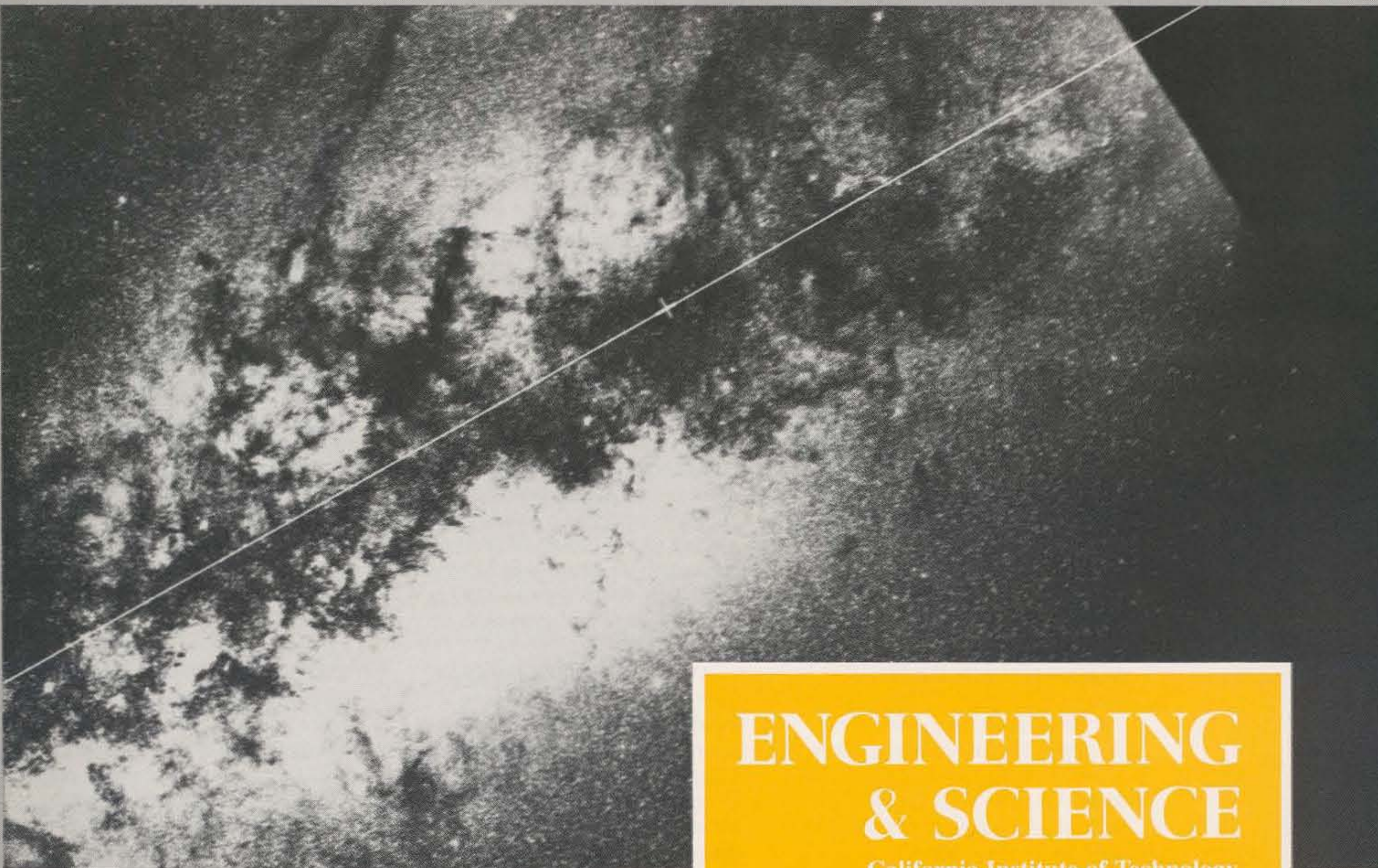
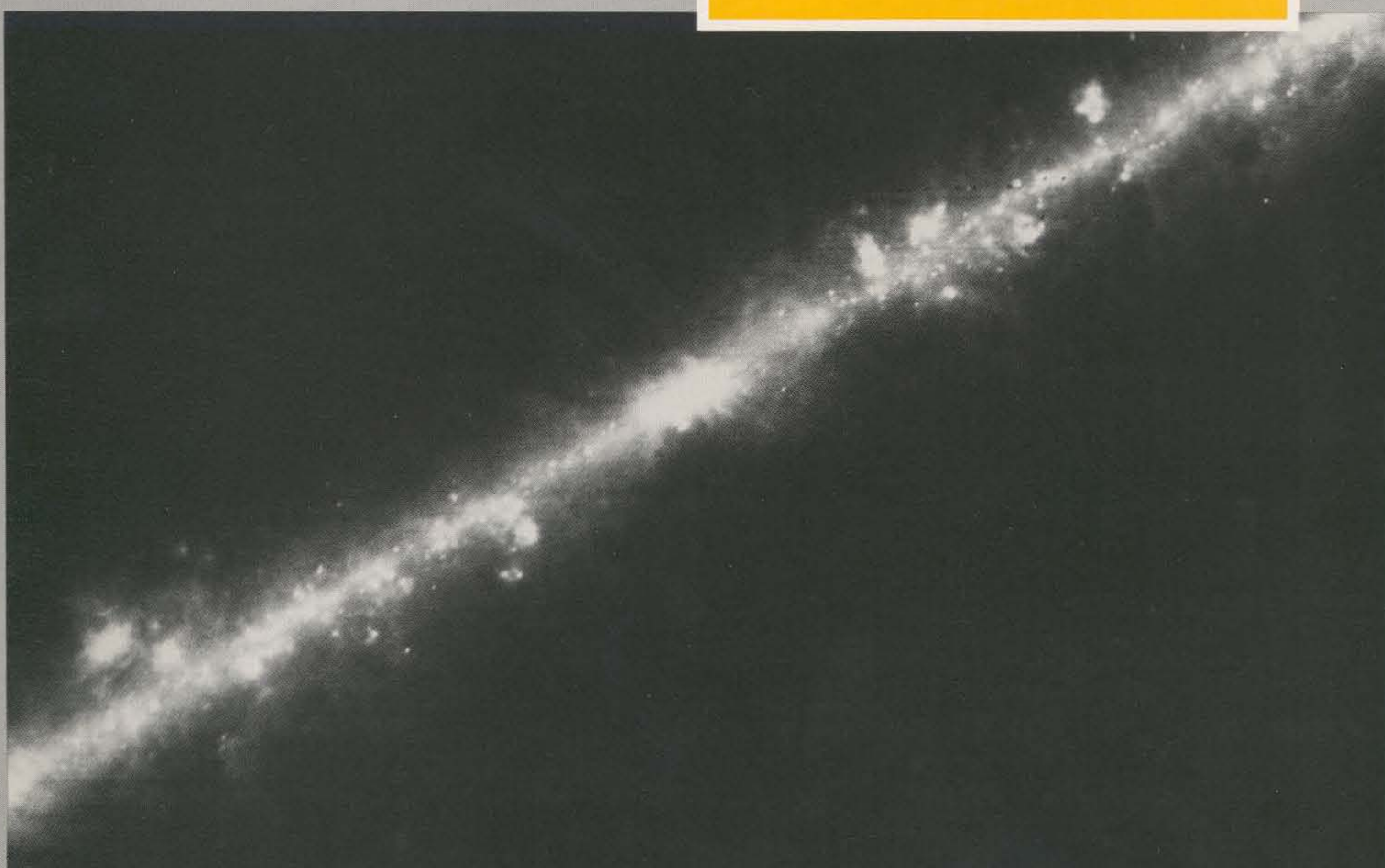


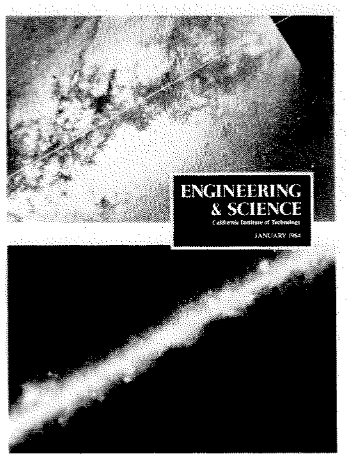
ENGINEERING & SCIENCE

California Institute of Technology

JANUARY 1984



In This Issue



Galactic Center

On the cover — two views of the center of the Milky Way. The top photograph shows the optical telescope version, the central plane of the galactic disk indicated by the diagonal line, with the center of the galaxy at the cross. Concentrations of dust around the galactic center limit the view of optical telescopes; hence the dark lane along the plane.

The bottom image, which corresponds in size and scale to the top one (a field of view of about 48 by 33 degrees), was produced from observations made by the Infrared Astronomical Satellite (IRAS), whose infrared telescope could see through the obscuring gas and dust to provide a complementary view. The largest bulge is the galactic center, and the other knots and blobs along the band are giant clouds of interstellar gas and dust heated by nearby stars.

Launched as an international project one year ago (JPL was the U.S. management center) IRAS finished its mission in November. A summary report on its findings begins on page 6.

Utopia Revisited

The idea of utopia has fascinated men from Plato to Orwell — as well as long before and often since. The instigator of the interview that begins on page 12, "The Question of Utopia," was journalist Mark Davidson, who has been intrigued by R. Buckminster Fuller's statement, "The moment of realization that it soon must be utopia or oblivion coincides exactly with the discovery that utopia is now possible." He has talked with a number of people about what utopia means to us today as a part of his research for a book on the scientific prospects for utopia — a sequel to his current book about systems science and philosophy, *Uncommon Sense*.

One of the people Davidson interviewed was Brian Barry, the Edie and Lew Wasserman Professor of Philosophy, who came to Caltech in 1982 from the University of Chicago. His particular areas of specialization are political and social philosophy, the philosophy of law, and ethics. He is responsible at the Institute for an interdisciplinary program in philosophy, including the philosophy of history and the social sciences, issues of ethical concern in public policy, the working of political institutions, and the philosophy of science. He is the author of four books and numerous articles, and has been editor of *Ethics*, an interdisciplinary journal of social, political, and legal philosophy.

Library Technology

When the Friends of the Caltech Libraries held a dinner meeting last fall, it was natural to ask the new head of Caltech's library system to speak. Glenn L. Brudvig, director of information resources, took over in Millikan Library on July 1, and the FOCAL members were eager both to meet the man and to hear directly from him what his plans and hopes for the library are. We couldn't arrange a personal meeting, but "A Look at Technology and the Future of the Caltech Libraries," which begins on page 15, is adapted from Brudvig's speech to give the wider circle of *E&S* readers the same information.

Brudvig comes to Caltech from the University of Minnesota, where he was director of the Bio-Medical Library. He was also director of the Institute of Technology Libraries at Minnesota. One of his specialties is the development of automated procedures in library services.

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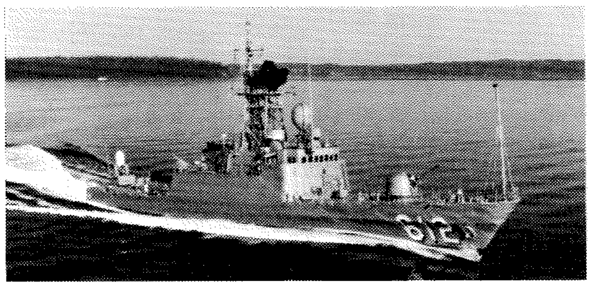

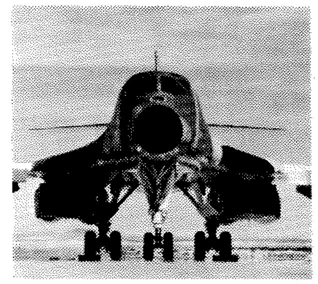

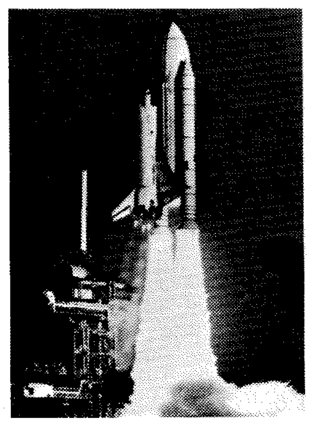

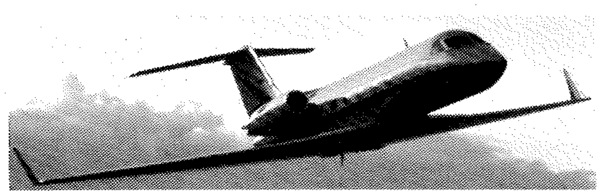

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SCIENCE/SCOPE

The space shuttle's new "eyes, ears, and voice" have revolutionized future missions. The integrated radar and communications system, also called the Ku Band radar because of its operating frequency, uses an antenna dish at the front of the cargo bay. The system lets shuttle crews talk to Earth or transmit TV, high-speed data, and payload telemetry through NASA's tracking and data relay satellites. Previously, crews could communicate with the ground less than 20% of the time because the spaceship passed beyond the range of ground stations. Now communications time increases to over 90% of a mission. The Hughes Aircraft Company system also allows the crew to rendezvous with satellites. It pinpoints objects as small as 1 square yard from up to 14 miles away, or up to 345 miles if the object is equipped with an electronic signal enhancer.

A new video graphics projector that's brighter and sharper than conventional projection TV may be the next addition to office computer systems. The Hughes projector displays monochromatic computer-generated alphanumerics, symbols, and graphics. It could be used for displaying dynamic computer data and facsimile video pictures in board rooms and other areas, and for teleconferencing. The projector uses a device called a liquid-crystal light valve, a cousin of displays in digital watches. This device intensifies the image from a cathode-ray tube and projects it onto a screen up to 12 feet wide.

Pioneer 10 is streaking into interstellar space with navigational help from its electronic imager. The spacecraft, which made history last June upon leaving the solar system, is using its imaging infrared photopolarimeter (IPP) to fix on the star Sirius. Pioneer 10 previously oriented itself with a sun sensor, but the sensor, now well beyond its design range, has reached its limits of sensitivity nearly 3 billion miles away. Pioneer 10 needs a reference point for spacecraft attitude control and interpretation of scientific data on solar wind. The IPP had been repeating various cruise-mode experiments since giving scientists their first close-up pictures of Jupiter and its four largest moons in late 1973. The IPP was built by the Santa Barbara Research Center, a Hughes subsidiary.

Molecular detectives using modern chemical analysis equipment solve important mysteries whenever advanced lasers or infrared sensors are contaminated with unknown substances during manufacturing. Hughes process engineers have at their disposal an array of computerized equipment, such as a scanning electron microscope X-ray fluorescent spectrometer. These devices separate unidentified substances -- solid, liquid, or gas -- into their various component elements. Once engineers have identified a contaminant, they can advise how to clean the hardware and how to prevent future contamination.

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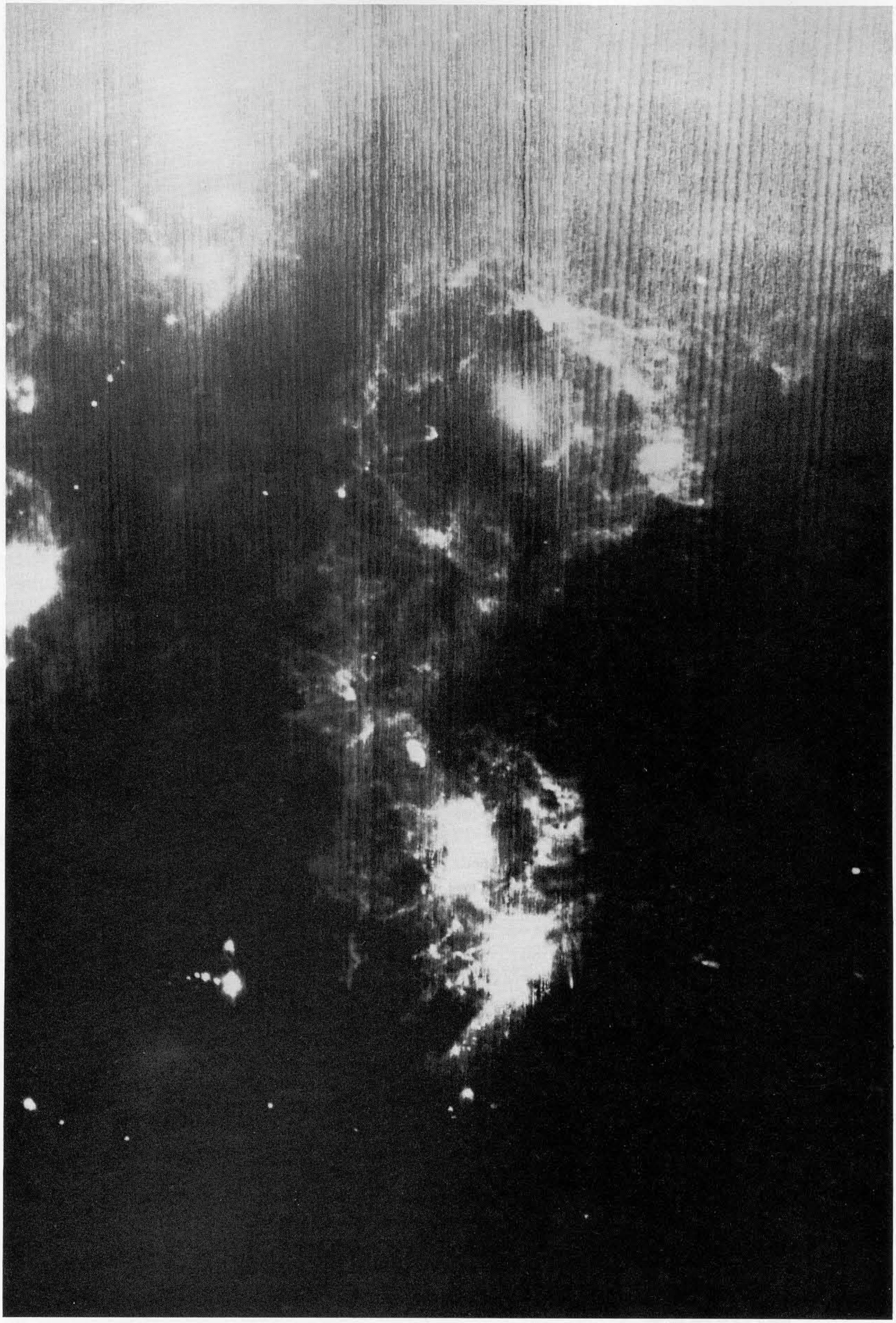


Discoveries From IRAS

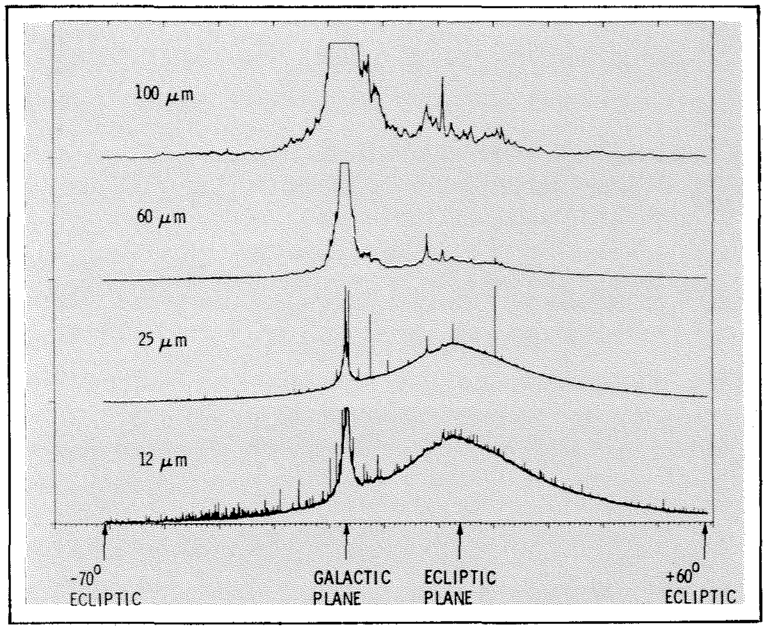
This familiar region of the sky around the constellation Orion looks very different viewed by IRAS. In the lower half of the picture the gases of the Orion molecular cloud, a well-known region of star formation, obsure the stars of the hunter's sword and belt. The circular feature at top center corresponds to a region of ionized hydrogen gas and dust heated by the star Bellatrix. Part of the Milky Way can be seen at upper left, as well as infrared emission called "cirrus" from dust littering interstellar space within the galaxy.

THE INFRARED ASTRONOMICAL SATELLITE (IRAS), a joint project of the United States, the Netherlands, and the United Kingdom, was launched a year ago. It finished its mission in November when its telescope's coolant was exhausted. During the time it flew, data from IRAS have led to discoveries of a variety of new phenomena in the universe, from unexplained celestial objects to rings of dust within the solar system. Other results include detection of unidentified cold astronomical objects; discovery of "infrared cirrus" clouds in interstellar space; infrared views of the Milky Way; and detection of large amounts of infrared radiation from visually inconspicuous galaxies. Papers on most of the findings summarized here will be published by the *Astrophysical Journal* in March.

IRAS was developed and operated by the Netherlands Agency for Aerospace Programs (NIVR), the U. S. National Aeronautics and Space Administration (NASA), and the United Kingdom's Science and Engineering Research Council (SERC). The Rutherford Appleton Laboratory operates the tracking station and preliminary science analysis center in England. Caltech's Jet Propulsion Laboratory (JPL) is the U. S. management center for the project.

Nearly 500 scientists, engineers, and technicians from the three countries have been involved in the project. Gerry Neugebauer, Caltech professor of physics and director of Palomar Observatory, is U.S. co-chairman of the Joint IRAS Science Working Group. Also a member of the working group and head of the final data processing team is B. T. Soifer, senior research associate in physics. At JPL Gael Squibb is currently the IRAS project manager; Jerry Smith was project manager during much of the pre-launch fabrication and testing periods.

Launched into a 900-kilometer orbit in January 1983 from Vandenberg Air Force Base at Lompoc, California, IRAS carried a highly sensitive, cryogenically cooled, 57-centimeter, infrared astronomical telescope, which conducted an all-sky survey of objects in the universe that radiate infrared energy. Its detectors are cooled to about 2.5 degrees above absolute zero (2.5 kelvin, or −270 degrees Celsius, or −455 degrees Fahrenheit) by superfluid helium, making the instrument the coldest man-made object ever flown in Earth orbit.



A scan across half the celestial sphere crossing both the galactic plane and the ecliptic plane of the solar system, produced these data from the four infrared telescope focal plane detectors, one for each of IRAS' wavelength bands. Cool dust from the galaxy produced peaks in the 60- and 100-micron regions (as well as some stars and hot dust in the 12- and 25-micron bands). Warm dust particles in the solar system radiate strongly at 12, 25, and 60 microns, but only weakly at 100 microns.

The first stage of the IRAS all-sky survey was completed in August. A second look at the sky has been under way since then to achieve 99.8 percent reliability for objects observed by the telescope.

Unidentified Objects

The orbiting telescope has detected more than 200,000 infrared sources, a fraction of which have not yet been correlated with previously known objects. Early in the mission, a small region of the sky was scanned repeatedly to provide the IRAS scientists with a basis for understanding the subsequent data. In this so-called "minisurvey," 8,709 sources were detected and confirmed, of which 133 cold, point-like sources were selected for further study. Most of these could either be correlated with already known objects or otherwise identified. It has not been possible to reach definite conclusions for some of the objects that are located in crowded regions of the sky. Nine objects remained in uncrowded regions of the sky, however, that could not be correlated with known sources, nor could evidence be found that they had been previously detected in any other sky survey.

The nine objects, which are quite cold (less than about -220 degrees C, -364 degrees F), do not cluster either around the planes of the Milky Way or the solar system. Since the initial analysis of the unidentified objects in the mini-survey, dozens more have been found in the main survey. The nature of the objects cannot be determined without more information about their distances; additional IRAS and other observations are required to allow approximate distances to be derived. Half the objects have been re-observed six months after they were initially discovered, and are at a distance of more than 6,000 astronomical units (one AU is 93 million miles, the distance from the Earth to the Sun). The distances of the other objects have yet to be determined.

If the objects are within the Milky Way, IRAS scientists speculate that some that appear near clusters of sources or in regions of star formation may be protostars (newly formed stars). Others that appear more isolated may be old stars obscured from view by thick shells of circumstellar material. In either case, they would be unusual in that they are colder than most objects of either type.

An intriguing possibility is that these objects are galaxies detectable only at infrared wavelengths and exist far beyond the Milky Way. Their very low temperatures are similar to the temperatures determined for distant spiral galaxies. No spiral galaxies have been detected in visible light at the locations of the nine objects. Therefore, if they are galaxies, they have unusually large ratios of infrared-to-optical emission — about 100-to-1 or more.

Zodiacal Dust Bands

IRAS has also discovered three narrow, continuous rings of dust within the solar system. These new features of the solar system may be the result of countless asteroid collisions in the main belt between Mars and Jupiter at a distance from 2.3 to 3.3 astronomical units from the Sun. It is also possible that a single, catastrophic collision between two solar system objects, such as between an asteroid and a comet or between two asteroids, produced the two outer bands of material.

IRAS mapped infrared emission from this interplanetary dust at wavelengths from 12 to 100 microns. The dust is also known as the zodiacal dust since it lies mainly in the zodiacal or ecliptic plane in which the planets travel. The temperature of the dust is -123 to -73 degrees C (-189 to -99 degrees F). This characteristic, in addition to the symmetry and position of the bands with respect to the ecliptic plane, associate them in space with the main-belt asteroids, according to IRAS scientists. The central band may be a permanent feature of the solar system, since it would be constantly replenished by dust from asteroid collisions.

Rather special conditions are required to form the two outer bands that are seen about nine degrees above and below the broad central band. According to the comet-asteroid collision scenario, a comet approaching the Sun at about a nine-degree angle smashed into one of thousands of asteroids in the main belt. After many orbits around the Sun, the remaining dust would spread evenly around the asteroid belt along part of a spherical surface extending nine degrees on both sides of the ecliptic. Each particle would orbit in a plane, tipped with respect to the ecliptic, that includes the Sun. The resultant distribution of dust appears as two parallel bands, since each orbiting particle spends more time at its most distant point from the ecliptic rather than closer to the plane. The estimated amount of material in the bands corresponds to the mass of an asteroid one kilometer in diameter.

Infrared Cirrus and Background Infrared Emission

IRAS has found that much of interstellar space is littered with wispy clouds of dust, which the science team termed "infrared cirrus," and which are believed attributable to dust particles found in interstellar space within our Milky Way galaxy. Viewed in the 100-micron wavelength region of the spectrum by IRAS, the sky appears largely highlighted by these cloudy features. Because of its temperature, IRAS scientists believe the cirrus consists mainly of graphite (carbon) particles formed in the outer atmosphere of stars and heated by starlight.

Left unexplained at present is another component of background infrared radiation spread more broadly across the sky as a whole. Its intensity and temperature will be determined when all the IRAS results have been processed and analyzed.

Milky Way

The Sun is located in the outer part of the Milky Way disk, about 30,000 light-years from the center. The space between the stars in the disk contains clouds of gas and dust that block our view in visible light. Infrared light, however, because of its much longer wavelength, moves through this dust with very little attenuation, allowing a view of distant regions within the galactic plane.

Images assembled from IRAS observations near the nucleus of the galaxy show, in addition to the nucleus, molecular clouds such as Sagittarius B2, seen for the first time at 12 and 25 microns. In addition, the images at 60 and 100 microns show the infrared cirrus described above as wisps of material all along the plane and extending into much of the sky.

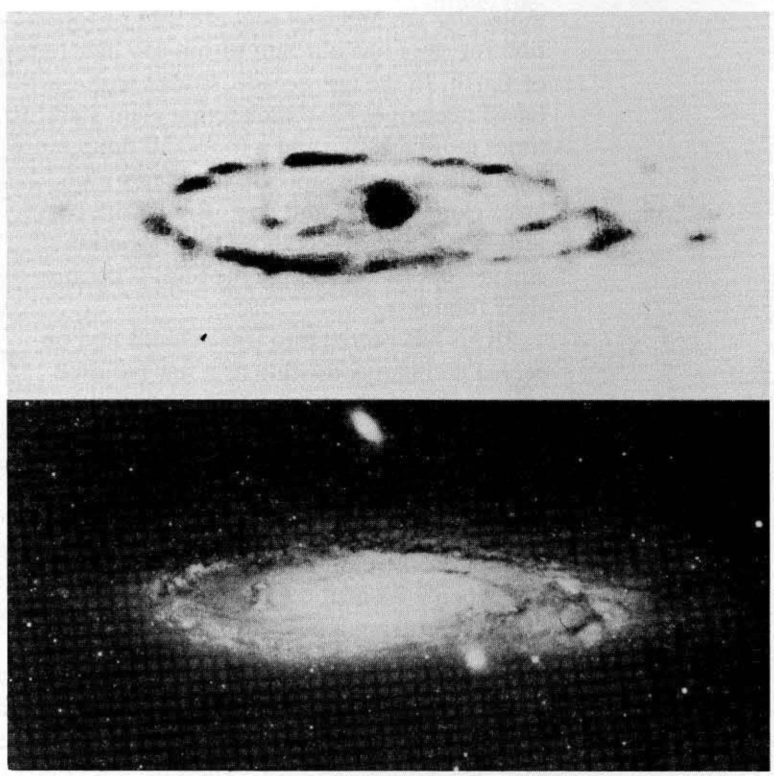
Galaxies

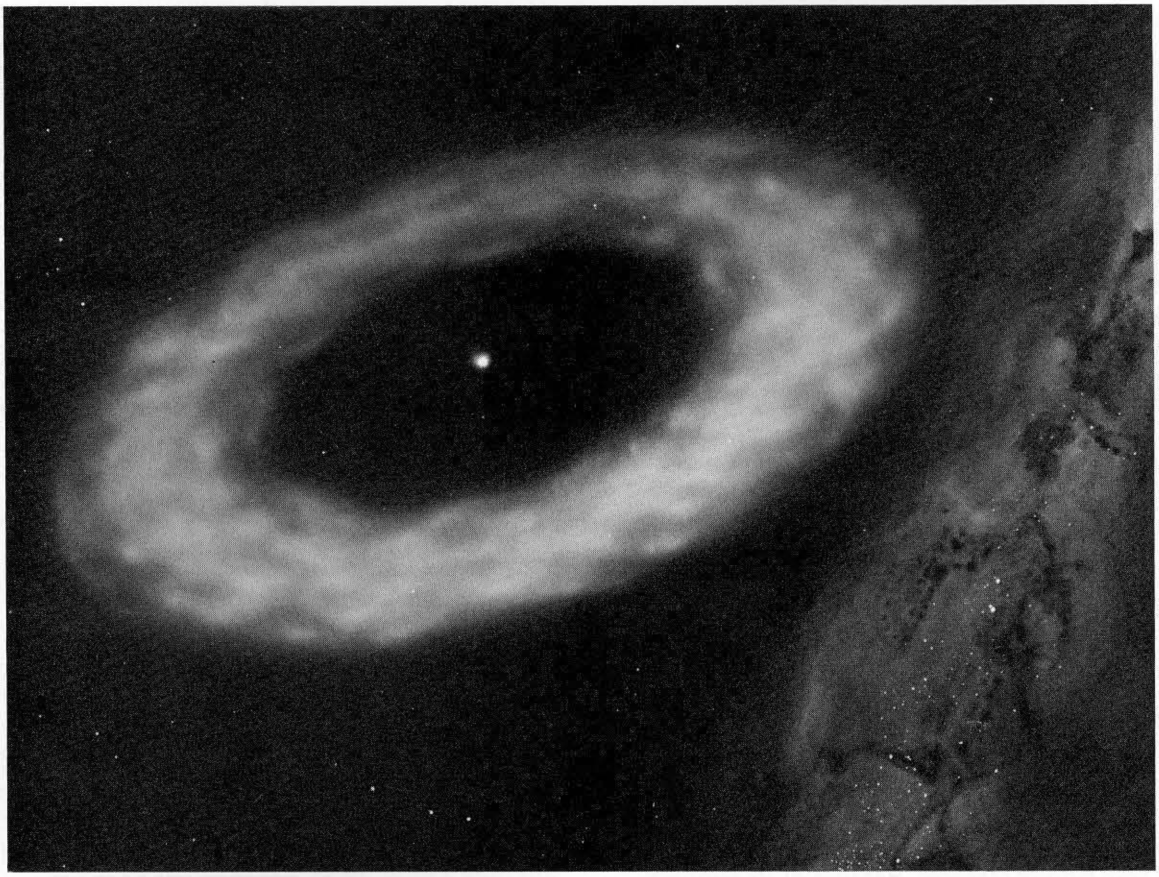
IRAS observations have revealed many infrared-emitting galaxies previously seen only as inconspicuous smudges in the most sensitive photographic atlases. In the minisurvey, which sampled only one percent of the sky, more than 80 galaxies were found that are faint optically but very bright in infrared light; some emit 50 times as much energy in the infrared as in the visible. For comparison, the infrared luminosity of the Milky Way is roughly equal to its visible luminosity. To achieve a better understanding of the energy sources and physical conditions within these galaxies will require further studies with other telescopes.

Spiral galaxies were found to exhibit a wide range of ratios between their visible and infrared luminosities. The infrared emission in normal galaxies is thought to be a measure of the rate at which new stars are forming, so the wide range in infrared-to-visible luminosity ratios is believed to reflect a similar range in the fraction of a galaxy's mass being formed into stars.

A detailed study of the Andromeda galaxy, our nearest neighbor giant spiral, has shown that much less star formation is occurring there than in most spiral galaxies and far less than in our own galaxy. IRAS observations have pinpointed the locations of current star formation processes in Andromeda as occurring predominantly in the outer dust lanes at roughly 30,000 light-years from the center. The luminos-

The Andromeda nebula, our nearest neighbor spiral galaxy, is observed here with the 48-inch Schmidt telescope at Palomar Observatory (bottom) and by IRAS at a wavelength of 60 microns. The dark ring in the IRAS image indicates the location of current star formation processes. IRAS scientists believe that the dark nucleus does not represent an area of star formation but rather thermal emission from dust mixed in with the stars.





This artist's conception illustrates the ring of material that IRAS discovered around the star Vega. IRAS scientists think that the ring probably consists of dust and small meteor-like objects that may be accreting into larger particles. This might represent an early stage of planet formation.

ity of these regions represents only four percent of the total energy emitted by this galaxy.

Star Formation

IRAS has found numerous small clouds of molecular gas and dust that are sites of formation for stars like our Sun within 650 light-years of Earth. In the last decade, studies with Earth-based telescopes have shown that giant stars, 10 times more massive and a thousand times more luminous than the Sun, are forming within large clouds of gas and dust. But before IRAS, little could be learned about the formation of smaller stars — those like the Sun — because of their faintness.

IRAS has peered into these clouds and observed globules consisting of a few hundred solar masses of molecular hydrogen gas that could collapse under their own weight to spawn stars of about the same size as the Sun. The IRAS all-sky survey has found that many nearby dark clouds harbor newly formed stars in a stage of evolution much like that of the Sun when it formed 4.6 billion years ago. The visible light from a newly formed star is hidden from view by the material left over from its formation. The curtain of obscuring dust is, however, heated by absorbed starlight much warmer than most matter in interstellar space. It is this heat from the hidden star that IRAS is able to detect.

One object that is probably much like our early Sun has been found within a dark molecular hydrogen cloud called Barnard 5. The object, one of four detected within the cloud by IRAS, is radiating at about 10 times the rate of the present-day Sun, at a temperature between −243 to +227 degrees C (−405 to +440 degrees F). It appears to agree with theories of stellar formation, which suggest that a star like the Sun goes through an extremely luminous phase in its first 100,000 years of existence.

Two other objects within the cloud appear to be slightly more mature young stars separated from the molecular cloud itself but still hidden by the warm dust (about −70 degrees C or −100 degrees F). The fourth object within Barnard 5 is more enigmatic. It may be no more than a clump of material at the edge of the cloud, or it may be a very cold, dense part of the cloud (about −250 degrees C, −418 degrees F), starting its collapse into another star. More sensitive observations with greater spatial resolution are planned to understand this object.

In another cloud, called Chamaeleon I, 70 sources were detected. Of these, 17 resemble objects in Barnard 5 — either stars deeply embedded within the cloud or stars clear of the cloud but still dust-enshrouded. Twenty-five objects were shown to be cool clumps of material, some perhaps about to collapse into stars. The rest were either normal stars unrelated to the cloud or were impossible to identify because of confusion with emission from other sources.

Vega

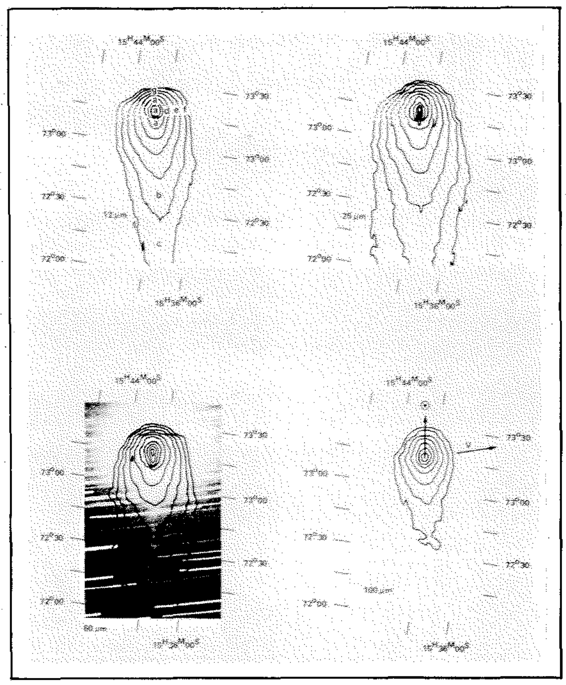
In studying observations of the bright star Vega, which was being used as a standard source to calibrate the telescope, IRAS scientists discovered evidence of a system of solid material orbiting the star. The telescope detected infrared emissions from large solid particles that are gravitationally bound to the star. The particles have probably grown from material left over after Vega's formation and may resemble meteoroids, zodiacal dust, and other solid material found in our solar system.

The discovery provides the first opportunity outside the solar system for scientists to study directly the phenomena that lead to formation of planetary systems around stars. Vega may represent a relatively early stage of planetary formation, where the material is accreting into larger particles, or it may have evolved along a path very different from that followed by the solar system.

Since the discovery, IRAS astronomers have searched for other stars that might also possess orbiting material. The search is complicated by several factors. Excess infrared radiation from a star does not in itself mean that the star possesses orbiting material, according to IRAS astronomers. Other types of processes are known to produce excess infrared emission. Conversely, a planetary system around a star may not produce a significant infrared excess. Our solar system, for example, would be difficult to detect by its infrared excess because most of the material is bound up in planets, which, because of their small surface areas relative to their volumes, radiate much less infrared than material like dust and small grains. In addition, there are only a few stars as bright or as well studied as Vega; thus an unusual infrared excess that might identify a star as a good candidate for possessing a planetary-like system would not be obvious around most other stars. To date, this search has turned up a number of interesting candidates but no other confirmed Vega-like system.

Comets

IRAS has discovered five new comets, detected extensive envelopes of dust around comets not previously known to be dusty, and observed a long, thin, invisible trail of cometary debris from the well-known comet Tempel 2.

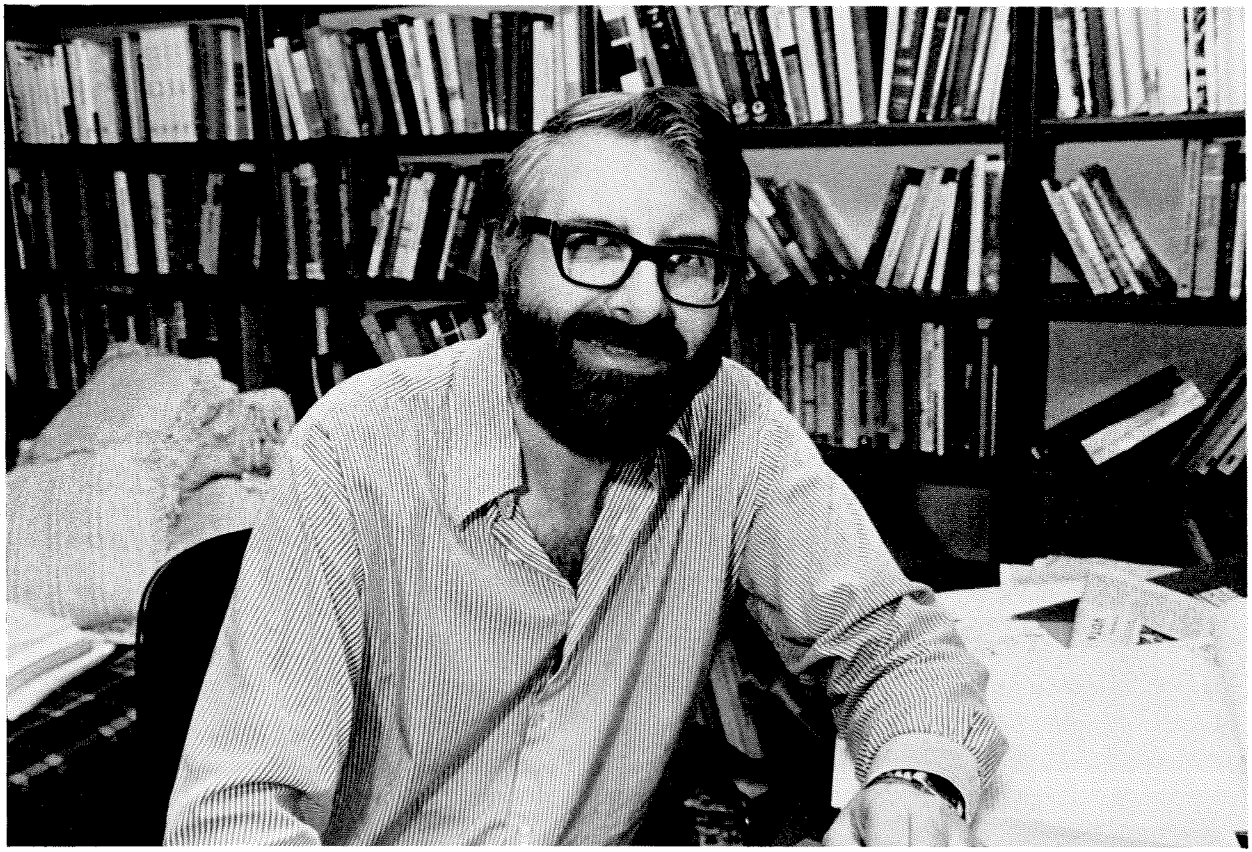


Maps of the infrared emission at the four IRAS wavelengths of comet IRAS-Araki-Alcock show the comet's extensive invisible dust trail. The 60-micron map at lower left is superimposed on a photograph of the comet. Emission at 12 microns is shown at upper left with the 25- and 100-micron maps following clockwise. The flux at each contour (from outside inward) is twice as bright as the preceding one.

It has also discovered a new object, designated 1983 TB, which appears to be the parent body for the Geminid stream of meteors, which is seen in December. If this is true (and current observations should make this clear), then 1983 TB may be the sixth comet discovered by IRAS. Most of the major meteor streams have been associated with parent comets; for example, the Orionid shower on October 21 is thought to be produced by debris in the orbit of Halley's Comet. Before the discovery of 1983 TB, no comet had been found to account for the Geminid shower.

The rapid detection of comets by IRAS is performed with the aid of computer programs developed jointly by the IRAS project at the Rutherford Appleton Laboratory and Leicester University. The great success of IRAS in detecting comets, beginning with IRAS-Araki-Alcock, is due to its extreme sensitivity and to the infrared emission from small, sun-warmed dust particles in the coma and tail. Detection of comets as faint as 17th visual magnitude (which would require a visual telescope of 20-inch diameter or larger for detection) is providing data to revise our present estimates of the total population of small comets.

Based on findings to date, IRAS scientists believe additional new information about the universe will certainly be revealed as the processing and analysis of IRAS data continue over the next several years. □



The Question of Utopia

An interview with Brian Barry, Caltech's
Edie and Lew Wasserman Professor of Philosophy,
by journalist Mark Davidson

Mark Davidson: Many people today equate utopianism with Orwellianism — out of fear that any utopian dream is an invitation to an authoritarian nightmare. Do you share that fear?

Brian Barry: I can't see any problem about saying, "Wouldn't it be nice to have such-and-such state of affairs?" — as long as you accept the fact that your proposed state of affairs should be brought about only if enough people want it and if, once they have it, they are free to move out of it if they decide they want something else.

In other words, I can't see any reason why utopia can't be just a conceptual construction that you put forward for the sake of discussion. It may then act as a magnet that attracts people toward it.

MD: So you view utopian thought as a legitimate tool of political theory?

BB: It seems to me that utopia-making is as valid a way of doing political theory as any other. Abstract arguments about social reform are certainly useful, but I think the attempt to illustrate how society might *look* with such reform is just as important. The depiction of a coherent idea of a society may in fact be a quite powerful way of presenting a political argument. In some cases it may be a more effective way than the expression of formal propositions.

MD: What intellectual function does utopian thinking actually serve?

BB: The utopian approach may help you think about whether or not some proposed state of affairs is internally coherent. That is to say, are you assuming one thing about the economy and another thing about family life — and they don't really fit together? More specifically, are you assuming incoherent motivations in people? So it seems to me that a utopian construction is a way of trying to see if the kind of society you're holding up as good is in fact conceivable. If you could get there, would it in principle be able to maintain itself?

Also, I think utopian thinking is useful to the extent that it reminds you to clearly separate out two questions that tend to get run together: What would be a good state of affairs? And how would you in fact get from here to there?

MD: The word "utopian" is often used pejoratively to mean "unrealistic." How justified do you think that usage is?

Mark Davidson

BB: When something is denounced in that way as utopian, there are really two possible objections, one of which seems to be valid and the other not.

The valid objection would be the argument that you simply could never have a state of affairs like that. Obviously, if that's true, then that's very relevant.

On the other hand, I don't think it's valid to say a proposal is no good — utopian in the pejorative sense — solely because you can't see how it could be accomplished under the existing social structure and the existing constellation of political forces.

For instance, if somebody says it's utopian to talk about reforming the tax codes to get rid of loopholes, all that means is that such a reform may be impossible because of the power of vested interests under the present political system. That doesn't mean you couldn't accomplish this reform in principle, that you couldn't justifiably envision a society of ours without the loopholes.

MD: So the utopian approach is a useful way of thinking about the future?

BB: Absolutely. Utopian thought helps free us from the limitations of our day-to-day thinking. It helps produce potentially valuable ideas for the long run. History shows that there are occasions when opportunities for major reform open up — sometimes rather suddenly — and at such times we may be grateful for the existence of utopian ideas that were worked out in advance.

MD: As the author of books and articles on social justice and international morality, you obviously have entertained ideas about a better world. What would you consider to be the essentials of a viable utopia?

BB: A full answer to that question would require a book. But I think one essential would be a fair degree of material equality. Without that, it would be very hard to arrive at what I regard as the right sort of relationships between people.

Beyond that, leaving aside obvious things like the elimination of war, I think I would attach a lot of importance to people being free to read, think, and say what they like. At the same time, there should be an awareness that some people really do know more than others and have better taste in certain matters than others. Superior ideas and taste would tend to emerge as a result of free expression, but the ideal of free expression should not be interpreted to mean that all ideas are equally good.

MD: Do you think humanity is giving enough thought to moving in ideal directions?

BB: In our society, at least, if you compare books written in the 1940s with those of the 1970s and 1980s, I think you see a shift away from idealistic speculation. I suppose that's partly a reaction against the often half-baked ideas of the 1960s. And I think a lot of it stems from the feeling that it's impossible to get governments to carry out the things they're supposed to do — which may be true at this time and place but is not true at all times and places.

MD: Has utopian thinking been eclipsed by the notion that people are incurably selfish?

BB: I think that factor may be playing a role. But I think the idea that everyone will always act in accordance with narrow self-interest is a crude notion that is being elevated to the level of absolute truth. That notion represents a simple-minded cynicism that unfortunately may sometimes be self-fulfilling.

MD: You feel there's more to human nature than self-interest?

BB: Much more. There are many examples of people acting out of higher motives. And people do sometimes vote a certain way because they think something ought to happen, not necessarily because it would benefit them.

MD: What's your reaction to R. Buckminster Fuller's thesis that the world has become such a dangerous place that humanity must choose now between utopia or oblivion?

BB: I hope Fuller's assessment was inaccurate, because I see no hope that we can accomplish a utopian transformation in the near future. To say we're going to solve the problems of preventing nuclear war or the ruination of our habitat only if we undertake a fundamental reorganization of social-political-economic relationships is really to place those problems in such a long-term framework that we would destroy ourselves before we could succeed.

MD: Are you saying that it would be suicidal to take Fuller's advice literally?

BB: Yes, I believe so. We must continue to work at short-term, incremental answers. Because even if we were able to achieve utopia, it would take too long. After all, we're talking about pretty deep-seated conditions. We're talking about systems of politics and economics that have been around for centuries.

MD: But you do have some hope that civilization can survive its present crises?

BB: Perhaps hope is a psychological necessity for individual survival. At any rate, one hopes that discussion of the issues does help. And there are some notable examples of this in the past. Civilization moved from a situation in which everybody pretty much took for granted that slavery was okay to a situation in which it became rather widely held that it *isn't* okay. And we've witnessed a similar change in attitudes about imperialism: the idea that it was perfectly okay to grab any place you *could* grab. (I realize that imperialistic activity continues today, but it's done apologetically or covertly.) And I think we've been witnessing some real change in attitudes about the rights of women.

MD: How do you rate current world leaders in terms of idealistic zeal?

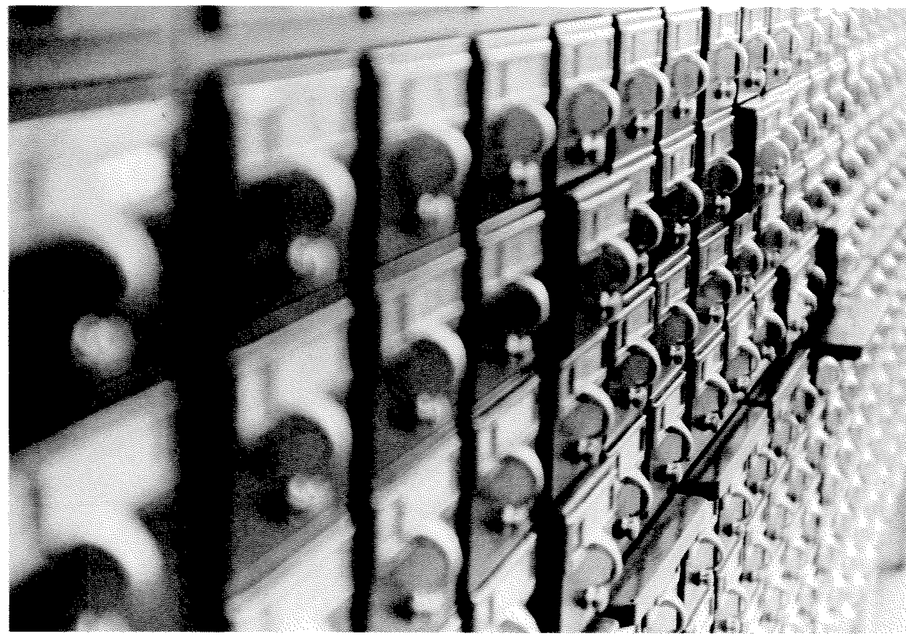
BB: I'd say they tend to be much more managerial than utopian.

MD: Would you prefer leaders with utopian visions?

BB: That depends. A utopian visionary can be just as dangerous as a simple-minded cynic if the utopian is the type who ignores the problem of how you get from here to there. The world needs visionaries — leaders who are not afraid to think about new approaches to our problems. But, more importantly, the world needs leaders who are willing to subject both new ideas and old assumptions to rigorous examination. □

A Look at Technology and the Future of the Caltech Libraries

by Glenn L. Brudvig



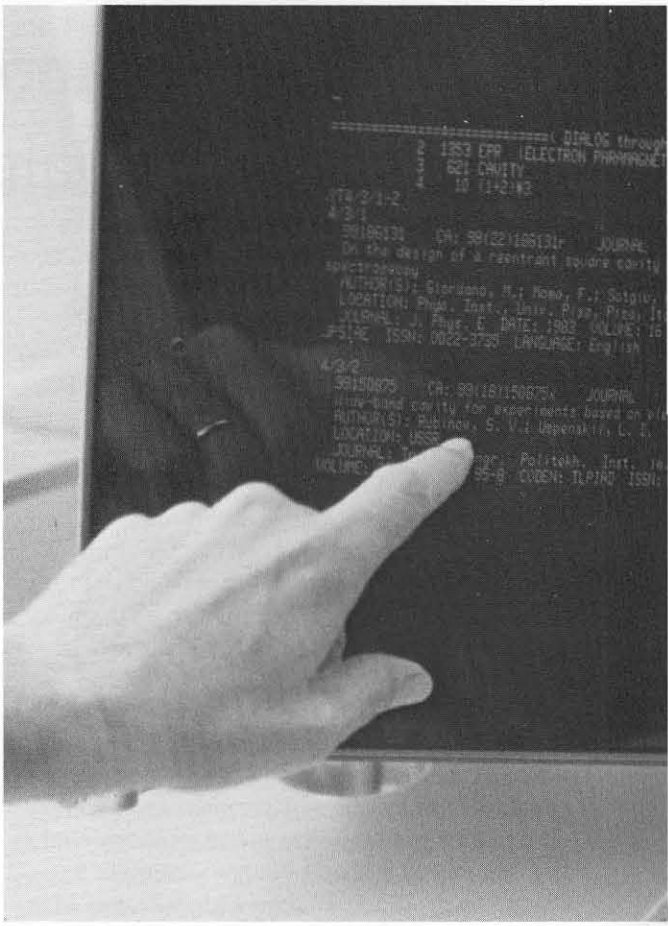
INFORMATION TECHNOLOGY and libraries are both in a period of rapid change, with technology being a major driving force behind many of the changes now taking place in libraries. As the Caltech Libraries begin to move from a largely manual operation to a computer-based system, we need to have a clear idea of where technology is heading so that we can make today's decisions based on reasonable projections of future developments. The library needs to fit into an evolving information system which includes the use of personal computers on one end of the spectrum and large national systems on the other. It needs to maintain its role of being a link between a global range of information and a community of users, but increasingly that link will be an electronic one.

The use of personal or office computers is growing at rates that could not have been predicted just a few years ago. At present, they are being used in academic settings primarily for word processing (for composing and editing textual material), but also for statistical and computational computing, for data management, for production of charts and graphs, and for access to other computer systems. The personal computer is becoming the scholar's work station and a focal point from which many information and computer sources can be tapped, including local campus computers, national information systems, and library computer systems. It is also providing a new means for scholars to communicate with one another through electronic transmission of information over telephone lines.

The capabilities of personal computers continue to advance at an incredible rate. Within the not too distant future we can expect to see multifont page formatting, which integrates both text and graphics and which can generate publication-quality copy that can be transmitted electronically to a publisher. Joint authorship of publications by colleagues located in different parts of the country, or even of the world, through the use of personal computers should become a common practice. Publications that are transmitted to publishers electronically can also be transmitted to colleagues or referees in the same manner. So, if writers write on line, editors edit on line, referees referee on line, and authors exchange preprints on line, can publishing on line be very far behind? Electronic publishing, whereby a paper copy would be produced only to meet a user's personal need, seems inevitable at some point in the future, possibly in 10 to 15 years, or maybe sooner for some types of publications. Although it may be very difficult for libraries to make plans for electronic publishing at present, or even to fathom how such systems may affect library services, we still need to be prepared to use them once they become available. The library systems that we develop today need to be planned with this eventuality in mind.

The personal computer will provide the potential for the scholar to gather information electronically from many sources, to build personal knowledge bases, and to construct a data base which will provide access to information now kept in file cabinets, note files, reference works, or reprint collections. Libraries should become an important source of electronic infor-

A year's worth of Chemical Abstracts, *containing about 500,000 entries, fills three shelves. The information contained in this publication can also be retrieved on line at Millikan Library.*

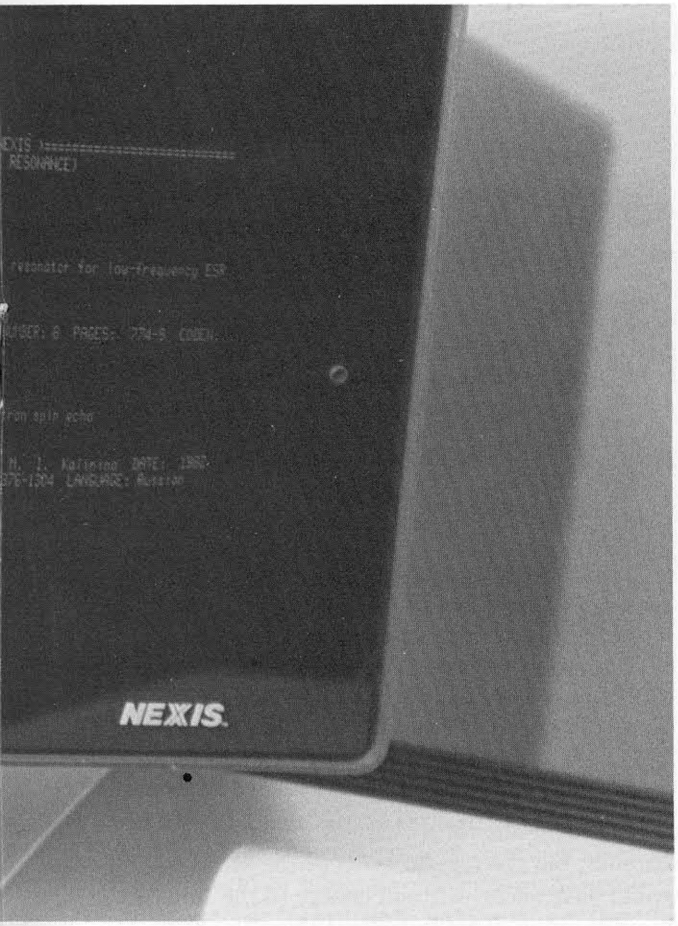


mation now and in the future. An important feature, therefore, of the initial plans for a computer-based library system for Caltech should be provisions for faculty members and students with personal computers to query the library's "card" catalog and indexes, to identify appropriate references, and to build bibliographies by transferring records electronically into their own files. A researcher's bibliographic files could also be automatically updated through a descriptive profile matched against the library's latest bibliographic records.

On the national scene, changes are taking place that will profoundly influence the kinds of services that libraries will provide in the future. What libraries will do in the future will depend to a very large extent on what the publishers do. When publishers shift from print-on-paper to electronic publishing, librarians will need to adjust their practices accordingly. Although this may be some years away, we are already beginning to see a shift from print to an electronic means of disseminating information in some areas. This shift has been taking place steadily in the publication of indexes and abstracts.

All of the indexing and abstracting services (for example, *Chemical Abstracts, Biological Abstracts,* and *Reader's Guide to Periodical Literature*) are now produced by the computer. Most are accessible, or are becoming so, through on-line computer terminals. Although most indexing and abstracting services continue to produce printed versions of their products, some of the newer ones (those established after on-line searching became commonplace) are available only in an electronic format and have no print equivalents. Most libraries that use computer terminals for searching the literature also continue to purchase the printed indexes and use the computer only for the more complex searches that are impossible or difficult to do manually. There are a few libraries, however (new, specialized ones that have been established fairly recently), that have decided not to buy the printed indexes but to rely entirely on the computer for access to the literature. They have found it cheaper to do this than to purchase and store printed indexes. We are beginning to see a migration from print to electronic methods for information transfer in this specific area, but there are other examples as well.

A wide variety of data bases, in addition to the indexes and abstracts, are becoming available on line — for patents, statistics, biographical information, drug information, and so on.



Many of these are geared toward the commercial sector, but a large number are aimed at libraries as well. These data bases can be thought of as an on-line version of the reference book. Many of these newer, nonbibliographic data bases do not have a printed counterpart, and a few that once had them have dropped them.

Access to the full text of some publications is also becoming available through electronic means. The *Encyclopaedia Britannica,* the *Federal Register, Business Week, The New York Times,* and *The Washington Post,* to name a few, can all be retrieved in full text through a computer terminal. The 18 journals published by the American Chemical Society can also be retrieved on line in full text, as can the *Harvard Business Review*. The use of the computer to retrieve an article for one's general reading enjoyment is neither economical nor aesthetically acceptable, at least not at this time, but it is an excellent way to locate specific information within the text of an article that may be very difficult or time consuming to find in any other way. And for rapid access to material that is not immediately available, it can be a very valuable resource.

The rate of change from print to electronic formats may be speeded up through new technologies, such as optical disks or more powerful software; but it could be slowed down by the costs of using such systems, by public acceptance, by inadequate copyright protection, or by a plethora of confusing and incompatible networks. Librarians need to stay abreast of these developments and evolve strategies for the future which can blend the new technologies together into a single system.

Because of the technological changes which have been taking place, the information resources of a library no longer need to be limited to the printed information in its collections. The library can move beyond its walls, encompassing an ever larger world of information which it can make available to its users, continuing its traditional role as the link between the information producer and the information consumer.

In planning an automation system for the Caltech Libraries, certain basic principles seem to be in order. First, as I have indicated, a library automation system needs to be a bridge between national information networks and personal computers, a bridge that can be used to transfer information to the individual user when it is needed. Second, it should be dedicated specifically to library operations, yet be able to interface with many different systems. Third, it should be an integrated system that will handle the full range of library and information retrieval functions. And fourth, it should be flexible so that it can continue to be expanded to take advantage of new technologies and to meet new demands that are placed upon it.

In planning for library automation, we need to begin with the ordinary "housekeeping" operations of the library — ordering books, handling the book fund accounting, checking in journals, and the activities related to getting a book onto the shelf. This is the process that will create an on-line catalog which is the index to the holdings of the library system. This process also involves a computer link to a national data base. For example, when a book has been recommended for purchase or is cataloged, the On-line Computer Library Center (OCLC) data base, which includes the cataloging records from the Library of Congress and 3,300 or so other libraries (including Caltech's), can be queried. If the record is found, it can be electronically transferred or copied into the library's computer file. This record can then be used to prepare a purchase order, an in-process record, and a catalog record. Very little typing is done in the process, and most paper and manual files are eliminated.

The building of the library's on-line catalog also requires the conversion of existing cataloging records from 3-by-5 cards to machine-readable records. Once this was completed for the most used portion of the collection, we would add circulation control to the system. This would enable users of the system, through terminals located in the various units and libraries on campus, to determine not only whether an item was held by the library but also whether or not it was checked out.

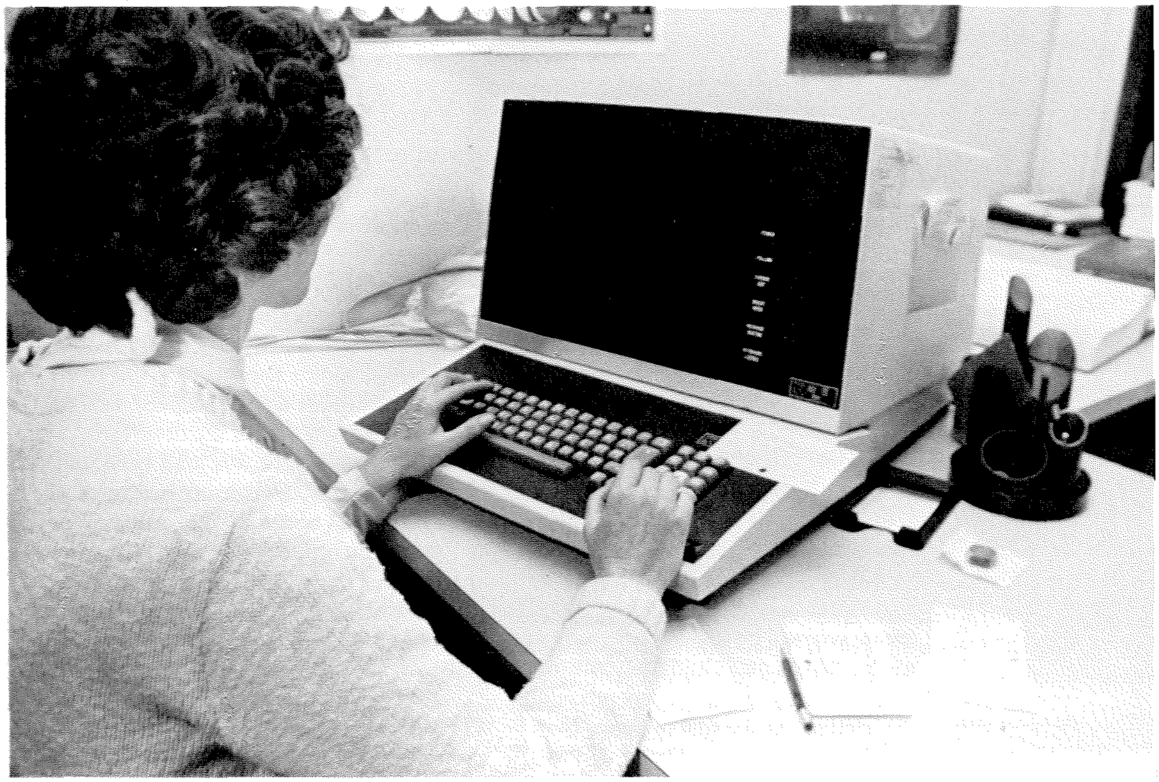
By putting the card catalog on line, information on the resources held by all libraries on campus would be available at any point on campus. With collections divided between 10 floors in the Millikan Library and 10 departmental libraries, the problem of knowing where a particular item is located can be a time-consuming process. With an on-line catalog, users would also have more in-depth access to library holdings. They could search the catalog records in the usual way, by author, title, and subject, but also by the keyword in the title, by limiting a search to a publishing date, call number, or publisher, or by combining terms to either expand or limit a search.

The card catalog includes only the books held by the library. At Caltech, with its primary emphasis on science, it is the journal literature which is the most important source of information. Thus we need to improve our access to this resource as well. Before World War II, when labor was cheap and more plentiful and the number of journal publications was considerably less, some research libraries cataloged not only books but also the articles in the journals which it received. Their card catalogs thereby represented an index to the total resources held by the library. Now we have an opportunity to again do something very similar, but to do it electronically. Citations to the articles included in the journals currently received by the Caltech Libraries could be captured from national data bases, either by a monthly magnetic tape received on subscription or possibly by a computer-to-computer transfer of data.

With some 50 million journal articles currently accessible on line, this vast amount of information needs to be filtered so that we get only what is most relevant to the users on campus. If journals are selected carefully and quality is maintained, then the citations received by matching our current subscriptions against a large data base should reflect that quality. Those 50 million articles would still be

accessible on line for a charge for individual searches, but the regular users of the library would have access without charge to the smaller numbers of citations in current journals. Files of the most-cited articles could also be obtained in a similar manner.

The process of developing library automation moves step by step and takes time. With "housekeeping" as the first function to be automated, with an on-line catalog next, then circulation records, and finally a subset of the journal literature, a total automated library system can be built. At an appropriate point in the process, we would have to make the library computer system accessible to individuals with personal computers. A faculty member with a personal computer in his office, as was mentioned, should be able to search the library's data base and build bibliographies in his own files. He should also be able to request a book loan or a photocopy from the library, transmit a reference question or a literature search request, recommend that a new title be ordered, or request that he be notified when a book in circulation is returned. Materials would still need to be delivered or picked up, but at some future stage of development, a request for a journal article could result in the transmission of the full text on line. This is far beyond any current plans, but the transition from a request for a photocopy of an article to a request for the electronic transmission of its full text should



The familiar but cumbersome card catalog may eventually be on its way to extinction. At left, Charlotte Pavelko converts card catalog records into a machine-usable format.

be an easy step to make, at least in concept.

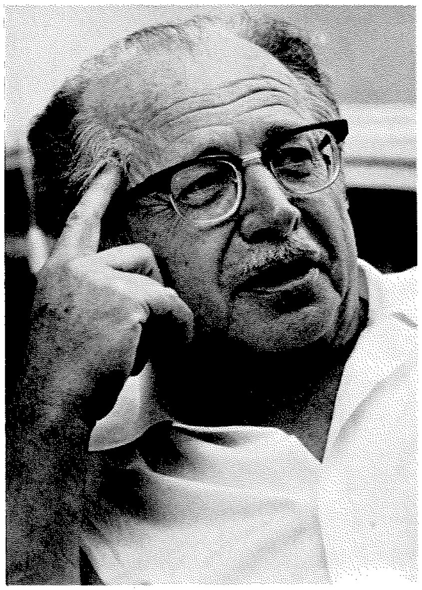
Even as it becomes possible to access an ever larger world of bibliographic information and more specific information hidden within that larger body of knowledge, something still is missing — methods for evaluating the published output. We can establish filters to screen the information from a global range of sources, such as matching our journal holdings against national data bases and obtaining files of most-cited articles, but that may not be enough. We may need additional methods for identifying the quality works in the literature. One method of doing this would be to have the computer keep track of use. This would identify the more heavily used, or popular, materials held by the library. Another approach would be to enable faculty members to indicate titles of high quality. It may even be practical to allow selected library users to comment on a book or article, giving the next user some indication of the value of the material being selected.

Once the library's bibliographic records were completely in the computer, it would then be possible for the librarian to enhance the record, to add information which would be useful to readers. Guides or pathways to the literature could be built into the data base. A library user could then determine what were the key texts in a particular field, the leading journals, the latest review articles, the special data bases, and so on.

Building the expertise of the reference librarian into the data base also becomes possible. The computer system could give instructions on how to use the system or the library, suggest search methods, provide directions to other sources of information outside of the library, or identify titles that need to be consulted to meet a particular information need. The possibilities of improving access to the literature increase tremendously with a computer-based library system. The development of the automated system for the library is therefore an open-ended process, as each new stage of development opens up new options for further development.

As we begin the development of an automation program for the Caltech Libraries, our immediate objectives are much more limited than the possibilities may allow. Our first steps will be to replace our manual operations with an automated system. To head up this effort we are now recruiting a systems development officer. We will be drawing up specific plans, establishing priorities, selecting software, purchasing equipment, and getting the project moving within the next several months. As we move ahead with this program, we intend to continue to take a long-range view of technology to help assure that our efforts will be compatible with the direction technology is headed and yet meet the immediate needs of the Caltech community.□

Jesse L. Greenstein — How It Was



Jesse L. Greenstein is the Lee A. DuBridge Professor of Astrophysics, Emeritus, at Caltech, and he was interviewed for the Oral History program of the Caltech Archives by Rachel Prud'homme. Those interviews led to 73 pages of transcribed material, only a small part of which has been excerpted here. We have, for example, touched only lightly on Greenstein's research, though it has been continuous and distinguished throughout his career, as has his service to a multitude of professional and governmental agencies. Retirement in 1980 has changed those aspects of his activities only slightly. We have chosen for this issue of E&S *to concentrate on his story of the history of astronomy at Caltech and of his organizational activities within the Institute since 1948.*

Rachel Prud'homme: You were appointed to the staff of Mount Wilson/Palomar in 1948 and professor of astronomy at Caltech. What were the Institute and the Observatory like then?

Jesse Greenstein: I was asked by Earnest Watson, dean of the faculty, to undertake the creation of graduate, and some undergraduate, teaching in astronomy at Caltech, to take the lead in acquiring faculty, which faculty would automatically become members of the Mount Wilson and Palomar Observatories staff. On my arrival, Caltech had only one professor in astronomy, Fritz Zwicky. The other people in astronomy were a research associate named Josef Johnson, who taught undergraduate astronomy, and Albert G. Wilson, a senior research fellow; both worked on Zwicky's research projects.

In a letter from Watson, before I came, he said, "If there were a department at Caltech, you would be department head. And if we create a department, you will be that." There were and are no departments and no heads, of course, but his letter was operationally descriptive. At the rate of better than one a year we began to build up the Caltech astronomy group. The other side of the scientific partnership was the Carnegie Institution of Washington, with offices on Santa Barbara Street a few miles from the campus. As a group, their astronomers had been in Pasadena since 1906 or '07 when George Ellery Hale came to Pasadena. The arrangements that led to the creation of the Mount Wilson/Palomar Observatories were complete before I arrived. The 200-inch reflector had been funded by the Rockefellers, the money given to Caltech, and its construction managed by Caltech. The formal dedication was in 1948, soon after I arrived.

RP: The administrative set-up was complex?

JG: It made my life miserable. Equally well I could say it made my life easy. There were nearby, as colleagues, about 20 distinguished astronomers of varying ages doing research in a wide variety of fields, mainly concentrating on observation rather than interpretation. As a group they had created large-telescope astronomy for the world. They had good operating 60-inch and 100-inch telescopes, solar telescopes, and a spectroscopic laboratory.

I was quite different from them. I had built up a reputation, both of observing and doing theoretical work, at the Yerkes Observatory of the University of Chicago. My thesis at Harvard contained both mathematical theory and observation. The pre-1948 Mount Wilson staff were an incredible bunch of gentlemen-scientists — a breed which doesn't now exist. They didn't share, perhaps didn't approve, my theoretical bent, but they never disagreed with my recommendations in the observatory committee (which was joint between the Caltech and Carnegie institutions) when I suggested appointment of still another young theorist I wanted. In fact, essentially all our early appointments were theorists from Yerkes — who all became very good observers. There was more observational material sitting in Pasadena unanalyzed, and there was more observational opportunity with big telescopes, than anywhere else in the world, even before the 200-inch was finished.

RP: Why did you take the Caltech appointment?

JG: I had had a little administrative experience in family business and enjoyed it. I liked the activity of the war, though not the war, naturally. I enjoyed dealing with the military, for example. Although I gladly went back to research in 1946, I could see problems in Yerkes' future. I was something of a "hot property" at the time in the sense of having several flattering offers, including one from the Lick Observatory, to join their staff. But I knew that I could build things up here in an excellent place and that I would enjoy building a group. And I found, in fact, that it was a pleasure. Almost none of the administrative duties were seriously time-consuming except finding interesting scientists and keeping them happy. And I could do good scientific work with the 100-inch, and later with the 200-inch when it was completed (in 1952).

RP: What were your impressions of the Institute and the community when you came?

JG: Caltech first seemed incredibly small. I remember walking from the Athenaeum, where I stayed (in November 1947), to the Robinson Lab and wondering whether they would ever be able to pay my salary, no matter how small that salary was. It was a very tiny institution, compared to Chicago.

I had a happy personal introduction through H. P. Robertson, a physicist in relativity theory, who had come to Caltech from Princeton. He was an old friend since I was a graduate student, and often visited. He was one of the decisive reasons for my coming. And there were also two outstanding Germans at Mount Wilson — Walter Baade and Rudolph Minkowski — with whom it was easier for me to form intellectual links, than with some of the older Mount Wilson spectroscopists.

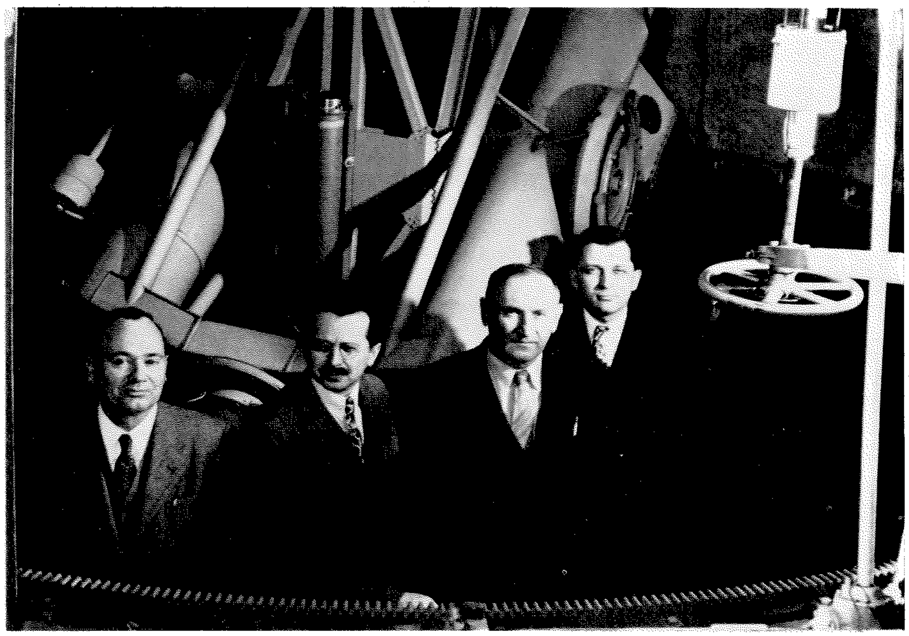
RP: You started out essentially building with the graduate department?

JG: Yes. Under the original agreement between the two institutions, those people at the Carnegie Institution who were able to and wished to teach were to be available for the graduate teaching program and thesis research guidance. My understanding had been that they would provide the teaching equivalent of a full-time faculty member; cooperatively they would provide a course every term. That proved unworkable. Ira Bowen, who was then the observatory director, tried very hard. Every spring when I called him up about it, he would sigh and say, "Well, I know, Jesse, I'll see." I felt, however, that their failure to provide astronomy education could be understood by their years of purely research orientation. It also gave me a strong hand at Caltech on new appointments. But Mount Wilson was an excellent source of thesis guidance.

RP: What about the students in astronomy?

JG: We started with only a few; three good students were plenty each year. I think that those who went to Mount Wilson, in the earliest years, did get significant help from the Carnegie people on Santa Barbara Street. They also got instruction on how to use the telescopes and on what were important outstanding observational programs. Of course, it was the beginning of the electronics era; electronics amounted to nothing much in the older astronomy, but was essential in the newer. Our students used the 100-inch and solar telescopes from the beginning.

RP: I want to go back to what the community was like; what your social life was like.



Caltech's astronomy "department" in 1949 consisted of, left to right, Josef Johnson, Jesse Greenstein, Fritz Zwicky, and Albert G. Wilson. One high priority for Greenstein was to build the department up in numbers and diversity.

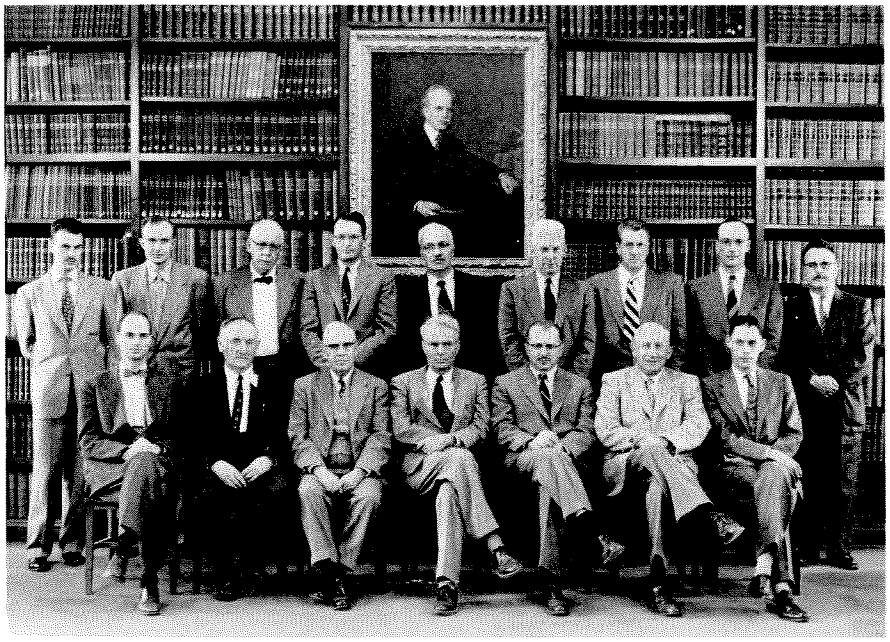
*JG:*Caltech was a remarkably sociable place. I'd heard before I came that the parties were extraordinarily good; and it proved to be true. The physics department had not only Bob (H.P.) Robertson, but Charlie Lauritsen and his son, Tommy, and Willy Fowler — all of whom were outstanding party people and outstanding scientists. A good deal of science and, later, national affairs were discussed at parties. We met a lot of important people and a lot of crazy people too. Robertson had been chief scientist for NATO and had Sir Solly Zuckerman, a leader of British science, as a frequent visitor. And of course, though I didn't know him as well, von Kármán always had distinguished visitors, including a baseball player, retired, who was his bodyguard. Whenever von Kármán was walking down the Olive Walk with the Guggenheim people to go to lunch, Moe Berg (the baseball star) was walking along, a little bit in front and a little bit on the side, looking around.

RP: Tell me about Lee DuBridge. What kind of person was he?

JG: Well, charismatic, as everybody says; square, which is part of his charisma. He has the best normal virtues of our country. Calling him "square" means that he is really absolutely straightforwardly sincere and conventional and conservative. And yet he will try anything. He is loyal to his friends. And he likes to see the best in people, which is a fine leadership virtue. And it was very easy to work with him. The only troubles I had were appointment troubles, never money troubles.

RP: DuBridge seemed to have a great knack for finding money.

JG: Appointments were always complex because of the Carnegie link and the fact that I also had to convince the Caltech physicists. The physicists cared and had opinions about astronomy. And so you had to fly a person through the astronomy group, the physics group (with Bob Bacher's help), the observatory committee (which meant also the Carnegie group), and Watson, and then past the presidents of the two institutions. In between, there was Bacher, the division chairman, later provost. But an exciting thing with DuBridge was that he would ask questions about whether this was the best possible man. If he was convinced, he said, "What can we do to make sure he comes?" He loved to know what was going on in astronomy right now, in the last few months. He'd know what to say when he gave a talk or had to raise money. And he was an extremely quick learner. He remembered and could explain what research everyone had done, even though he was far from the actual work. We were lucky in our administration.



A portrait of the founder of the Mount Wilson Observatory, George Ellery Hale, is an appropriate backdrop for its staff in the mid 1950s. Front row, left to right, William Baum, Fritz Zwicky, Milton Humason, Ira Bowen, Jesse Greenstein, Walter Baade, and Armin Deutsch. Back row, Guido Munch, Allan Sandage, Edison Pettit, Horace Babcock, Rudolph Minkowski, Seth Nicholson, Robert Richardson, Donald Osterbrock, and Olin Wilson. The observatory celebrated its 50th anniversary in 1955.

RP: What kind of people did you look for?

JG: I looked for people who could understand the physics applicable, at that time atomic or nuclear physics, and were good mathematicians as far as astrophysics required, and who might become interested in observing. I tended to feel that the best input for astronomy were ideas of what was going to be important next. And since we had the best instruments in the world, such bright people would be attracted by the opportunity of always doing something new. It's less true now than it was; people have gotten more specialized, are labeled by their subdisciplines. I liked generalists, and tried to get them.

RP: Did you eventually promote your own students?

JG: We did keep some. Also graduates from Yerkes, McDonald, or Princeton would come here as postdocs. Some would stay and some would join the Carnegie staff if their dominant interest was observing rather than interpretation. In the mid-fifties when we started in radio astronomy, it was different. We needed experienced engineering and electronics types, and we had no one on whom to build.

RP: There was a big conference on radio astronomy that you partially organized, didn't you?

JG: I was secretary of the organizing committee in 1954. Walter Baade, Rudolph Minkowski, and I had been yelling that radio-astronomy observations were essential for optical astronomy. The interpretation of extragalactic radio sources based on the identifications by Baade and Minkowski had shown that we were finding more luminous, exciting galaxies by radio means than by others. For example, after 30 years, the largest red shift found by Milton Humason, who had worked on normal galaxies, was 20 percent. But a strong radio galaxy was measured by Minkowski at a red shift of 46 percent. Radio astronomy made that possible in one jump. And when quasars were identified, red shifts passed 300 percent in a few years. That 1954 conference was a decisive turning point in U.S. radio astronomy.

Our first radio astronomy head, John Bolton, was a Brit living in Australia, who had identified many of these extragalactic radio sources. Taffy Bowen, the head of radio astronomy research in Australia, was an old friend of DuBridge's. While it may have been an old-boy, old-school-tie club, none of these characters wore ties. They were engineering-oriented, practical. John Bolton could do a better weld than most welders, and he welded most of our first radio antenna himself. Our radio observatory became successful, and radio and optical astronomy are fully integrated. The present executive officer for astronomy is a radio astronomer, Marshall Cohen. We try to compete on all fronts, we really try.

RP: Is there any place left in the world that has the biggest and best and the greatest and grandest? Is there institutional competition?

JG: Oh, sure, there is. I would say that we compete with the National Observatories, all of them. The National Radio Observatory is much bigger than ours, but I think we've got the wave of the future going in what's called "submillimeter radio astronomy," which Robert Leighton, Tom Phillips, and others are developing here. And also in very-long-baseline interferometry, in which Marshall works. Probably the most important future rival in optical astronomy doesn't as yet fully exist, and that won't belong to one institution. It is a location, 14,000 feet high on Mauna Kea in Hawaii, where many new telescopes are being placed by groups from Canada, Hawaii, France, Great Britain, and the United States. You can't beat excellent seeing weather and everybody cooperating. I mean, it's going to be *the* center.

Whether a private institution, even with government support, can still be preeminent, we don't know. In optical astronomy, we have enough square inches of telescopes in good locations so that, if we can keep up with current instrumentation, I won't worry, as long as we attract bright young people. We, unfortunately, having bright young people, also have become a target, losing those people. I can't blame them for going; I left Yerkes. And the other thing is, there's danger if you don't build up young staff continuously, and get self-satisfied. We don't have enough money now to add young people, as we used to.

RP: You spoke of Fritz Zwicky. What was he like?

JG: Fritz was a self-proclaimed genius, and in many ways he was a real one. He was a protégé of Millikan, and had not been happy in the physics department because his opinions in physics and his methods of teaching were both amusing and controversial. His teaching was directed to potential geniuses who would think as he did. And his interests in physics were premature for the state of physics then, some involving solid state problems. He became a professor of astronomy and gathered a small group of people who were personal admirers and who worked with him in pursuit of what he called the "morphological" approach to science. His major contribution, well before I came, was in discovery and study of supernovae. Also his early interest in neutron stars and stellar collapse.

He was not popular with any establishment, and he was often wrong. However, from his study of the clusters of galaxies, on the 48-inch Schmidt, Zwicky published several important catalogs. He also discovered and cataloged individual galaxies of interesting appearance, interacting or blue, i.e., hot or disturbed. Although he misinterpreted some of these observations on the basis of his general philosophical theory, in my opinion his factual discoveries in this cataloging are his largest claim to fame. There are good reasons why younger astronomers in observational cosmology depend heavily on his work and admire his contributions. He had an open mind of his own.

RP: You mentioned Bob Robertson.

JG: Bob was the leading exponent of the application of general relativity to astronomy. He was a brilliant applied mathematician. He thought through the possible observational tests of general relativity, which he helped develop, and which guided extragalactic research for years. He invented the "Robertson/Walker line element," the usual relativistic description of the geometry of the large-scale universe. After he came here from Princeton, he worked closely with the observers at Mount Wilson — before we started astronomy at Caltech — and with Richard Tolman, another great general relativity expert. Tolman had, for many years, worked with Edwin Hubble. Tolman had much national influence and was one of the first scientists to recognize the fundamental dangers of nuclear weaponry, and among the first of the modern breed of doubters.

RP: You've had so many well-documented major projects. Would you talk about some of them or any event in relationship to the people you collaborated with?

JG: The most exciting thing that has happened is the de-astronomization of astronomy. We had to keep an open mind. New astronomy grew in Robinson Lab; but has colonies all over campus and at JPL. It has links with the planetary sciences group, and links with infrared, which is in the Downs Laboratory. We have the new millimeter-wave astronomy, the principal growth area of our radio observatory, also over in physics, with the receiver development centered there. Cosmic ray physics, exemplified by Ed Stone and Robbie Vogt, is in physics; they do experiments in space. For years, our closest link in physics was with Kellogg, the low-energy physics lab.

I worked with Leverett Davis in 1951 because I'd done a thesis on interstellar absorption by small dust particles. A new phenomenon was discovered in 1949 by astronomers, polarization of light in space. Leverett was a classical physicist capable of solving any problem, and we got together. We had a hot race with Lyman Spitzer of Princeton, who had a different theory. I think we proved to be essentially right. It's amazing that a correct theory can be 30 years old, improved and modified, but with no serious errors found in our analysis. The collaboration involved my ideas on what could be out there, in space, how small particles interact with light, plus Leverett's wide knowledge of classical mechanics. He was particularly expert because of World War II, in which he had studied rocket ballistics. Our problem was how little non-spherical dust particles in space are spun around by collisions, speed up, and how they can be lined up. We solved it. Such collaboration became possible only because we knew of each other; Caltech is a small place where you could always talk to an expert.

My relation with Fowler on the growth of the new discipline of nucleosynthesis, the origin of chemical elements in stars, began in 1950. This was also based on an old interest of mine. In 1940, one of the stars whose composition I worked on provided the first analysis of the composition of a star in which nuclear reactions had drastically altered things. I had invented a practical method for the mass-production analyses of stars of either normal or abnormal composition. At first, there were few clues as to what abnormal composition meant. I began worrying about that, and it seemed to be all related to nuclear physics. When I was writing my first paper on the amount of lithium in the sun and its isotope ratio, I found that Ed McMillan, later a Nobel prizewinner, had worked on that when a graduate student here. That was one of the first nuclear reactions produced in the laboratory, lithium destruction by proton bombardment. They found that the sun also destroys lithium. It took me a dozen years to start exploring what McMillan had noted — there was something interesting to find out about nuclear physics in the stars.

My first paper trying to make sense of stellar nucleosynthesis, after getting a surprising result on carbon isotopes, was in 1952, at a meeting in Rome. In 1952 I also mentioned a process in which neutrons are produced in stars, neutrons which are important for the production of peculiar elements. Clearly I was beginning to have to understand nuclear physics. So I learned by listening to Fowler, studying the possible astronomical reactions that might occur at various stages of nuclear evolution of the stars. The walls of Kellogg were covered with diagrams of energy levels in the light nuclei, based on laboratory experiments. Nuclei that reacted easily would be destroyed, and therefore be rare. If we could see the central, hot nuclear furnaces, we could test nuclear theory directly, and also our ideas of how hot stellar interiors were. But my composition measurements were only of the surface layers. That is a typically astronomical predicament. We can only measure what nature gives us. Fortunately, in evolving stars, material from the center eventually reaches the surface to show what happened. Some stars explode, others blow most of their mass into space in stellar winds. So I emphasized programs to search for elements or isotopes that would be clues to processes in the core. With many collaborators, with spectra from Palomar and Mount Wilson, we analyzed nearly a hundred stars. I collaborated with Willy only a few times, while he built up a large group of physicists and theoretical astrophysicists in Kellogg. But much of the factual information about the results of element building in the stars came from our, and my, observations of stellar spectra.

RP: You worked with Sir Fred Hoyle?

JG: Well, only a little; there I served as a catalyst. Fred was a bright person in many fields; he was deep and worked problems out. But he had not been accepted by the English establishment. It took something of a revolution even at Caltech for me to get him a visiting appointment in astronomy to lecture in 1952-53 on his theory of the origin of the chemical elements in stars. That course was well attended, especially by the Kellogg nuclear physicists. Fred predicted a certain new property of nuclei in the reaction that produced carbon — there had to be a bound level. This level mediated the reaction of an unstable nucleus called beryllium 8 with helium atoms, to make stable carbon 12. Since carbon is known to exist, abundantly, in the universe, he predicted the existence and energy of this strong resonance. In advance, he certainly could not know whether the resonance actually existed. Within a few months, the Kellogg group made the experiment and found the energy level, right where he said it would be. That, of course, is how science is supposed to work, theory giving a testable prediction — it doesn't often — and Fred became deeply endeared to the hearts of the nuclear physicists in Kellogg.

RP: Where did your postdocs in astronomy come from?

JG: For the about 15 years in which I was bringing people in, half were Europeans or Japanese. Many of them are now distinguished leaders in astronomy. One was Wallace Sargent, now on our staff, who had done a thesis in England on shock waves in nova explosions. Another was Leonard Searle, on the Santa Barbara Street staff. Such people had previously had little access to observational possibilities. If you can find good people like that, and if they want to come, you've got a real treasure trove. Beverly Oke, who's on the faculty here, was one of them. One Japanese postdoc discovered a rare isotope of helium in stars, helium 3.

Another, George Wallerstein, a Caltech PhD student, was a frequent collaborator. Many postdocs were our own students, kept on for a year or two. Robert Parker, now a science astronaut, worked with us. Kodaira, a leader in Japanese astronomy, was a postdoc. One visitor was a Belgian working on the composition of comets. Bob Kraft, now director of the Lick Observatory, was still another collaborator. And a woman astronomer, Ann Merchant Boesgaard, now professor in Hawaii. We broke the woman barrier.

RP: She's only the second woman you've mentioned as a colleague of yours in astronomy. Is this peculiar to Caltech? I know you worked with a lady at Harvard.

JG: Cecilia Payne, yes. She was the pioneer in understanding the composition of the stars in 1920. If you have a place like ours, which is so competitive, you cannot — and in those days you didn't have to — justify getting somebody only because she's a woman.

RP: Is this changing, do you think?

JG: Not much. We have only one woman on the astronomy faculty. We have no woman student. While my own collaborators were largely men, I collaborated in 1969 with Judith Cohen, now on our faculty; and in 1967, with Virginia Trimble, who is on the faculty of Maryland and UC Irvine. And my best paper for years, my 300th paper, was written in 1974 with Anneila Sargent, Wal's wife. She worked with me as a research assistant; and only later did she go for a PhD degree, working in the infrared. There's an inexcusable imbalance, but it exists.

RP: Do you see a brighter future for women in science at Caltech?

JG: Oh, I hope so. Still, I have a black name because I wrote that I was pessimistic about the opportunities for women in astronomy. When vice president of the American Astronomical Society, I was called on the carpet by women who tried to beat me up, intellectually, while I tried to explain why I had felt it was difficult. There are historical examples within astronomy where women made enormous contributions, possibly because of certain advantageous mental sets they had. The past doesn't mean they lack other abilities necessary for the future. In seeing things in the large, seeing synoptically, getting an idea that comes out of many clues in different areas, I think they've been wonderfully creative. In astronomy, that's what the older generations of women have been good at. Women make up about 10 percent among the few hundred astronomers, with good positions active in research; there are thousands of astronomers with jobs. They do good work in all fields, and several have been elected to the National Academy.

On the practical side, even the best of the women astronomers have had problems because of the requirements of family life. We're still playing those games; a woman often can't be a competitive scientist because she's got to put her husband's job first. I don't think there's a prayer of getting equality in numbers. But while I think we have, as much as possible, created organizational equality of opportunity, the trained people don't yet exist to use it. It will become better.

RP: You've received many, many honors. Are there any that really meant an extraordinary amount to you?

JG: I was elected to the National Academy of Sciences in 1957, which I feel was too late to make me happy. The scientifically significant honor was the Russell Lecture of the American Astronomical Society in 1970. Another honor I cherish is that they made me the DuBridge Professor in 1970. I think that from the point of view of what a scientist actually does, you must look not only at honors received but at what is better called responsibilities imposed. It's often called an honor to be made, say, an editor of a journal, or something like that. But when, five years ago, I compiled a list of lectureships, visits, and committee memberships, I was startled to find I had given, in the period 1960 to 1975, about 50 named lectures or lecture series around the country. Most of those were not really given to communicate — people didn't want the information. They wanted a big name trying to give them a short and painless encounter with current research. The question about honors is how does one reciprocate and fulfill the duty to propagate enthusiasm for science. The hope is that, by the communication to this audience, somehow something sinks in which in the long run is good for science.

As for TV, I participated in several major films involving astronomy, much of it PBS stuff. I dedicated four buildings, new laboratories or observatories, which seemed to be a popular thing. It's a part of the game of interaction with the public; it's something you have to do without knowing why.

RP: You got a gold medal from the Royal Astronomical Society.

JG: That is certainly, as far as prestige goes, one of the best. It has Newton's bust on it. And I got an even larger amount of gold from the Astronomical Society of the Pacific. I shared the California Scientist of the Year Award in 1965 with Maarten Schmidt. And I received various government citations for classified work. Scientists at a symposium of the International Astronomical Union dedicated the book of proceedings to me for my 70th birthday because I'd helped start the modern activity in the study of white dwarfs. But a more meaningful kind of honor is work remembered. In the *Monthly Notices of the Royal Astronomical Society* for 1982, two scientists from New Zealand start their paper with, "Although Canopus is visually the second brightest star in the sky and the brightest supergiant, it has been relatively neglected. A table of line identifications and equivalent widths has not been published since Greenstein's 1942 work nearly 40 years ago." When you see yourself as some kind of not-yet-dead figure from the past, that's fun. But most honors come too late, or for the wrong reasons. Some involve enormous amounts of work — notably the National Academy, for which I ran a major study of required government funding of astronomy in the 1970s. I am told that the cost to the taxpayer of the funded, recommended programs was nearly a billion (1970) dollars. That's good. Honors, track record, past services helped persuade the federal agencies to listen to our recommendations and support a marvelous science.

RP: You were involved with administrative committees within Caltech, and you were chairman of the Faculty Board. What did the Faculty Board do?

JG: Originally, the Faculty Board was a group of professors who met with Earnest Watson to express their opinions with regard to Institute policy and administrative questions. Not long before I became chairman in 1965, it became more active and more democratic. During the tenure of my immediate predecessor, the trustees felt it important to open a line of communication with the growing and changing faculty of the sixties. There should exist, in addition to the president and the provost, a broader faculty voice so that actions taken, including the rules, policies, and procedures, are exposed to and receive faculty acceptance. I did feel that, although we had a fine president, we should make sure that there would be no conflict between "The Administration" and "The Faculty."

I also felt there should be a way of getting our extraordinary faculty interested in the future of the Institute, in its general planning. Being a non-academic politician, which meant usually that I did what I wanted, I didn't know Robert's *Rules of Order.* At my first Faculty Board meeting I tried to appoint a committee to study what the Institute's goals were to be. I had come to the idea after speaking to people whom I felt to be the young, forward-looking men in various divisions. Eventually, that "Aims and Goals" committee produced many interesting think pieces, for example, about the role of the humanities at Caltech, or about women in the undergraduate/graduate school. It also helped produce almost all our recent administrative leaders. I appointed the committee to choose the next president and also the committee to choose the next provost. I worked with an excellent chairman of the Board of Trustees, and many new ideas arose in conversations with Arnold Beckman. All in all, when I was Faculty Board chairman, it was a real time of change, in the Institute's ideals and structure, and in the position of the Faculty Board, now an important part of Caltech.

RP: That was true across the country; in the sixties, you had to be more flexible and more receptive to change and to new ideas.

JG: That's right. Caltech people are

NBC's program "The Immense Design" in the early 1960s used three distinguished Caltech scientists (above) — William Fowler, Greenstein, and Allan Sandage. Below, a 1969 meeting of the "Aims and Goals" committee brought out (from the left) Thayer Scudder, Robert Christy, David Smith, Thomas Lauritsen, C. J. Pings, Rochus Vogt, Herbert Keller, Rodman Paul, Norman Brooks, and Fred Anson.

Greenstein provides a group of schoolchildren with an expert's guided tour of Palomar Observatory.

susceptible to scientific change, but rather conservative on organizational change.

One of the interesting things for me about giving advice within Caltech came from involvement with the humanities division. I'm interested in other things than science, specifically art, music, and literature. One obvious defect of Caltech student and faculty life is the narrowness of cultural distractions. Humanities contained people doing good jobs of teaching recalcitrant students — not necessarily to read or write, but at least beginnings, and for some, active interest. The humanities division also had within it economists, people like Alan Sweezy, for example, and Horace Gilbert, who served the useful function of teaching the elements of macro-economics. They had broad interests and powerful effects on students. (So does the Caltech Y, on whose board I served, which has long been the ethical, humanizing center for undergraduates.) The humanities division was an important humanizing influence. When I was active in local academic politics, I hoped to see that influence expanded.

I was still an elder statesman when Harold Brown came as President. He asked me to discuss the future of humanities and economics. So I went over the arguments at considerable length. I pointed out that it would cost him nothing at all to create a new division, possibly allied with engineering in the mathematical economics area, and put expanded and scholarly work in history, literature, languages, psychology, and related subjects in an independent humanities division. He listened to me with his typical attention span of around seven or eight flashes of an eye, and he said, "No, Jesse, I won't do it." I had many other losing causes. I also tried to persuade people that it might be a good thing for undergraduate life for Caltech to swallow Immaculate Heart College. Only a few of the faculty were in favor of that. I thought among the humanizing things we could do was to hire someone distinguished in depth psychology. I was again absolutely overwhelmed. Our committee had several visits from Dr. Carl Rogers, a wonderful man who invented encounter therapy. But all of our big thinkers didn't agree on the importance of soul-oriented, rather than brain-oriented, parts of behavioral biology. As an amateur humanist, I never won a single one of these fights.

RP: You have said that finding interesting people and keeping them happy was your greatest administrative headache at Caltech. What made them unhappy?

JG: Most brilliant people have problems coping either with success or failure, mostly with success, coping with other people, keeping creative and not becoming self-destructive. In a certain sense, World War II was a good thing for some of us in the older generation, providing an external stimulus for leadership rather than the internal, self-judging, destructive situation in which most people find themselves after they have had some success.

Rivalry is an essence of success. In science, you can look back a long time and have as a rival somebody in the far past. You can kill your spiritual father, but that father is already dead. You improve on classical physics with quantum physics, or you prove relativity better than Newton. But, now at a level of scientific achievement below that of the greatest discoveries, you deal with a contemporary rival, a nearby father. You face a pattern in the development of science in which the fact that you created a new subject guarantees that you will not be a leader for long. This creates personal stress. Other competent people take up the subject. If they have access to reasonably good equipment, they are likely to do better than you.

RP: So your job as an administrator was then, quite often, to provide solace.

JG: It seems to me that I ran a 5 p.m. psychoanalytic hour. I'd sit in the office with the lights off and listen to somebody. I'm partly a frustrated father, I guess, with too many scientific children. When I use the phrase, that's arrogant, because those scientists were independently good, and not really my intellectual children. But many were people with whom I've had a somewhat parental relation. I had to cope with people who were going to leave, people who were going to give it up, people who were going to leave their wives because they were unhappy with their science, or vice versa. There's no prescription for how such help works. Sometimes you make people happy by listening to their troubles. Sometimes you make them happy by denying they have troubles. I think part of how one helps bright young scientists is that — by not being that person or doing that work — you can help them find their own solutions or suggest new things that are relevant. That really has been the greatest pleasure — seeing people grow and change.

We work awfully hard to try and attract bright people. And after all the rigamarole, they still don't come, or they come and they go. The real thing I've learned is that if you really have good people, and have done your best to give them facilities, financial support, and personal encouragement, if in their life's history they go or don't go, it's really all the same. You've done your best, and their work is good for science in the large. You must feel the larger life of science, of scientists coming and going, changing, building their own thing, as part of the structure. You just have to realize that a scientific institution has life and death built into it, with the coming and going of people. You try to survive and enjoy it happening. □

Research in Progress

Missing Mass

MISSING MASS. Non-luminous matter. Dark halo.

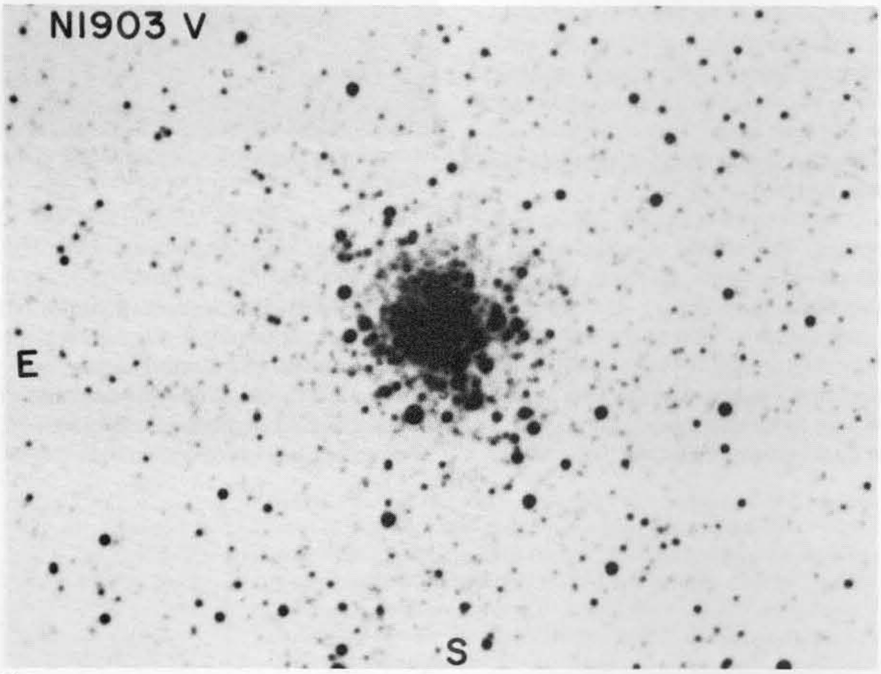
These terms all apply to an intriguing problem uncovered by astronomers in recent years. They have found that all the matter in a galaxy is not accounted for by its stars alone. The mass in a galaxy actually extends far beyond its bright outer edge. How far beyond is a question being pursued by several Caltech astronomers.

Although this mysterious mass can't be seen, its gravitational influence on visible objects is observable. Stars and clusters of stars orbit about the center of our galaxy. Those confined to the disk of the galaxy follow roughly circular paths; those that fill out the galaxy's spherical halo travel in more eccentric orbits, plunging through the disk and back out again on their million-year circuits.

Stellar orbits are controlled by the mass in a galaxy and its distribution. Even though some of the mass doesn't shine, its presence can be inferred through the motions of the stars. Recent doctoral recipient Abhijit Saha used this approach to examine the Milky Way's dark matter.

With Palomar Observatory's telescopes, Saha searched selected sky fields for RR Lyrae stars, rhythmically pulsing stars whose light variations can be used to deduce their distance. And because they are bright, RR Lyraes can be detected even when far out in the Milky Way's halo.

For such distant objects it's only possible to measure the line-of-sight component of their orbits from shifts in the positions of spectral features. This component could be a large part of the total motion for plunging, radial orbits, or a small part if the orbit was more circular. Knowing that the actual orbits fell between the extremes, Saha examined the average motions of these RR Lyraes with the idea that the faster they are moving around, the more mass is required to confine them. In this way he showed that the Milky Way's mass extends at least ten kiloparsecs, or 30,000 light-years, beyond the visible outer edge.

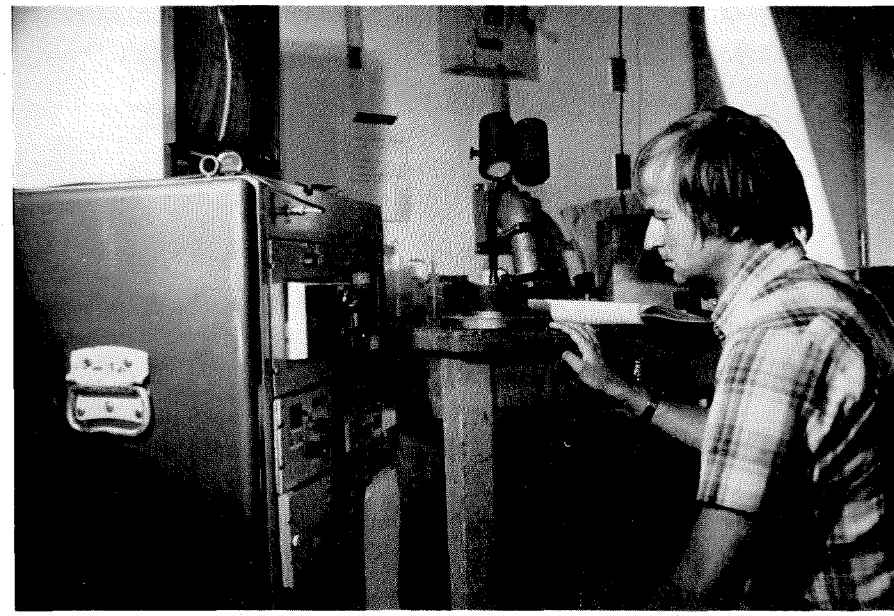


This globular cluster is one of many in the Magellanic Clouds, which contain the nearest dwarf galaxies. Measurement of the motion of globular clusters leads to an estimate of a galaxy's mass.

Saha's findings neatly corroborate a 1978 study by F.D.A. Hartwick of the University of Vancouver, and Wallace Sargent, Caltech's Ira S. Bowen Professor of Astronomy. Their study examined the motions of globular clusters about the Milky Way. These dense, compact stellar systems spend most of their orbit far out in the galactic halo and so are a good indicator of distant conditions. Hartwick and Sargent found that our galaxy's mass extends as much as 45 kiloparsecs, or 150,000 light-years, past its nominal outer edge and contains two to four times as much matter as previously thought.

More recently, Sargent has been trying this method to estimate the size of the dark halo around Andromeda, our nearest, full-sized galactic neighbor. His problem so far has been isolating the globular clusters for study. At Andromeda's distance, the clusters, although bright enough to be seen easily, cannot be distinguished from individual stars except in a large telescope. Unfortunately, it would take too long to scan all the outer regions of Andromeda through a large telescope. Instead, Sargent has used Palomar's 48-inch Schmidt telescope to take wide-field photographic plates. To analyze the plates, he has enlisted the help of a researcher in England who recently devised an automatic plate-scanner. More sensitive than the human eye, the scanner can discern images that appear slightly non-stellar and are potential clusters around Andromeda.

Once a catalog of clusters has been compiled, Sargent will begin a more detailed study, probably similar in method to Associate Professor of Astronomy Jeremy Mould's current efforts. Mould also uses the motions of globular clusters to delineate the dark matter in a galaxy, but he has no trouble discerning the clusters. Mould is studying dwarf galaxies, miniatures of a size between a globular cluster and the Milky Way. Since dwarf galaxies are small, they must be nearby to be seen; at these distances, their globular clusters are easily detected.



To study dwarf galaxies, which are nearby and have easily detectable globular clusters, Jeremy Mould uses the data recording system of the CCD (charge-coupled device) camera at Palomar Observatory. The picture is displayed a few seconds after it has been taken.

Even though the clusters can be detected, their individual stellar members cannot be easily resolved. Mould has been using Palomar's Hale Telescope to create spectra from the overall light of the clusters, from which he will derive their line-of-sight velocities. This in turn will lead to an estimate of the mass of the dwarf galaxy, including the mass that doesn't shine.

Ultimately these investigations of unseen matter could provide information important to a number of astronomical studies. The most dramatic among them is perhaps the critical cosmological question of whether the universe is open or closed, that is, whether there is enough matter to gravitationally halt and reverse the universe's expansion. The final fate of the universe may be determined by the dark, unseen matter that astronomers have only recently become aware of. □ — *John Gustafson*

Improving on Nature

THE MOST commonly used antibiotics are produced in nature — by plants, by fungi, by bacteria. There are plenty of other natural products that are of potential therapeutic value to man, but whose toxicity outweighs their benefit. Actually, anything poison to us is also potentially useful simply because it interacts with the human body, according to Robert Ireland, professor of organic chemistry. The trick is to modify the chemical structure so as to maintain the biological action while diminishing the potency of the toxin. In a way, it is the fine tuning of a biological response through chemical modifications.

Ireland's research involves the synthesis of natural products of potential therapeutic value. The goal of such synthesis is not simply to make more of a particular substance but to be able to change the chemistry slightly and make a molecule better than the one that nature has produced. With any particular molecule the ultimate aim is to broaden the critical gap (called the therapeutic dose range) between the amount of a drug necessary to be effective and the amount that will kill you. "If we can make it, we can change it," Ireland says. He compares his procedures to planning a drive from Los Angeles to New York by the most direct route; then, while actually driving, adjusting the route slightly to end up in Philadelphia.

Since Ireland and his group are interested in the science of synthesis rather than just building better drugs, an essential criterion of a candidate molecule is that it be a complex and challenging problem. His "building block" approach to the problem involves first designing a multistage synthesis strategy — figuring out the components (the building blocks or synthetic intermediates) into which the molecule might be broken and then put back together most efficiently (planning the most direct route to New York). The second stage consists of developing the reaction pathways to reassemble the pieces with slight modifications (because you'd rather be in Philadelphia).

Some of the Caltech chemist's recent work has concerned a biologically important molecule called X537A (also known as lasalocid A). Currently it's used as an additive in chicken feed to combat coccidiosis, a common infection in chickens. It's also, however, a powerful stimulator of the human heart muscle. The trouble with it is the narrow gap between effective dose and lethal dose — a little bit could either cure you or kill you.

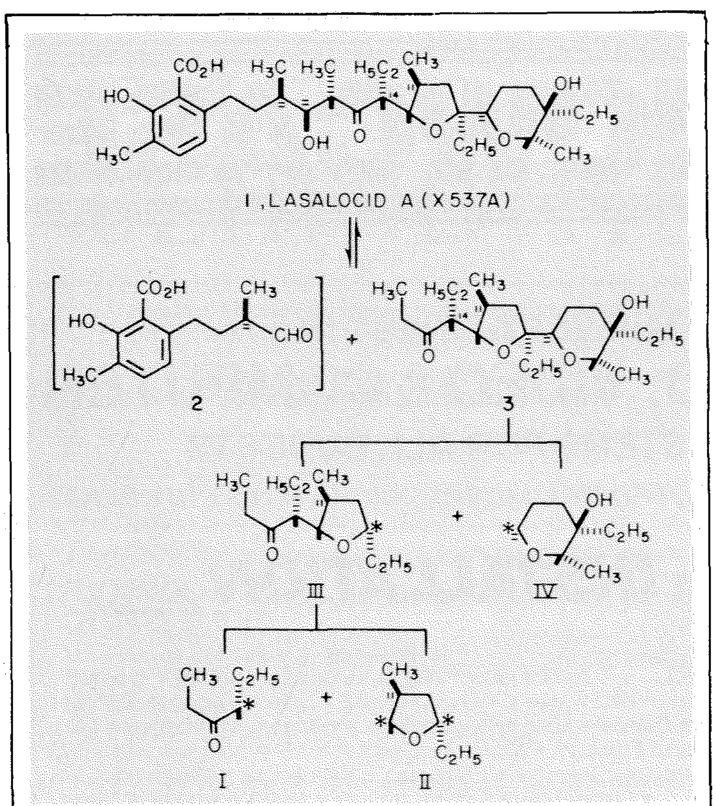
X537A is a polyether ionophore, a group of antibiotics that facilitate the transport of ions across the cell membrane. They do this by surrounding a cation, which is lipophobic, and providing a lipophilic shield, so that the complex can ooze easily through the cell membrane. In the case of the X537A complex, two molecules link together to form a ball around a calcium ion.

Ionophores such as X537A, like most all antibiotics and most other biological molecules in general, are optically active; that is, they are asymmetric in such a way (either left handed or right handed) that they will rotate the plane of polarized light either to the left or to the right. Most antibiotics are dependent on this chirality, or handedness, for their activity; they have to be able to recognize the correct fit with the asymmetric shape of another molecule. It's like shaking hands, says Ireland; if you try to shake someone's left hand with your right hand, nothing fits.

But the theory of ionophore action suggested that even though the X537A-Ca^{+2} complex is indeed chiral and the cell membrane is also chiral, their interaction (and hence transport through the membrane) is achiral — the handedness doesn't matter. X537A exists in nature only in the right-handed form, so to test this theory Ireland and his group have recently accomplished total synthesis of left-handed X537A, made with slight modifications after their successful design for synthesis of natural X537A. Biological testing has proved the theory correct — both left-handed and right-handed X537A molecules have the same biological activity. This achirality makes the drug unique among antibiotics and potentially extremely valuable. Analogs that could widen the drug's therapeutic dose range may be easier to synthesize when a molecule's handedness can be ignored.

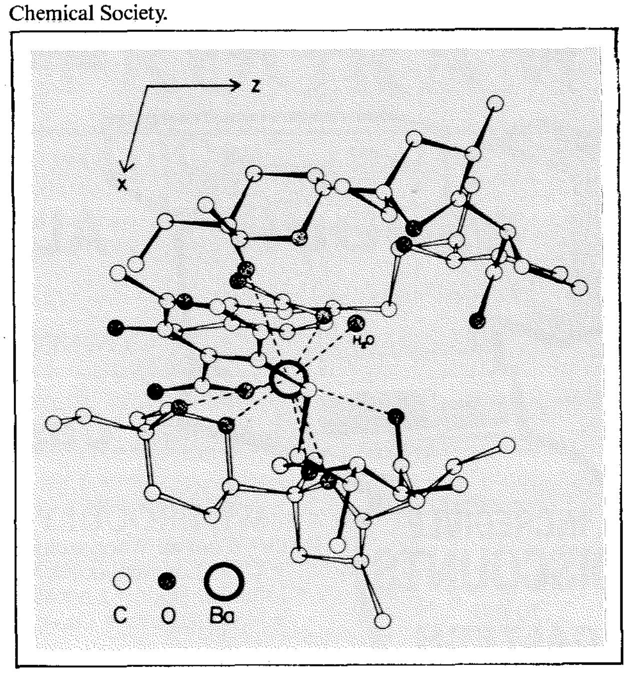
This assumption, as well as Ireland's synthesis strategy for X537A, can be adapted to other ionophores with even more complex structures, such as the molecule monensin. Monensin, however, presents another difficulty that makes its synthesis and modification a very sticky problem. Where other ionophores have a hydrophilic (lipophobic) "inside" to bind to the cation and a hydrophobic (lipophilic) "outside" to ooze through the cell membrane, the monensin-cation complex still has one of its hydrophobic oxygens on the outside, impeding transport. This imperfect structure occurs because nature is restricted to a small set of starting molecules. Chemists, however, are not, and once they can synthesize natural monensin, they can change the starting materials to form a "better" molecule than nature did. Ireland is currently trying to develop a monensin-like structure that has a lipophilic carbon atom in place of the outside lipophobic oxygen of natural monensin.

Among other molecules Ireland is working on are aplysiatoxin (a marine toxin) and streptolydigin (a potent antibiotic). This portion of Ireland's research is funded by the Public Health Service, the National Heart and Lung Institute, and the Hoffmann-La Roche Foundation. □ —*JD*



J. Am. Chem. Soc., 1980, 102, p. 1155

In the figure at left, the top configuration represents the structure of X537A, which is broken down below it into synthetic intermediates, or "building blocks." Below is a three-dimensional drawing of two molecules of X537A surrounding a barium ion (similar to calcium) to form a complex with a lipophilic exterior. Reprinted with permission from the Journal of the American Chemical Society.



J. Am. Chem. Soc., 1970, 92, p. 4430

Books — by, about, or of interest to Caltech people

NO PLACE TO GO
Effects of Compulsory Relocation on Navajos

by Thayer Scudder

Institute for the Study of Human Issues $17.50

The compulsory relocation of over 5000 Navajos and up to 90 Hopis was mandated in 1974 by Public Law 93-531. In 1978 the Navajo-Hopi Land Dispute Commission of the Navajo Nation asked that the Institute for Development Anthropology make a study of the human and economic costs for the Navajos of such a relocation. That study was carried out under the direction of Thayer Scudder, professor of anthropology at Caltech.

Scudder is a recognized authority on relocation and settlement of rural populations in many parts of the world — an expensive and emotionally unsettling process even under the best of circumstances. He is the senior author of this book, which describes the findings in this particular case. The book also provides photographs, figures and tables, maps, appendixes, references for further study, and an index.

PROJECT EVALUATION IN THE CHEMICAL PROCESS INDUSTRIES

by J. Frank Valle-Riestra

McGraw-Hill Book Company . . . $31.50

Alumnus J. Frank Valle-Riestra (BS '48 in chemistry, MS '49 in chemical engineering) is now senior associate scientist in Dow Chemical's western division. He is also an adjunct professor at UC Berkeley. In this book he uses both of those experiences to provide a text for a course in project evaluation, plant design, and senior design. His goal is to provide students with insight into how to apply acquired project evaluation tools, along with what they have learned in academic disciplines, to "real world" industrial situations. The time value of capital investments, for example, is explained in terms of quantified risk and past corporate performance, and the mathematics of finance are presented as a straightforward extension of techniques acquired in earlier mathematics courses. The professional development of engineers is examined in the context of the early assumption of project management responsibilities in industry. Marketing research is presented as a discipline that is subject to quantitative analysis.

The book's approximately 400 problems are typical to the industrial environment and offer students practice in problem-solving techniques. There are also 10 to 20 worked examples in each chapter, case studies, exercises, photographs, and bibliographies.

Random Walk

Real Time

IN OUR September issue Charles Elachi of JPL reported on the ancient dry river channels beneath the Sahara, which were discovered by the shuttle-borne radar. Part of his story concerned optically developing the 1,000 meters of film retrieved from the shuttle after it landed — and the scientists' surprise at first sight of the buried channels — months later while still developing film.

Now Demetri Psaltis, assistant professor of electrical engineering, has come up with a camera that will process the radar data in real time. In place of film it uses an "acousto-optic" device — a tellurium oxide crystal transducer and charge-coupled devices — to detect the signal and display the synthesized image on a TV screen. Astronauts on board the shuttle can view the images in real time and adapt experiments. And investigators on the ground won't have to wait months for the surprises.

In Memoriam

THE CALTECH community recently lost two of its long-time members. Dr. Lawrence A. Williams, a life member of the Board of Trustees since 1975, died on December 1 at the age of 79. He first became a trustee in 1954, and he was a life member of The Associates even before that. Williams, who began the practice of medicine in Pasadena in 1939, was a prominent local physician, having served as chief of staff at the Huntington Memorial Hospital, on the senior attending staff of County General Hospital, and as an associate professor of medicine at USC. He is survived by his wife, Lovina.

Arthur L. "Maj" Klein, professor of aeronautics, emeritus, died on November 25. He was 85. Klein had been at Caltech since 1916, earning his BS in 1921, his MS in 1924, and his PhD in 1925. He retired in 1968. Klein was responsible for much of the design and engineering for the building in 1929 of Guggenheim Laboratory and the wind tunnel. He also supervised renovation of the equipment 40 years later. Beginning in 1932, he was a consultant for Douglas Aircraft. A memorial service was held on December 8, and a fund in his honor has been established. Contributions should be sent c/o Susan Walker, Caltech 1-36, Pasadena, CA 91125.

For Old Times Sake

OUR SEPTEMBER story, "A United Vision," showing some old buildings at Caltech evoked several responses from alumni, the focus of which was the photo of the Old Dorm on page 15. One of our correspondents pointed out that — contrary to what our caption said — Throop Club did not meet in the Old Dorm but occupied a separate building connected to the Old Dorm by a roofed porch.

Another spoke of a sentimental journey for his memory to return to the Old Dorm in which he had lived as a graduate student. "If you still have some old photos to show of some other corners of Caltech," he went on, "please publish them. They are certainly most sentimental and nostalgic to all old alumni."

We had no luck finding a picture of the outside of the Old Dorm that would show its relation to Throop Club, but we did find the picture above that we thought might interest all those "old alumni."

The occasion was a Throop Club housewarming in 1936, and these men gathered around the fireplace in "The Dugout" for a group photo. We can't name the first and third men from the left, but the others are Frank Jewett, Bob Mahoney, K. Watanabe, Hugh Colvin, Wally Swanson (from whom, via the Caltech Archives, we got the photo), Paul Hammond, Howard Hamacher, and Ed Kasnika.

For the Record

WE ARE indebted to James Bonner, professor of biology, emeritus, for some interesting information about Barbara McClintock, winner of the 1983 Nobel Prize in physiology or medicine. Bonner points out that none of the recent news stories about her seems to have mentioned her Caltech connection, to wit, that she was a National Research Council Fellow in Caltech's Division of Biology from 1931 to 1933. She was, in fact, the Institute's first woman postdoc. She also returned as a visiting professor in 1946 and 1954.

Bonner was a graduate student in the 1930s, and his lab was close to McClintock's on the third floor of the Kerckhoff Laboratories — along with that of another National Research Council Fellow and future Nobel prizewinner, George Beadle. Beadle was, however, usually off in Temple City hoeing his corn at the corn farm maintained by the division.

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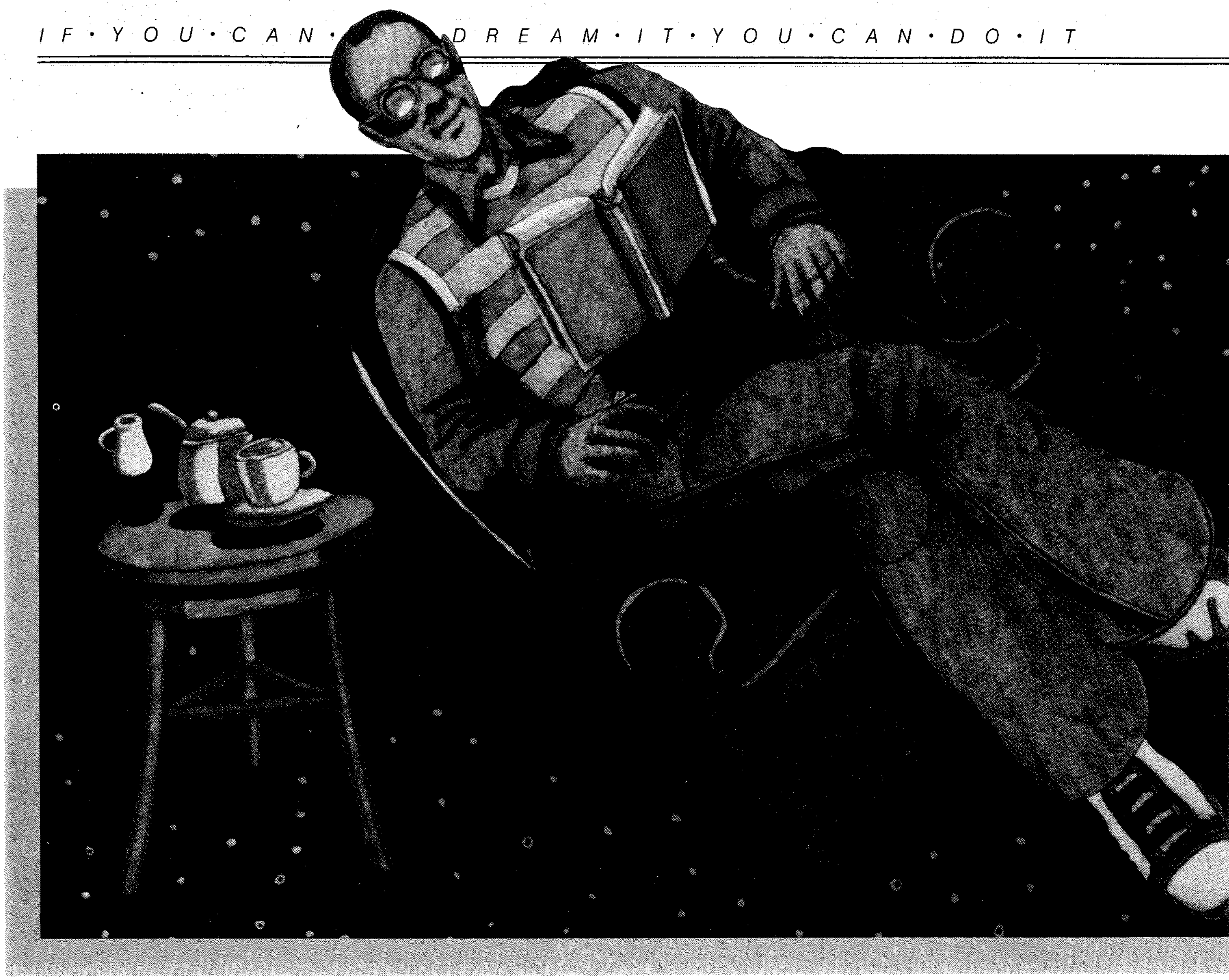

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