle's, specifically the relationship between genes and enzymes. Working with the bread mold *Neurospora*, he investigated the biochemical pathways of genetic mutations and is co-author of the first textbook on gene-enzyme relations.

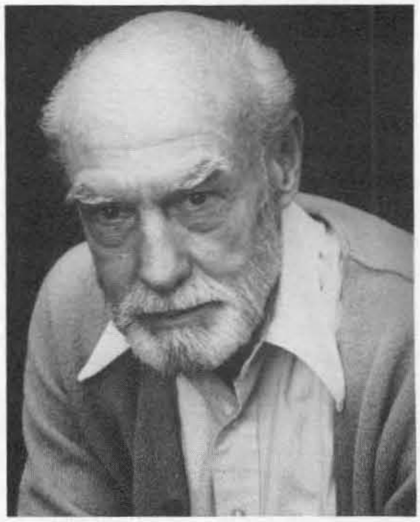
Mitchell had previously been a research associate at the University of Texas from 1941 to 1943, where his research involved the isolation and synthesis of B vitamins (he produced the first synthesis of the B vitamin, pantothenic acid), and a research fellow at Stanford for three years before Caltech. He was made associate professor in 1949 and full professor in 1953. In June 1984 he became professor of biology, emeritus.

In the late 1950s Mitchell turned his attention to developmental biology, making use of the fruit fly *Drosophila melanogaster*. His major work in recent years involved the discovery that a heat shock on living cells temporarily turns off the expression of most genes, but at the same time it turns on the expression of a small number of specific genes. The latter produce proteins that are conserved among many species and apparently have roles in protection against environmental stress. His heat-shock research with fruit flies is providing insights into the mechanisms that cause birth defects and control cancer cells.

Mitchell has taught the biochemistry laboratory at Caltech for many years. His AB is from Pomona College (1936); he received his MS in 1939 from Oregon State College and PhD in 1941 from the University of Texas.

He's also known around campus for his talents as a glassblower and for his enthusiastic participation in sports. He expanded a chemists' baseball team in the Pasadena Recreation Department league into a campus-wide program including basketball and volleyball as well, which thrived for 25 years before being taken over by the graduate student organization. Also among the regular players was Roger Sperry.

Roger W. Sperry



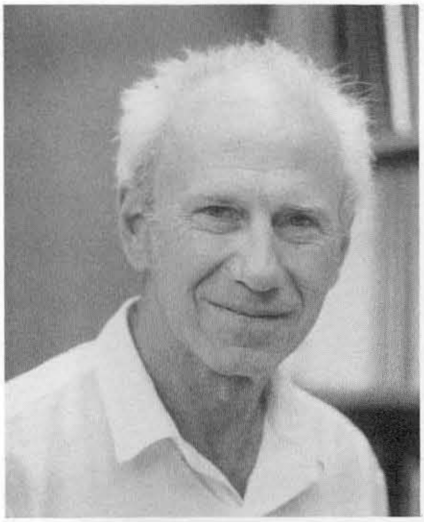
NOBEL LAUREATE Roger Sperry, who became Board of Trustees Professor of Psychobiology, Emeritus, in 1984, was captain of the basketball team during his undergraduate years at Oberlin College, and also played varsity baseball, football, and track. After his AB in English in 1935 and AM in psychology in 1937 (also from Oberlin), he earned his PhD in zoology from the University of Chicago in 1941.

Sperry joined the Caltech faculty in 1954 as Hixon Professor of Pyschobiology. He had been on the Chicago faculty since 1946, with a joint appointment at the National Institutes of Health from 1952, and was previously at Harvard and the Yerkes Laboratories of Primate Biology. In his earlier work with visual perception Sperry demonstrated that the circuits of the brain are largely hard wired, that basic patterns are fixed in early development and cannot be modified by subsequent experience. This basic determinism of the brain discovered by Sperry is "loaded with meanings at many levels and raises many fascinating and still unsolved questions," said Norman Horowitz, professor of biology, emeritus, at the May faculty dinner. "It would be nice if, in his next incarnation, Roger returns as a molecular neurobiologist and solves some of these problems."

Sperry won the Nobel Prize in Physiology or Medicine in 1981 for his work on the functional specialization of the hemispheres of the brain. The two halves, normally connected by a large band of fibers (corpus callosum), transfer information between them and are usually in agreement. By means of ingenious tests with subjects whose corpus callosi had been severed, Sperry and his students demonstrated that each hemisphere is a conscious system with its own character and function, the left half dominant in language, mathematics, and analytic and sequential reasoning, and the right one superior in spatial, conceptual, and creative tasks. Sperry's most recent work on a changed theory of the relationship between mind and brain and its value implications helped spark the "consciousness revolution" of the 1970s in behavioral science, bringing a turnabout in the scientific status and treatment of consciousness.

Charles H. Wilts

CHARLES WILTS is described in *The Climber's Guide to Caltech* as " probably more knowledgeable about every toehold, finger space, and ledge on campus than any other man at the Institute." Known as a "master



climber on the techniques and teamwork of the sport," Wilts has also taught a popular PE course in rock climbing and lists among his publications the *Climber's Guide to Tahquitz Rock*.

Wilts has spent his entire career at Caltech — long enough to learn every toehold and ledge on the older buildings; the modern ones, he claims, don't offer many realistic climbing routes. He earned all of his degrees here — BS (1940), MS (1941), and PhD (1948), all in electrical engineering — and became a member of the faculty immediately thereafter. Promoted to associate professor in 1952 and professor in 1957, he was named profesor of electrical engineering and applied physics in 1974. In 1984 he became professor of electrical engineering and applied physics, emeritus. Wilts has also served as chairman of the electrical engineering graduate studies committee (1967-70), vice chairman of the faculty (1970-71), and executive officer for electrical engineering (1972-75).

Initially Wilts worked on the development and application of large-scale analog computers. His research since 1960 has primarily concerned ferromagnetism in metals and alloys with an emphasis on thin films as a research medium, most recently concentrating on ferromagnetic resonance as applied to single crystals. He developed a mathematical model of spin waves in materials with depth-dependent magnetic properties. His technique can be applied to measure these properties — for example, in garnets, which are used in bubble memories, and in other magnetic materials used in recording technology.

Opinion

In his concluding remarks at the 90th annual commencement, Caltech President Marvin L. Goldberger issued a timely, and serious, message for this election year.

There is much to be serious about, as you well know. Students used to be insulated from most of the problems in the world outside the campus, but that hasn't been the case for many years now. I shall spare you the list of problems that fill the popular journals and the radio and television news programs — an unending series that seems to be without any reasonable solutions. In this election year we get an added dose of unreality in the posturing and sloganeering that unconvincingly promise so much. Unlikely though it seems, November 6, 1984, is almost upon us. I can promise you that all the current problems will still be there for you to solve.

How can you contribute to the solutions that are so desperately needed? For some of you the answer will be to join industrial firms (or become entrepreneurs and start them yourselves) and bring your various specialties to bear on making new products, improving old ones, and increasing the efficiency of production — making vast amounts of money, all of which you'll give to Caltech. For others the answer is to continue in universities, generating knowledge and reproducing yourselves in your students. Those are the two paths that Caltech students have followed historically, and for good reason. Both these kinds of careers offer not only personal rewards but genuine opportunities to contribute to the solution of difficult and important problems. However, on this occasion I want to urge you to think about another course, one that departs from the traditional careers for women and men with scientific, technical training.

Think about becoming involved in politics — in one or another aspect of the political process. Not a single one of the problems we have been talking about is missing a strong technical component. Start with the local scene. There are the problems of smog, local and freeway traffic, fires and floods in the hills. At the regional level there are the problems of earthquakes, water resources and environmental pollution. At the state level we face the collection of problems associated with large-scale agriculture and industrial employment. And so on, right up to the problems of national defense and arms control. It is a tragedy that we do not have engineers and scientists making decisions at all levels from local neighborhoods, through city and state government, to the federal government and beyond, in international relations.

Caltech alumni, faculty, and administrators have taken important appointments in government — I'm thinking of people like Si Ramo, Dick DeLauer, Eb Rechtin, Lee DuBridge, Harold Brown. The advice of Caltech research specialists is often sought by government agencies, and some of you may have taken part in research that was carried out for that purpose. But we have never to my knowledge had a governor from Caltech and only a couple of congressmen. There has been one senator — Harrison H. Schmitt. who received a Caltech BS in geology in 1957 and, after a slight detour to the moon, became a United States Senator; still, one out of 16,000 plus Caltech graduates is not nearly enough. And they are needed, not only by us here but by the country and the world.

But why am I setting my sights so low? I'd like to see a Caltech graduate as president — one of you, say, in 2004. So go for it, and I promise to do everything in my power to be there for the inauguration.□

Create computers that capture the mysteries of common sense.

The brain does it naturally. It wonders. It thinks with spontaneity—advantages we haven't been able to give computers. We've made them "smart," able to make sophisticated calculations at very fast speeds. But we have yet to get them to act with insight, instinct, and intuition.

But what if we could devise ways to probe into the inner nature of human thought? So computers could follow the same rationale and reach the same conclusions a person would.

What if we could actually design computers to capture the mysteries of common sense?

At GE, we've already begun to implement advances in knowledge engineering. We are codifying the knowledge, intuition and experience of expert engineers and technicians into computer algorithms for diagnostic troubleshooting. At present, we are applying this breakthrough to diesel electric locomotive systems to reduce the number of engine teardowns for factory repair as well as adapting this technology to affect savings in other areas of manufacturing.

We are also looking at parallel processing, a method that divides problems into parts and attacks them simultaneously, rather than sequentially, the way the human brain might.

While extending technology and application of computer systems is important, the real excitement and the challenge of knowledge engineering is its conception. At the heart of all expert systems are master engineers and technicians, preserving their knowledge and experience, questioning their logic and dissecting their dreams. As one young employee said, "At GE, we're not just shaping machines and technology. We're shaping opportunity."

Thinking about the possibilities is the first step to making things happen. And it all starts with an eagerness to dream, a willingness to dare and the determination to make visions, reality.

An equal opportunity employer

If you can dream it, you can do it.

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