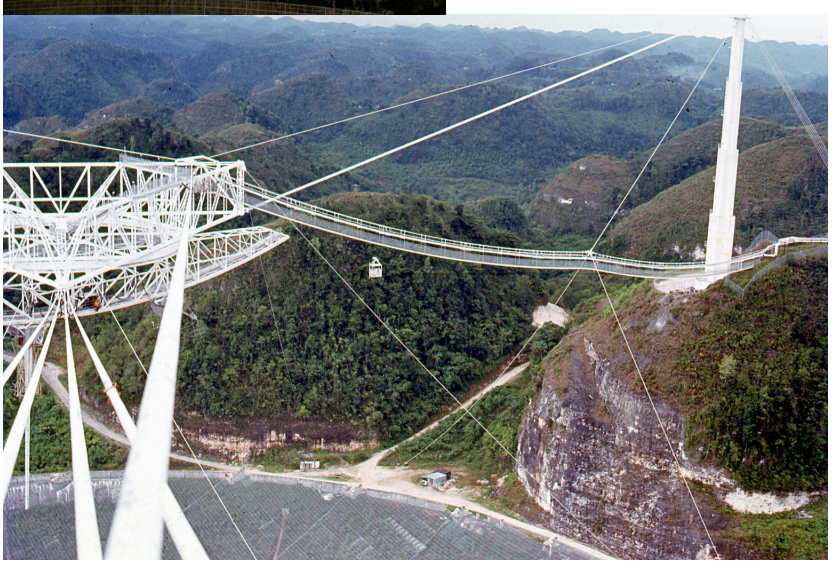
Selections from

Cornell Alumni News

Concerning the History of the Arecibo Observatory



Assembled by J. Robert Cooke as background for the Collection of Oral History Interviews at
https://ecommons.cornell.edu/handle/1813/33201

©2016 Cornell University

Preface

This booklet contains selections from the *Cornell Alumni News* for the years 1963 through 2007 concerning the history of the Arecibo Observatory. A companion collection has been assembled from the *Cornell Engineering Quarterly*.

The PDF containing these articles (in chronological order) includes bookmarks, and with the Acrobat Reader, the file opens with the bookmarks displayed.

These materials were written for a broad audience and, hopefully, provide additional context for the collection of oral histories about the Arecibo Observatory.

The original articles may be viewed and downloaded from the eCommons collection, "Publications of the Cornell Alumni Association," at https://ecommons.cornell.edu/handle/1813/3157

An Oral History of the Arecibo Observatory is at https://ecommons.cornell.edu/handle/1813/33201

These include extended interviews with persons who were intimately involved with the creation and use of the Arecibo Observatory. The on-camera participants include:

Baker, Lynn A.	Gordon, William E.
Bartell, Eugene F.	Haynes, Martha
Campbell, Donald B.	Kelley, Michael C.
Carlson, Herbert C.	Kulkarni, Shrinivas R.
Cohen, Marshall H.	LaLonde, Kay
Corson, Dale R.	LaLonde, Mary Kay
Craft, Harold D., Jr.	Maldonado, José
Drake, Frank D.	Matyas, Robert M.
Dyce, Rolf B.	McGuire, William
Farley, Donald T.	Pettengill, Gordon H.
Feyjoo, Miguel	Talpey, Elizabeth
Forrest, Janet	Talpey, Thomas
Forrest, Robert	Terzian, Yervant
Giovanelli, Riccardo	Thompson, Thomas W.
Gordon, Larry	Ward, Nancy Gordon

This video collection also includes a short history of the Arecibo Observatory and the Memorial honoring the late Bill Gordon.

The assistance of Dianne Ferriss and Hal Craft are gratefully acknowledged.

Enjoy!

JRC
March 2016

Contents

[To scroll to the associated article, click an entry. Use command left arrow to return. Or use the Bookmarks.]

"Big Ear at Arecibo," *Cornell Alumni News*, v66n5 (Dec 1963), cover & pp 5-14.

(William E. Gordon PhD '53, named the Walter Read Professor of Engineering) *Cornell Alumni News*, v68n1 (Jul 1965), p 21.

(Vice President Humphrey visits AO) *Cornell Alumni News*, v68n7 (Feb 1966), p 56.

(University) "Signals for Science; Space for Science," *Cornell Alumni News*, v70n10 (May 1968), pp 20-21.

(Talking to the Stars) *Cornell Alumni News*, v74n10 (May 1972), pp 9-17:

"This picture is meant to be seen by extraterrestrial beings …
but what if they have no eyes?" by Geof Hewitt '66, pp 10-13.

"Deciphering a Message from Another World," by Prof. Frank D. Drake '51, p 14.

"Deciphering Some of the Deciphering," by the Editor, p 16.

"Astronomy: How Complex is the Universe?" by Martin O. Harwit (The Arts College Observer, n2, Nov 1974); in *Cornell Alumni News*, v77n4 (Nov 1974), pp 33-36.

(Caribbean stars wheel above the 600-ton suspended receiver) *Cornell Alumni News*, v77n3 (Oct 1974), p 64.

(A photograph of Barrett Gallagher) *Cornell Alumni News*, v77n4 (Nov 1974), p 43.

"Tuning the Big Ear," *Cornell Alumni News*, v77n5 (Dec 1974). Cover: A workman holds one of 38,000 panels of aluminum mesh that make up the reflector of the world's largest radio radar telescope at Arecibo, Puerto Rico; photo by Barrett Gallagher '36.

"Listening to the Stars," *Cornell Alumni News*, v77n5 (Dec 1974), pp 10-15.

"Learning by Listening," by Dava Sobel, *Cornell Alumni News*, v77n5 (Dec 1974), pp 16-19.

"Astronomical Possibilities," by Geof Hewitt '66, *Cornell Alumni News*, v78n2 (Sep 1975), pp 18-20. Review of *The Cosmic Connection—An Extraterrestrial Perspective* by Carl Sagan.

"Camera Work," *Cornell Alumni News*, v83n8 (Apr 1981), pp 24-31. On the exhibit by photographer Barrett Gallagher '36, in the Johnson Museum of Art.

"Etcetera: Contributors," *Cornell Alumni News*, v87n6 (Feb 1985), p 26. On Jose Anzel '76 and Robert Matyas '51.

"Peter's Principles," by Brad Edmondson '81, *Cornell Alumni News*, v87n8 (Apr 1985), pp 36-39. On George Peter, a hard worker on the staff who insisted its nonacademic employees are members of Cornell, too, and who was also involved in designing and constructing the Arecibo telescope.

"Sagan's Universe: Beyond Venus, Jupiter, and the clouds of Titan," by William Steele, *Cornell Alumni News*, v89n7 (Mar 1987), pp 20-25. Astronomer Carl Sagan explores life in outer space while crusading to save life on Earth.

"A Space First," *Cornell Alumni News*, v91n2 (Sep 1988), p 13.

(Arts & Sciences) "Black Holes," *Cornell Alumni News*, v93n8 (Apr 1991), p 11.

"Metal Asteroid," *Cornell Alumni News*, v94n3 (Oct 1991), p 14.

"Gold Strikes Oil," by Kathy Bodovitz, *Cornell Alumni News*, v94n5 (Dec 1991), pp 5-6.

(Research - Alexander Wolszczan) "Out of This Universe," *Cornell Alumni News*, v94n8 (Apr 1992), p 16.

(Research) "The Fastest Guitar in the Galaxy," *Cornell Alumni News*, v95n10 (Jun 1993), p 20.

"Carl Sagan (1934-1996): A Special Tribute," *Cornell Magazine*, v99n6 (Jan/Feb 1997), pp 19-20.

"Eye on the Universe," by Beth Saulnier, *Cornell Magazine*, v99n8 (May/Jun 1997), pp 38-45. The Arecibo radio telescope is getting a new lease on life with a $30 million upgrade. A visit to the university's tropical outpost, where astronomers explore the cosmos as they dodge the occasional vampire.

"Stars in the Ascendant," by John Yaukey & Beth Saulnier, *Cornell Magazine*, v100n5 (Mar/Apr 1998), cover & pp 36-43. It's almost an embarrassment of riches. In the wake of NASA's downsizing, Cornell's astronomy department has won a mother lode of space agency grants, from studying comets to collecting rocks on Mars. Says chairman Yervant Terzian: "It's a happy, happy place."

"Galaxy Quest: More Power for Arecibo," *Cornell Alumni News*, v105n5 (Mar/Apr 2003), p 15.

"The Wrong Man," by David Dudley, *Cornell Alumni Magazine*, v106n2 (Sep/Oct 2003), pp 52-59. Astronomy professor emeritus Thomas Gold has spent his life questioning the scientific orthodoxy about everything from the clockwork of the universe to the origins of life on Earth. Trying to prove the experts wrong, however, has come at a price.

"Coming & Going: More Changes to Administration" (Hal Craft), *Cornell Alumni News*, v107n1 (Jul/Aug 2004), p 11.

"Maverick Mind: Thomas Gold, 84," *Cornell Alumni News*, v107n2 (Sep/Oct 2004), p 13.

(Correspondence) "Arecibo Alert," by Jonathan Friedman '84, *Cornell Alumni Magazine*, v109n4 (Jan/Feb 2007), pp 4 & 6.

"Sky's the Limit," by Beth Saulnier, *Cornell Alumni Magazine*, v110n2 (Sep/Oct 2007), cover, contents page & pp 40-43.

"Star Trek: Astronomers Aim to Save Arecibo," *Cornell Alumni Magazine*, v110n3 (Nov/Dec 2007), p 13.

CORNELL ALUMNI NEWS

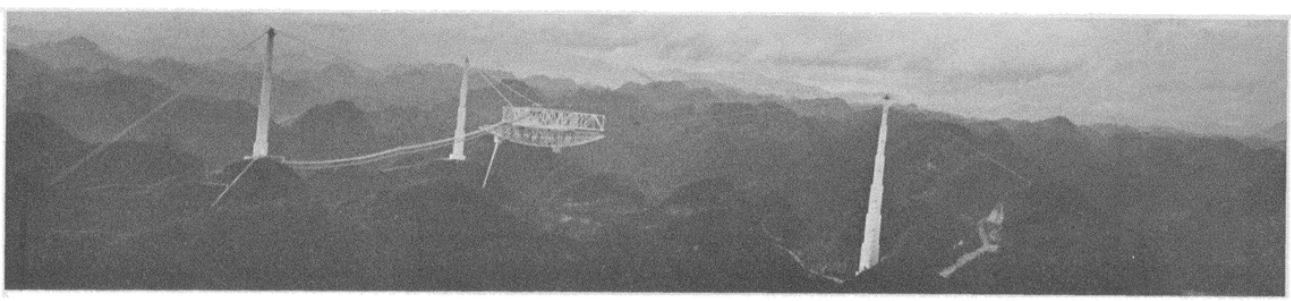
VOL. 66, NO. 5 DECEMBER 1963

"Big Ear at Arecibo," *Cornell Alumni News*, v66n5 (Dec 1963), cover & pp 5-14.

Prof. William E. Gordon and the Cornell observatory's giant transmitter platform stand out against the Puerto Rican sky.

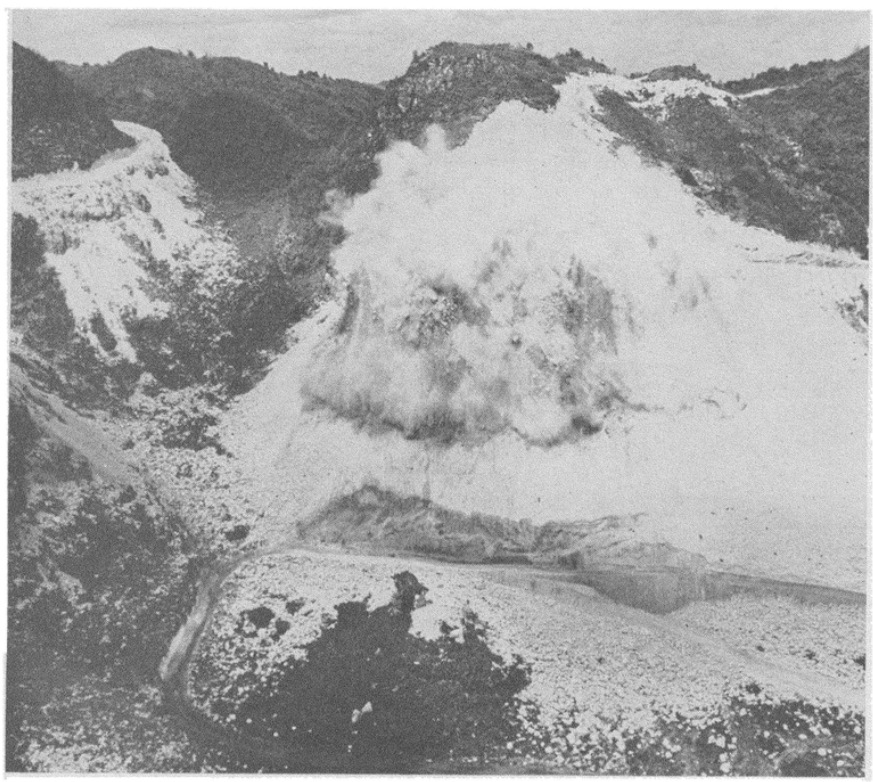
Biggest Ear on Earth

Cornell's 1,000-foot radio telescope goes into use in Puerto Rico



Futuristic towers and power arm of the observatory hang amidst rugged hills, 12 miles south of the port town of Arecibo.

Pre-construction view of the hollow chosen by Prof. D. J. Belcher for the Arecibo observatory.



Dynamite blasts a bowl out of the raw hollow. 'Little Cayuga' Lake formed in its bottom.

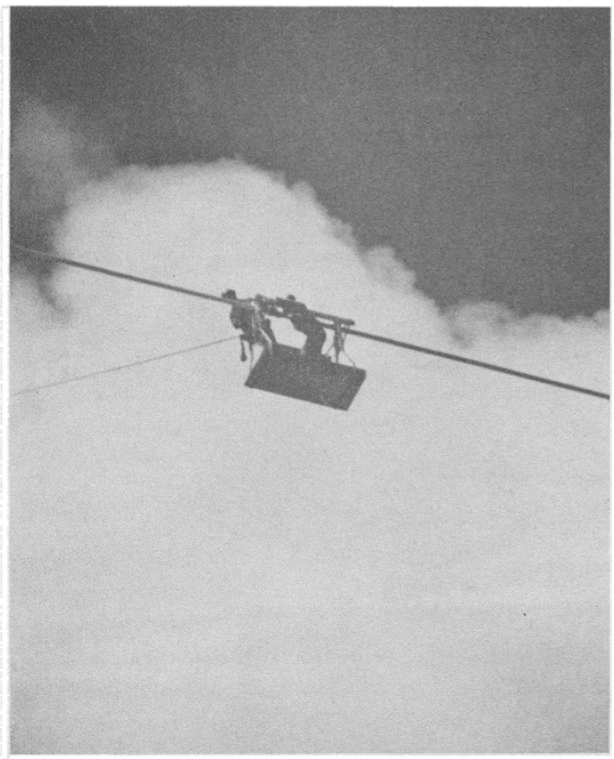
The dream come true

■ Several young scientists in the British Navy got to wondering during World War II if the new phenomenon of radar might some day be used to bounce radio waves off planets and other matter in space so as to explore the true nature of space. The young men dismissed the idea. Radar sets could then reach a plane 100 miles away. Maybe some day the moon might be reached, but to explore space in detail would require a bowl a thousand feet across, and energy output of millions of watts. Too fantastic.

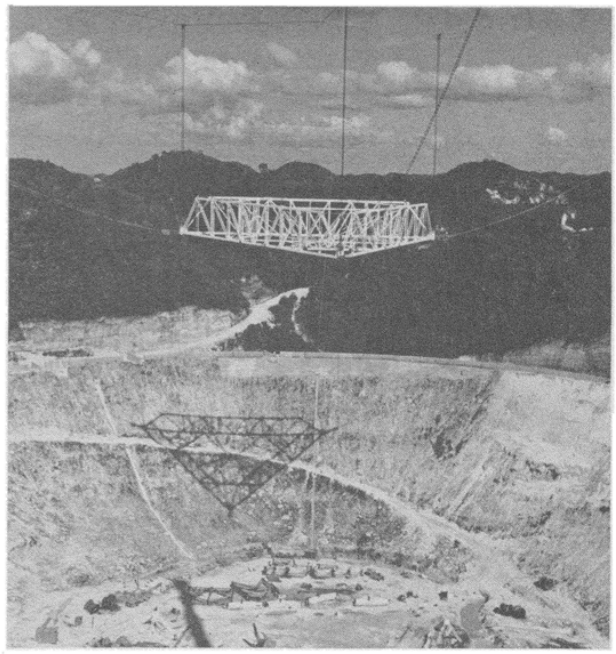
After the war, radar-radio telescopes were built, with large moveable parabolic dishes for antennas, and the strongest power supplies available at the time. Still, the signals received were weak and left much to be desired. Not until about five years ago was there a chance of reaching the young Britons' dream, when Professor William E. Gordon of the School of Electrical Engineering came up with the idea of a gigantic fixed, spherical bowl for an antenna. Find a natural depression near the Equator, he suggested, and suspend a power arm above that bowl. Move the arm, not the antenna, and you will be able to send and receive in various directions.

Simple? Yes, but since 1959 aerial surveyors, scientists, and engineers have wrestled with the job of bringing such a giant observatory into existence.

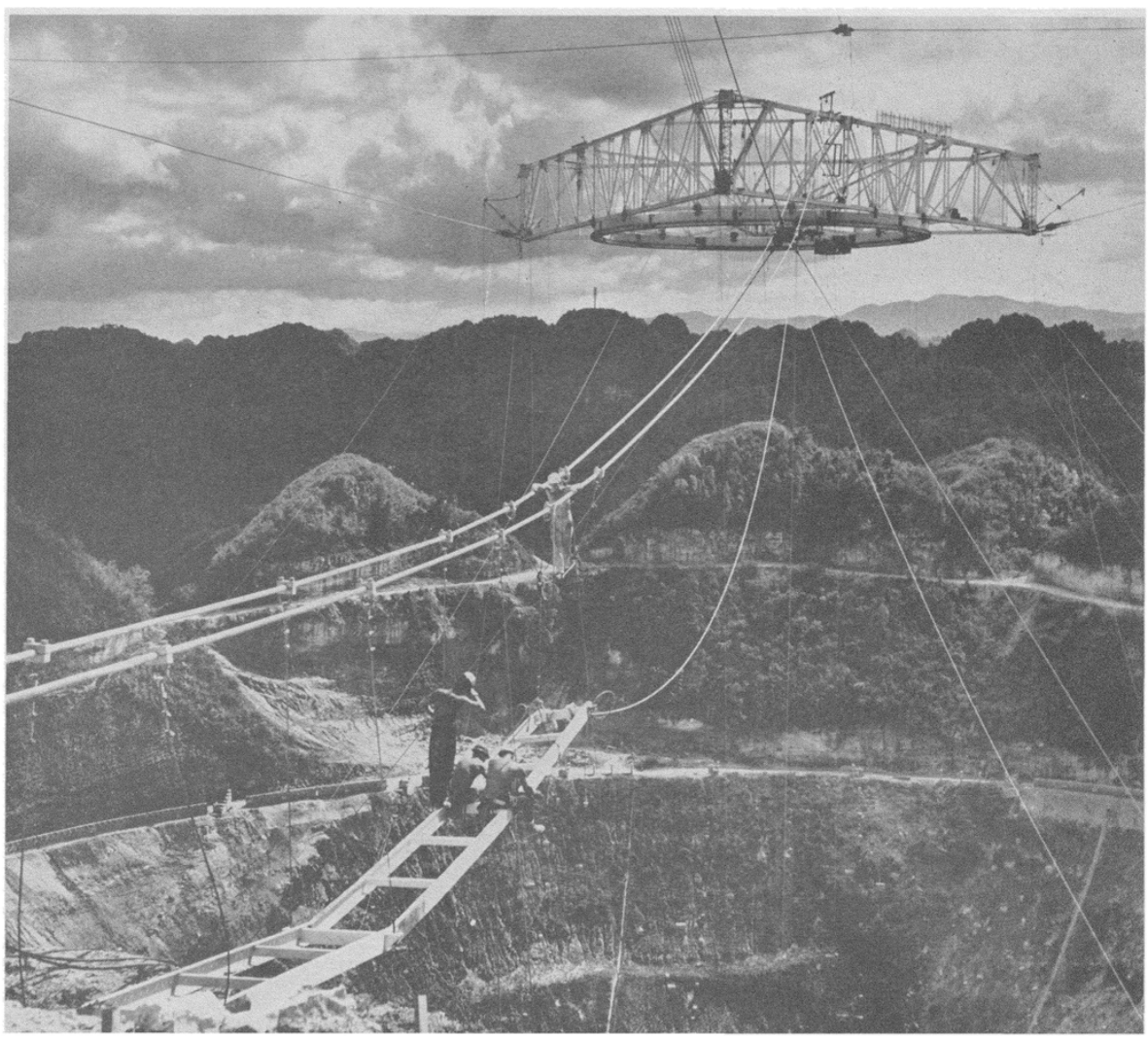
This new tool for scientists, known as the Arecibo Ionospheric Observatory, is now a part of the university's Center for Radiophysics and Space Research. To bring the story full circle, Professor Thomas Gold, who is today director of the Center, was one of those young British technicians who twenty years ago discarded as too fantastic the idea of using radar to study the geography of space.



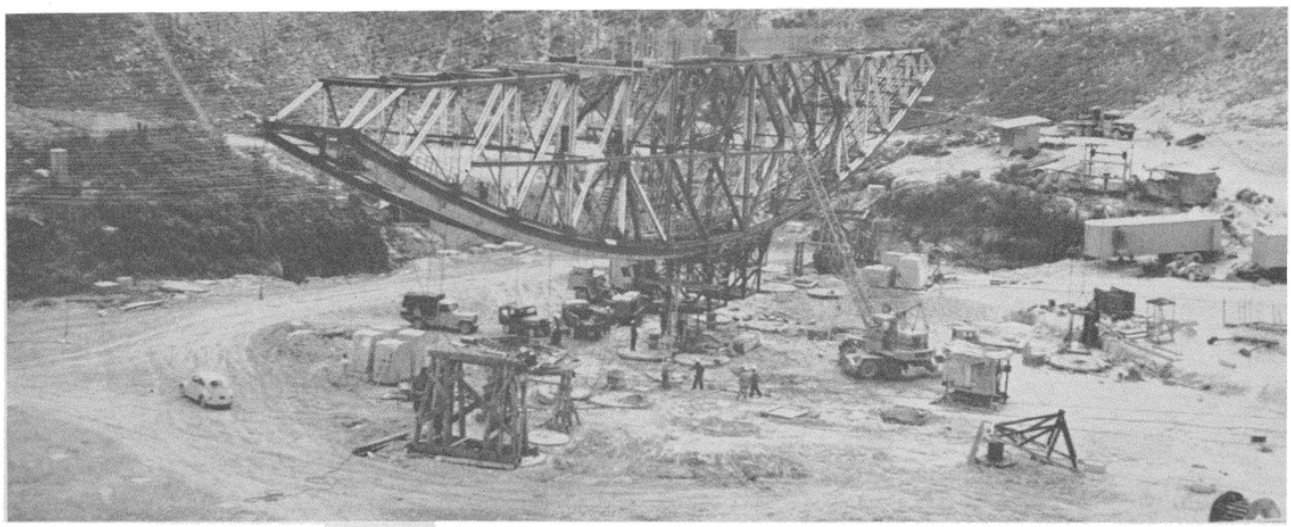
Workmen ride a sling across early cable that spans the bowl.



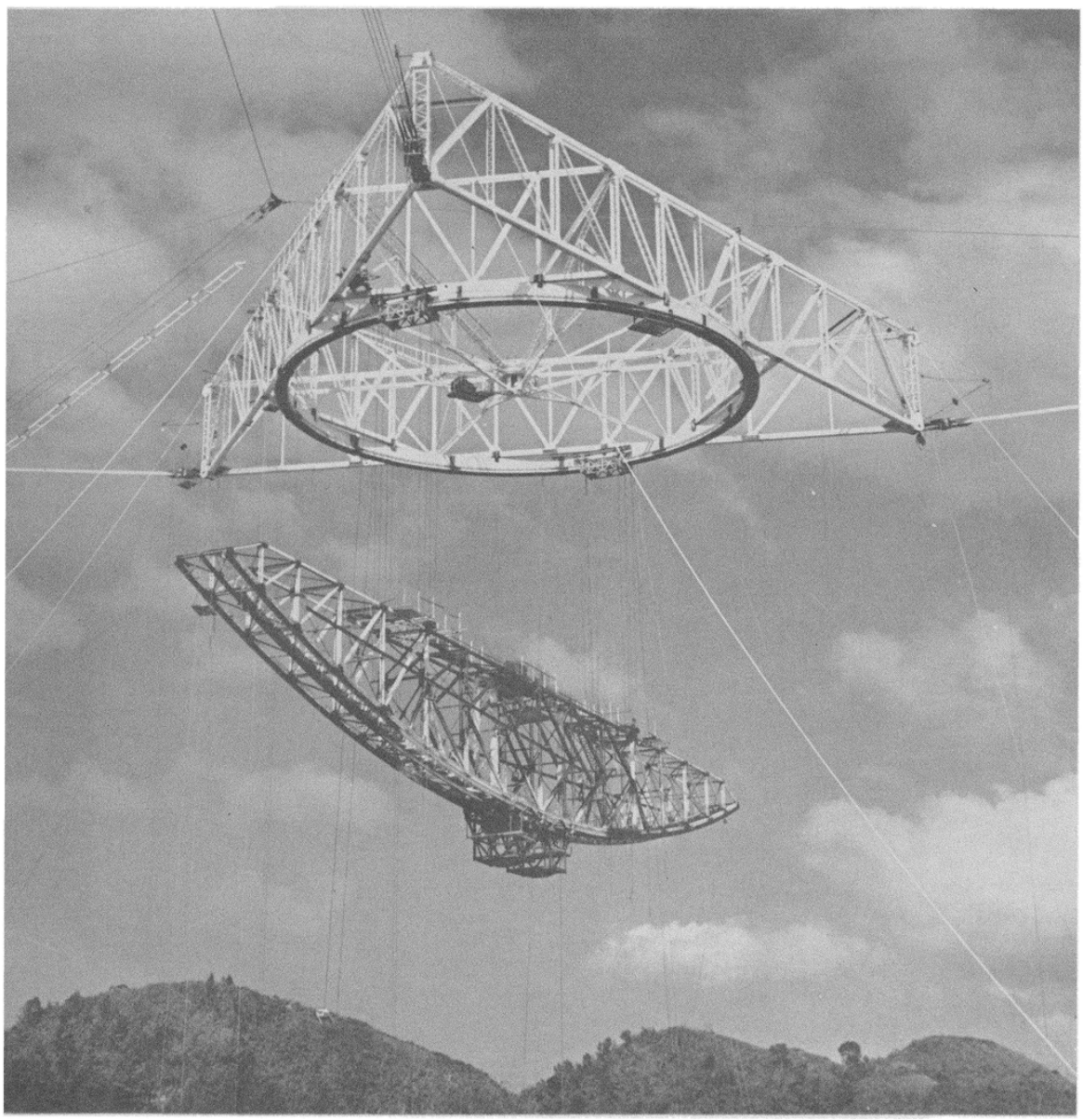
Platform is lifted into place above the bowl on Nov. 1, 1962.



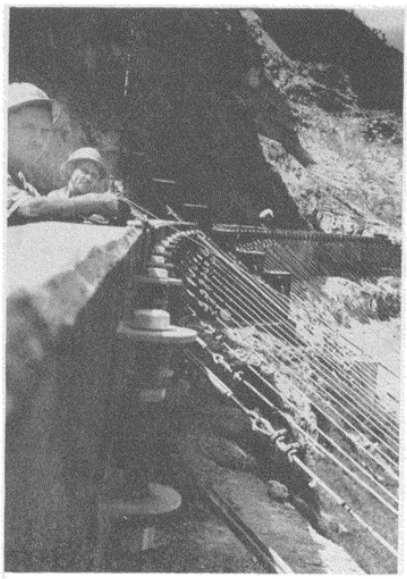
Four steel men begin to string a catwalk from the base of a tower to the platform, 500 feet above the valley floor.



On March 1 this year, the truss beam is lifted off ground. Note the size of trucks for scale.

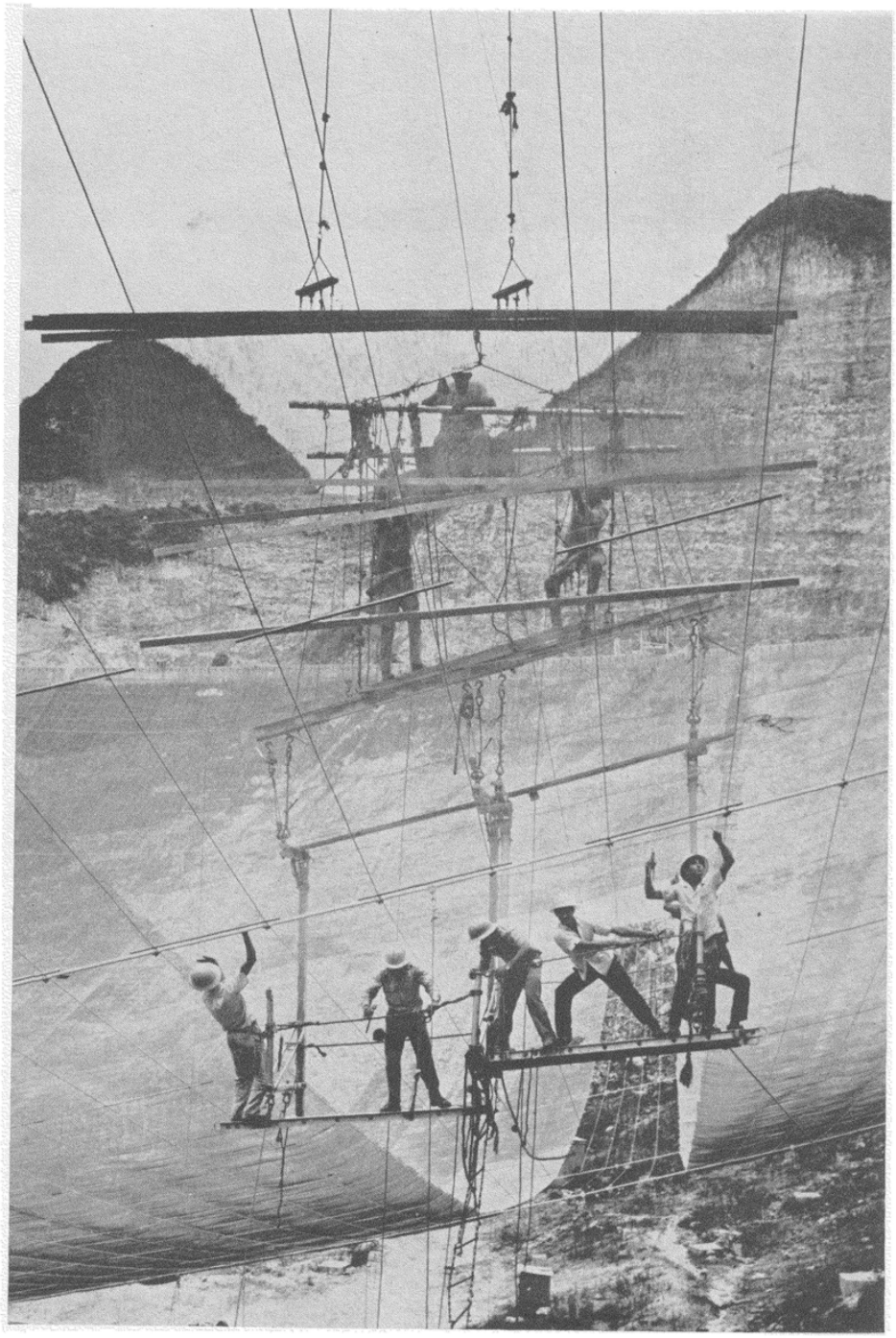


Two days later, the beam has nearly reached the point where it will attach to a ring on the overhead platform. The truss beam will rotate on the ring, and carry the power feed arm.

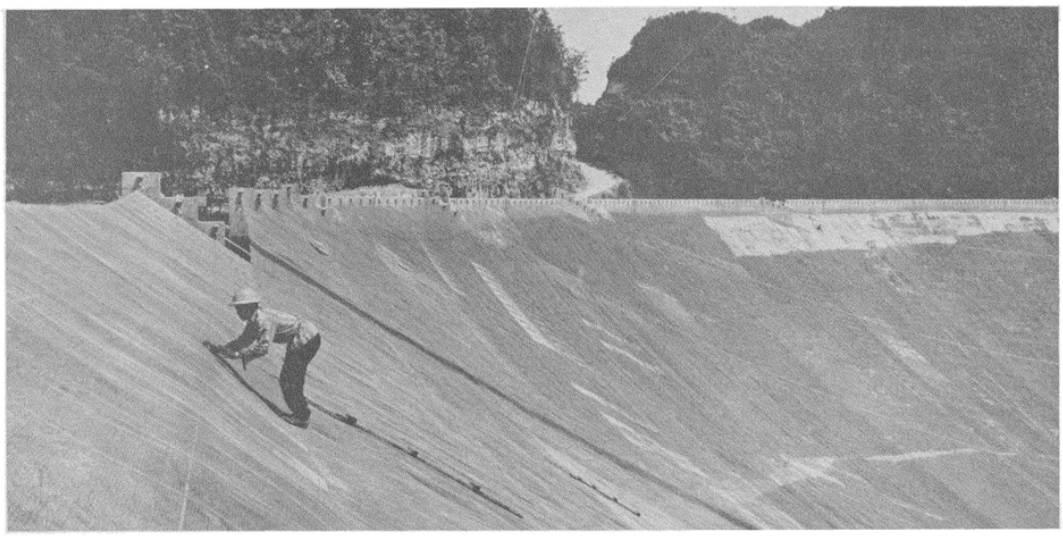


By early 1963, reflector cables are set.

Worker attaches reflector mesh to cables.

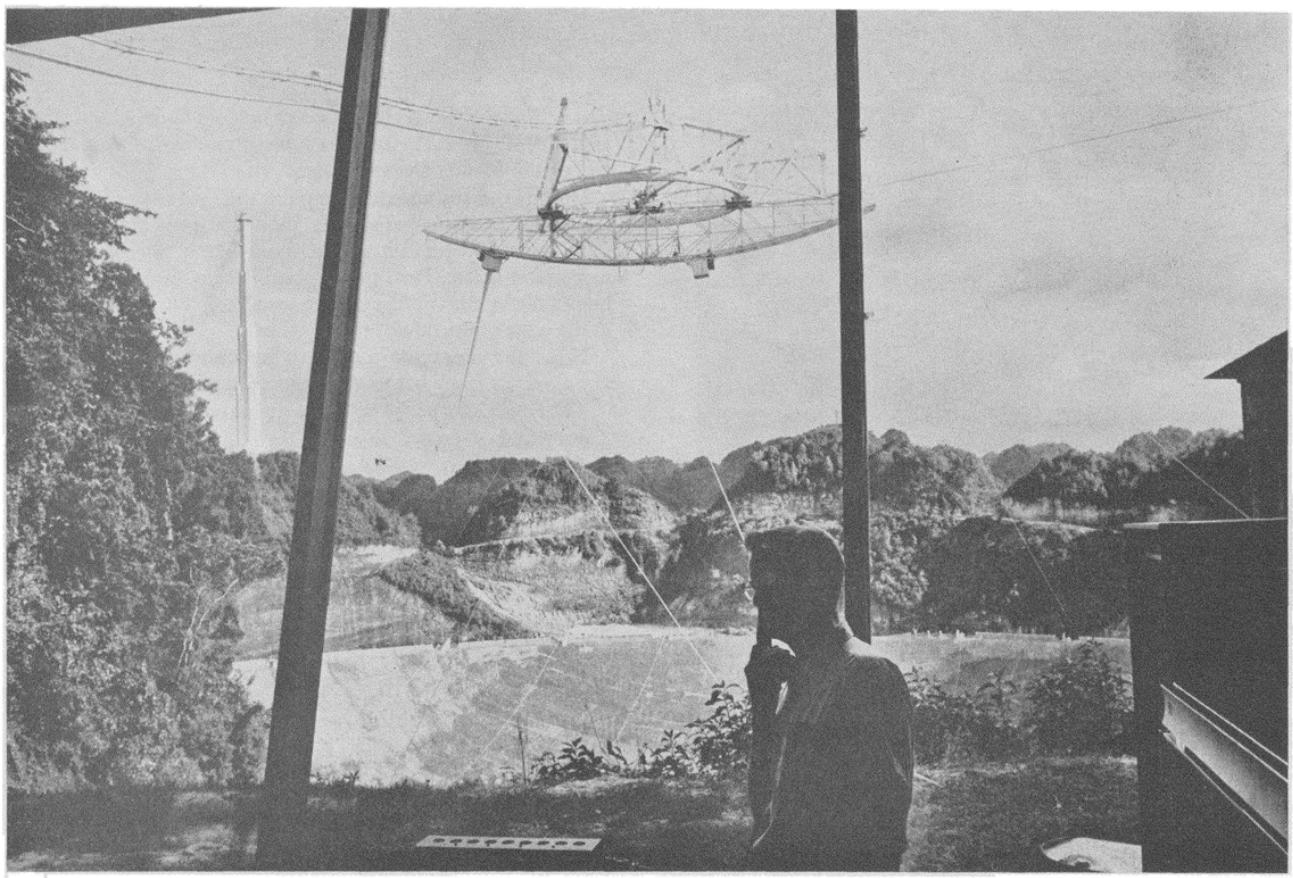


Final strips of mesh are wired into place on the suspended reflector, in mid-July.



Steep-sloped net gets final touches this fall.

Completed observatory has a reflector, towers, a platform with moveable power arm, a walkway, and roads leading down into the bowl.



From the control building, Director Gordon talks with receiver room while waiting for power arm to be put in position for a 'shot' into space.

To Venus and back: How the big dish will be used

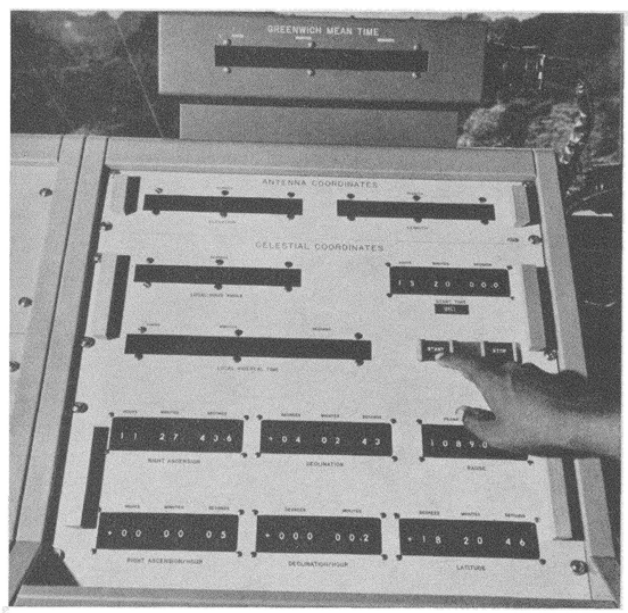
When testing is completed in the next several months, the staff at the Arecibo Ionospheric Observatory will begin a number of detailed investigations of space. The pattern of such studies is already set. What follows is a typical example:

We are standing behind the operator as he leans over his control panel making final adjustments. He is about ready to press the red start button which—if all goes well—will trigger the most detailed radar study yet made of the planet Venus.

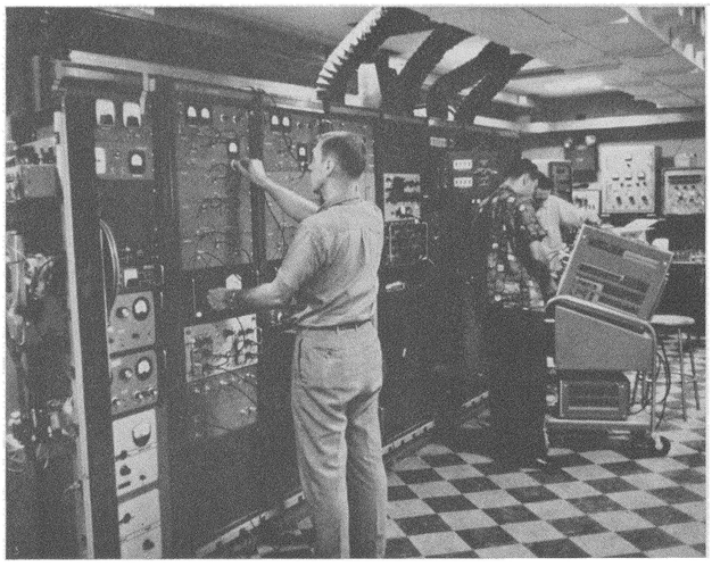
As his hands move expertly across the rows of buttons and switches the operator looks anxiously through the windows to his front. Following his gaze we see the vast reflector that makes Cornell's Arecibo Ionospheric Observatory the largest radar-radio telescope in the world. The nineteen-acre space ear looks like a giant soup bowl measuring almost a quarter of a mile from rim to rim.

"He's lining up the beam guide now," says Cornell's Professor William E. Gordon.

The tall, lanky observatory director is pointing toward a long metal shaft hanging from a platform of steel girders high above the reflector's center. During operation the feed directs electromagnetic pulses from the radar transmitter down onto the reflector surface which beams them into



Button starts a 'shot' from board that shows time, Earth's position.



Research associate T. E. Talpey '47 and part of the receiver room.

Equipment is checked in the data-processing room.

space. The feed, which can be swung up to twenty degrees away from vertical in any direction, provides directional control of the facility's space probes.

Despite our distant vantage point the feed-element support structure, which weighs more than 500 tons and measures more than 200 feet on a side, looks like a row of box cars suspended in air. It seems impossible that such mass can be held aloft by the cables running to it from the graceful towers at the edge of the bowl.

Now, the ninety-six-foot-long feed arm moves in a slow arc along its track below the support platform, then stops.

"The feed's in position," says the panel operator.

Professor Gordon is squinting through the windows. "Okay, let her go."

The operator presses the start button.

Instantly the control room fills with the whine of whirring generators as the observatory's powerful transmitter begins firing two-and-a-half-million-watt bursts of energy through the feed onto the reflector which beams them out into space at the speed of light. Their target—Venus—is 30,000,000 miles away.

"If our aim is good," says Gordon with a grin, "we'll be getting our return signals in about five minutes.

Double-duty dish

Located in the rugged foothills of southeastern Puerto Rico, Cornell's huge space probe began operating last month after a monumental, four-year construction effort. The radar-radio telescope sends spurts of power through space and, when their faint echoes return, can tell from the time lapse, intensity, and other characteristics of the echoes much about the nature of that portion of space that reflected the signal back. The giant dish also doubles as a super-sensitive radio antenna to collect natural signals from sources in space —signals that may some day bring evidence of intelligent life on worlds far distant from our own.

As the most ambitious research undertaking in the university's history, the nine-million-dollar facility is already producing information sorely needed by the US space program. In addition, it is expected to answer some of the age-old mysteries concerning the solar system.

As we wait for the Venus signals to return, Gordon strolls out of the observatory building to get a close-up view of the reflector. At the base of one of the skyscraper-tall towers, he describes the development of the Arecibo system, whose basic design he evolved while serving as a member of the School of Electrical Engineering.

"The idea was relatively simple," he relates. "We considered the most powerful transmitter and the most sensitive receiver available at that time and then computed the size of the reflector needed to do the job we had in mind."

Funds needed for the multi-million-dollar project were offered by the Department of Defense's Advanced Research Projects Agency and the Air Force Cambridge Research Laboratories was assigned to administer the contract. Professor Gordon was named to head the twenty-five-man Cornell team responsible for constructing the huge facility.

Nodding toward the reflector, which looks like a man-made Grand Canyon when viewed from its rim, Professor Gordon recalls that "four years ago, this was nothing more than a limestone sinkhole. We saved millions of dollars and a lot of time by using the natural cup of the sinkhole to hold the reflector . . ."

He also points out that a site close to the Equator was

needed so that the powerful radar-radio telescope would be in a position where the Sun, Moon, and planets pass almost directly overhead, well within the scanning limits of its antenna.

"We will be getting more detailed information about the Moon and the planets than any other radar in existence," the professor continues, "but it is important to remember that our prime purpose is to study the upper limits of the Earth's ionosphere." Little is known about this portion of the atmosphere. It is a region of ionized gas enveloping the earth from an altitude of 200 miles out to a distance of several thousand miles. This is the very sector, however, in which man is concentrating his initial space ventures.

Scientists at the observatory are now scanning the upper ionosphere, measuring the density of electrons, their temperatures, and effects caused by the Earth's magnetic field. When completed, these investigations will provide the first detailed information about properties in the upper atmosphere that must be known to understand fully the behavior of vehicles, equipment, and men operating there.

We have returned to the main observatory building where Gordon H. Pettengill, associate director of the Arecibo facility, has joined us. He is describing some of the projects planned for Arecibo. "We should be able to answer many of the questions about the solar system that have been intriguing man since the days of Galileo," he explains.

Pettengill is a widely respected radar astronomer. He made the earliest radar observations of Venus and developed extremely accurate radar maps of the Moon when he was associated with MIT's Millstone Hill radar installation.

"The echoes which we expect to receive shortly from Venus will be about 20,000 times more powerful than those first detected at Millstone Hill. We plan eventually to measure the rotation speed of Venus and pick up mountains and water if they exist there."

This last point explains why Cornell's Arecibo facility is considered a bargain. The US has already spent more than 150,000,000 dollars on the Mariner program which over the past several years has made five unsuccessful attempts to penetrate the cloud layer of Venus with instrumented spacecraft that would relay data about the planet back to Earth.

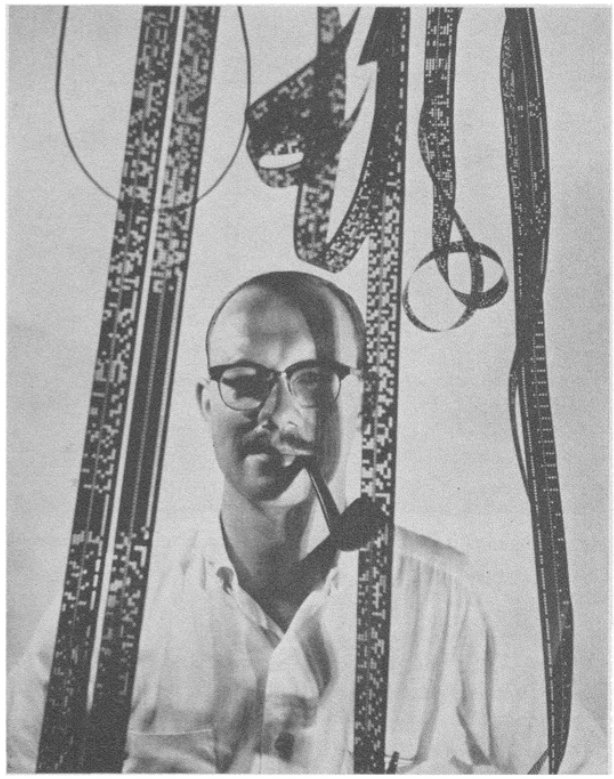
What about the Moon and Mars?

"And what about those dark spots on Mars?" asks Pettengill.

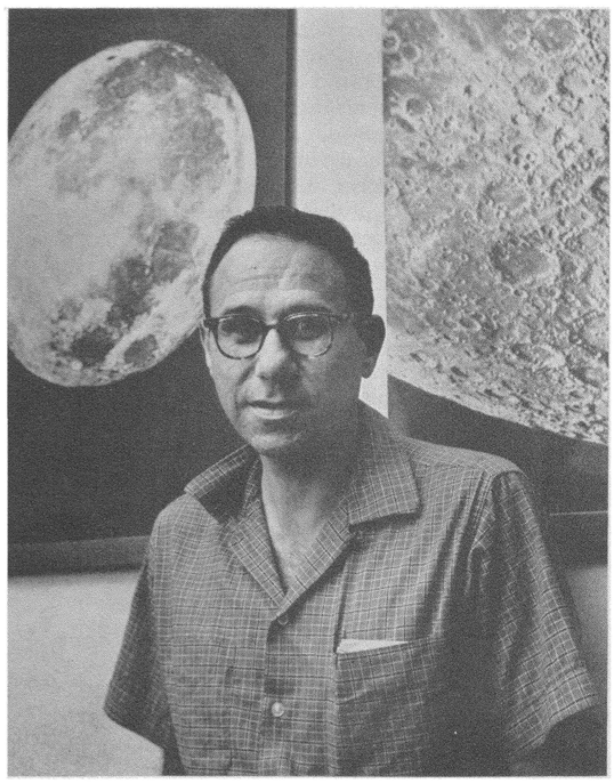
"If they are caused by vegetation, as some people suspect, our system at Arecibo will pick it up. We know that the radar scattering properties of vegetation on Earth vary with the seasons and similar effects on Mars will definitely be spotted by our radar."

Cornell's new observatory might also settle the increasingly important problem of determining the exact nature of the Moon's outer crust. The success or failure of the US Apollo program which is scheduled to land a man on the Moon within seven years could well hinge on accurate knowledge of the lunar surface.

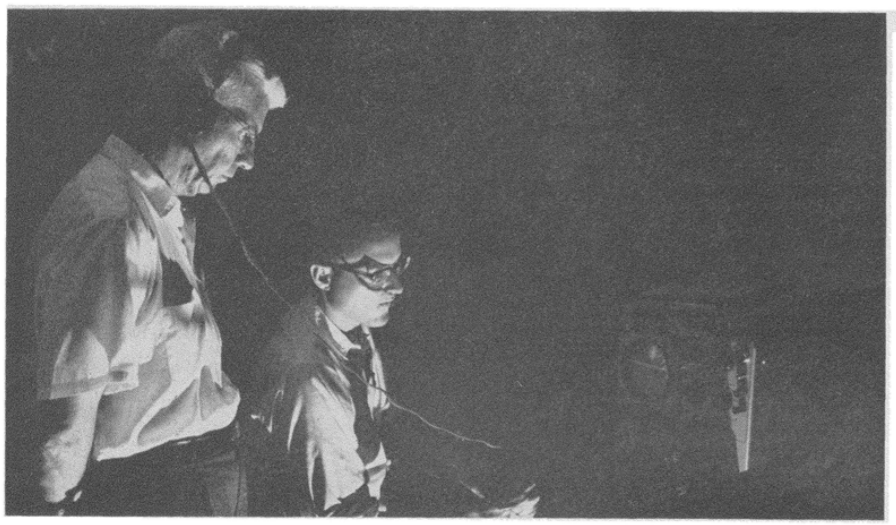
One of the several prominent scientists who contend that the Moon's surface is covered with a layer of finely powdered rock is Professor Thomas Gold, director of Cornell's Center for Radiophysics and Space Research, which coordinates Arecibo's activities with the university. If Professor Gold and others are correct, this layer of rock dust would present a serious hazard to vehicles or men landing or walking on the lunar surface. Since Arecibo's powerful signals will penetrate



Robert B. Forrest and tapes that record signals from antenna.



Prof. Marshall H. Cohen directs graduate students at Arecibo.



An oscilloscope is watched for evidence that a trial signal into space has returned.

PHOTOGRAPHS
BY
ROBERT B. BRADFIELD '51
AND
THOMAS E. TALPEY '47

at least several feet below the moon's surface they might well determine whether it has the consistency of a snow bank or is made of more substantial stuff.

Pettengill pauses for a moment to watch the electronic clock atop the control panel as it flashes the passing seconds.

"In exactly two minutes we'll know if we hit Venus."

"When we are successful here, we plan to go beyond Venus, possibly to the Sun where we hope to obtain recognizable echoes from solar flares," he continues. "Data of this sort will help explain the complex events taking place on the Sun. This information could make it possible to predict the occurrence of the violent solar flare-ups which bombard space with such intense bursts of radiation that they are considered one of the major dangers facing future space voyagers."

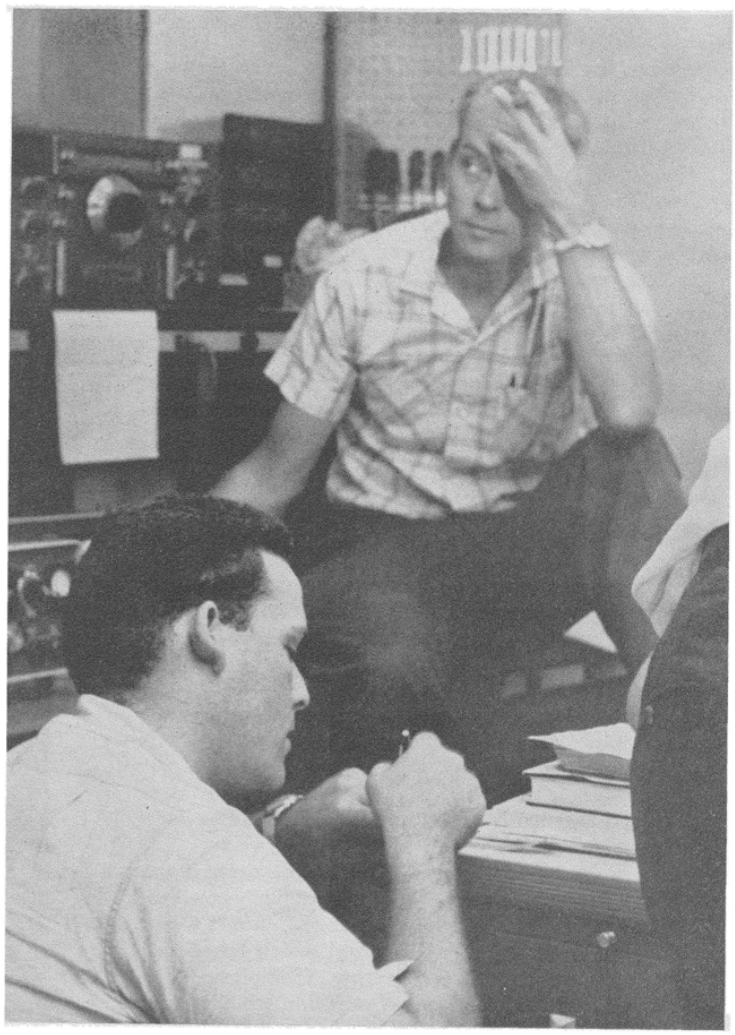
We are clustered in semi-darkness in front of an oscilloscope. An intense white line cuts horizontally across the faint green field of its circular viewing screen.

"If we hit Venus you will see the echoes as blips on the screen in exactly five seconds," says Professor Gordon. "Four . . . three . . . two . . . one."

The white line on the scope breaks up into a jumble of peaks and valleys that run across the screen from left to right

"There they are . . . right on schedule."

Watching the screen we gradually become aware of the clatter of data recording equipment at the rear of the control room. The machines are noisily punching the perforated tapes that will later be fed into computers to tell the details of a multi-million-mile journey from the rugged foothills of central Puerto Rico to Venus and back. —THOMAS TOBIN

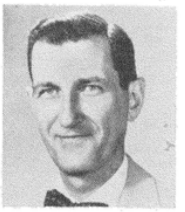


Associate director G. H. Pettengill waits patiently for return of a planetary echo.

"Big Ear at Arecibo," *Cornell Alumni News*, v66n5 (Dec 1963), cover & pp 5-14.

Two outstanding scholars have been appointed to distinguished professorships in the College of Engineering, according to Dean **Andrew Schultz Jr. '36, PhD '41:**

William E. Gordon, PhD '53, director of the Arecibo (Puerto Rico) Ionospheric Observatory and a Cornell professor of electrical engineering, will become the Walter Read Professor of Engineering.

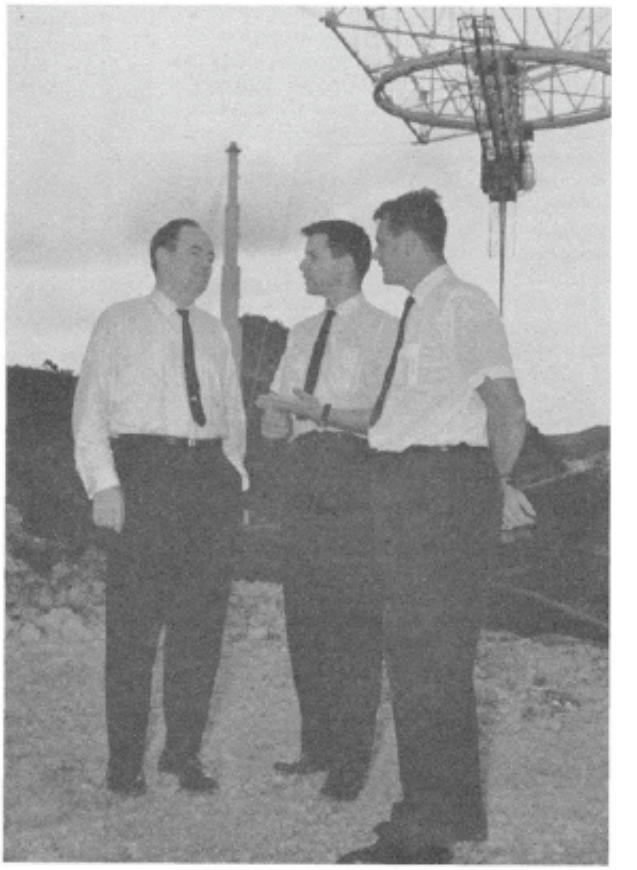


Gordon joined Cornell as a research associate in 1948, receiving his doctor's degree in radio propagation. In the 1950s, he conceived the basic design of the radar-radio telescope at the Arecibo observatory, the world's largest. With modifications, his design was used as the basis for construction of the instrument, which cost nearly $9,000,000 to build. Funds were supplied by the Advanced Research Projects Agency (ARPA) of the US Department of Defense.

Gordon supervised construction of the observatory and has been its director since it began operations in 1963. He will return to Ithaca in the fall to teach and pursue research in his main field of interest, the ionosphere. His professorship was named in honor of **Walter R. Read, ME '15,** a Milwaukee businessman who gave $300,000 to the Centennial Campaign.

(William E. Gordon PhD '53, named the Walter Read Professor of Engineering) *Cornell Alumni News*, v68n1 (Jul 1965), p 21.

Vice President Hubert Humphrey, on a recent orientation visit to the Arecibo Ionospheric Observatory (AIO) in west-central Puerto Rico, discusses the world's largest radio-radar telescope with **Rolf B. Dyce '51, PhD '55** (center), associate director, and John Burry, business manager, for the Observatory. The AIO carries out radar studies of the earth's ionosphere and the moon and the nearer planets, and radar astronomy studies of such distant celestial objects as stars and galaxies. It is operated by Cornell under a research contract with the Air Force Office of Scientific Research, of the Office of Aerospace Research, USAF, and with support from the Advanced Research Projects Agency, of the Department of Defense.



(Vice President Humphrey visits AO) *Cornell Alumni News*, v68n7 (Feb 1966), p 56.

University

Signals for Science; Space for Science

■ Science held the center of the university stage at mid-term, with announcement of work on strange signals from space received at the university's giant radio radar telescope in Puerto Rico, and word that Lower Alumni Field will be the site for future buildings for the new Division of Biological Sciences.

Signals from Space

American radio astronomers are spending their time these days hunched over oscilloscopes, observing a newly discovered series of unique radio signals from space. The signals were first observed last summer in Britain and have also been seen in West Virginia, but the most intensive work is taking place at Cornell's Arecibo Ionospheric Observatory in Puerto Rico. The big disk there is ideally suited for listening in at the relatively low frequencies of the pulses, and the Arecibo telescope is able to track sources.

What the oscilloscopes show is blips from four different sources in space. Blips from each source occur at extremely regular intervals (from one, roughly every quarter second, from another, slightly over once a second). Each pulse varies in intensity, to the extent that some are too weak to be observed. At peak power, however, observed at a frequency of 111.5 megacycles per second, the pulses are one of the strongest radio emissions yet discovered in the sky. Each observable pulse is so sharp that it now appears its source must be only a few hundred miles in width.

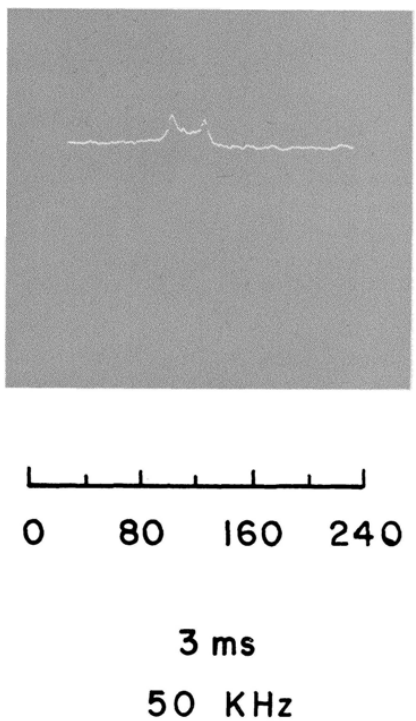
These pulses are unique because most celestial radio sources emit continuously, rather than in blips, and those which do yield a variable pulse, such as flare stars, do not emit with the regularity the new pulses show.

The possibility of intelligent life producing the pulses was one of the first that came to mind to explain the signals. However, scientists considered this unlikely: the lowness of the frequencies points toward a natural origin. Moreover, a civilization with the technological sophistication to generate the amounts of power involved would be very unlikely to use such a broad radio frequency (pulses from one source can be observed as low as 40 megacycles and as high as 430).

Astronomers are excited more from a purely scientific point of view. Some think the sources could be "white dwarf" stars. No white dwarfs have been observed to behave as these new "pulsars" do, but it is theoretically possible that they could.

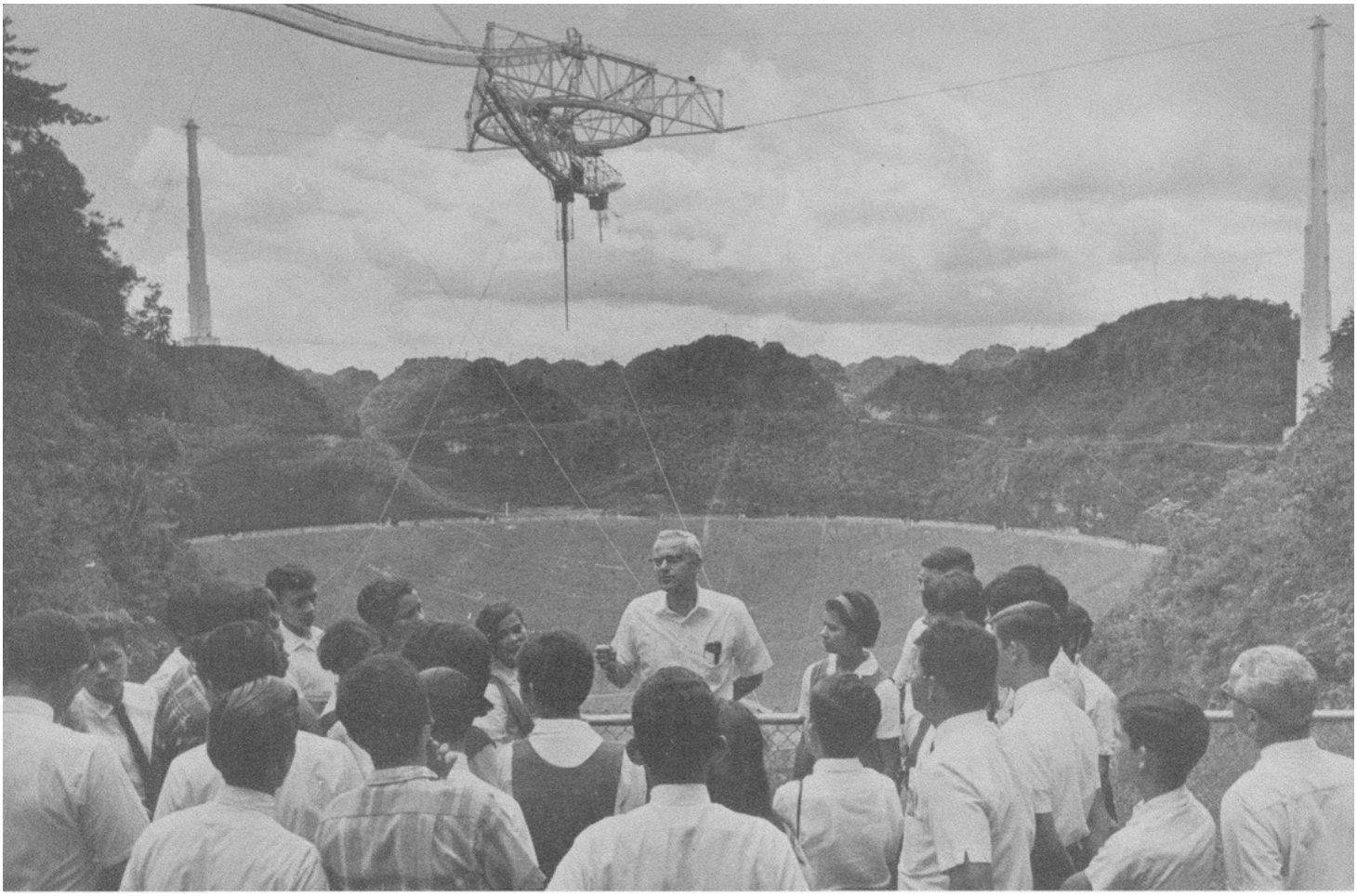
Another suggestion is that the pulsars are neutron stars. A neutron star is a star at the end of its life which has collapsed by its own gravity to reach a mass of up to a million tons per cubic inch. The concept of such a star is necessary to the rest of what is known about stars, and their existence is not seriously questioned, but no one had ever observed one. Now, it is thought, astronomers at Arecibo may actually be "seeing" a neutron star.

Observation of the four known pulsars will continue through the spring, at least, and the technique (see the December 1967 NEWS) of using two synchronized radio telescopes to effectively create one enormous telescope, will be used. Meanwhile, the hunt for more pulsars is on. If the sources of the radio pulses are indeed some kind of star—known, hypothetically known, or unknown—there should certainly be more.



Oscilloscope face portrays one of the newly recorded signals at Arecibo.

(University) "Signals for Science; Space for Science," *Cornell Alumni News,* v70n10 (May 1968), pp 20-21.



Frank D. Drake, Arecibo director, explains the giant telescope to a local school group. —Sol Goldberg '46

(University) "Signals for Science; Space for Science," *Cornell Alumni News,* v70n10 (May 1968), pp 20-21.

CORNELL ALUMNI NEWS

MAY 1972 70 CENTS

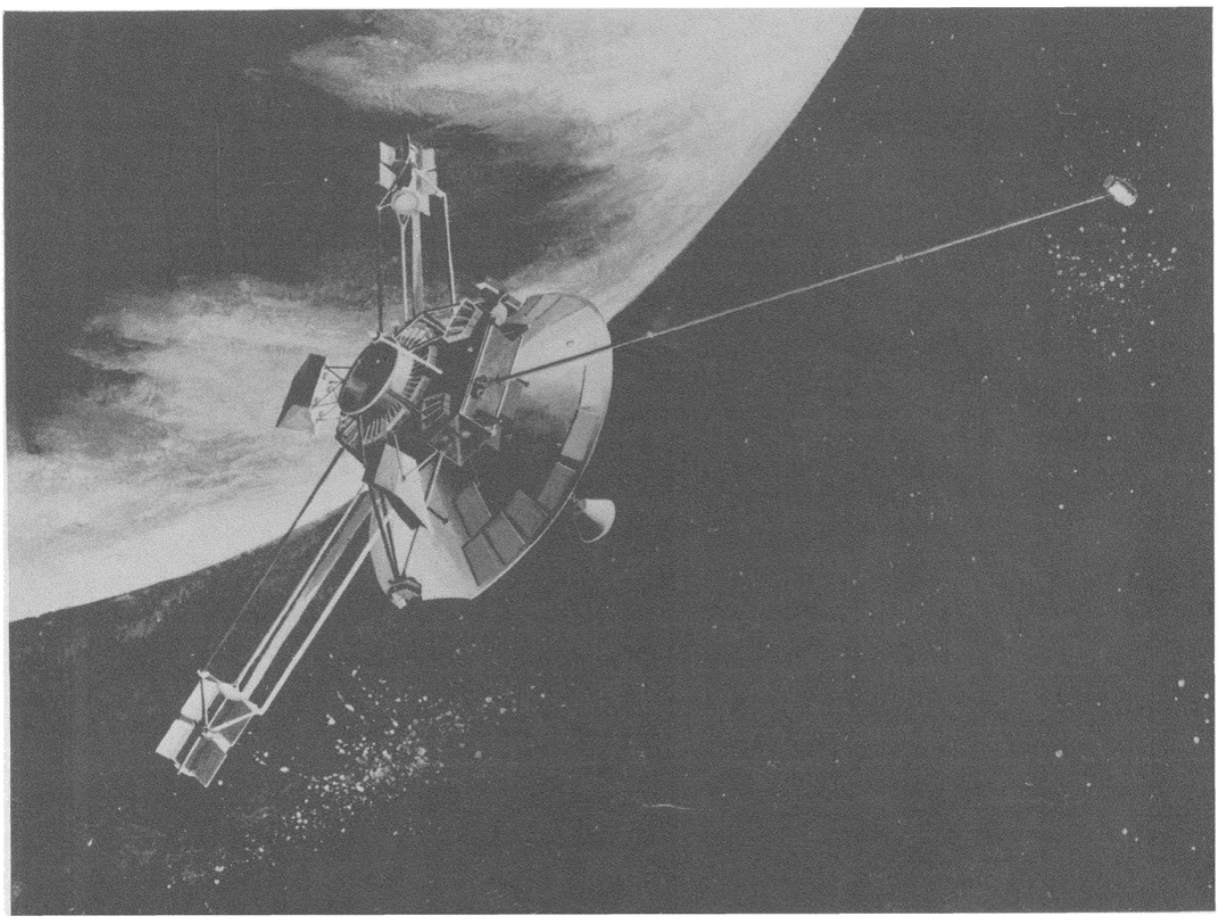
URIS LIBRARY

Talking to the Stars page 9

1111000010100100001100100000001000001010 0
1000001100101100111100001100001101000000
0010000010000100001000101010001000000000
0000000000100010000000000101100000000000
0000000100011101101101101010000000000000
0000100100001110101010100000000010101010 1
0000000001110101010111010110000000100000 0
0000000000010000000000000100010011111000 0
0011101000001011000001110000000100000000 0
1000000001000000011111000000101100010111 0
1000000011001011111010111110001001111100 1
0000000000011111000000101100011111110000 0
1000001100000110000100001100000000110001 01
0010001111001011 11

URIS LIBRARY

Talking to the Stars



March 2, 1972, was the first day of what could be a 100-million-year voyage for Pioneer 10, man's first spacecraft designed to leave the solar system. At the last minute, a dramatic addition was made: a six-by-nine-inch aluminum plaque, etched with the figures of a man and woman and a series of messages hopefully intelligible to some distant civilization. This plaque was designed by two Cornell astronomers, Professors Frank D. Drake '51 and Carl Sagan, with the help of Linda Salzman Sagan, an artist.

On the next seven pages we explore why it is that men on earth think it worthwhile to try to talk to space, and how they try to go about it.

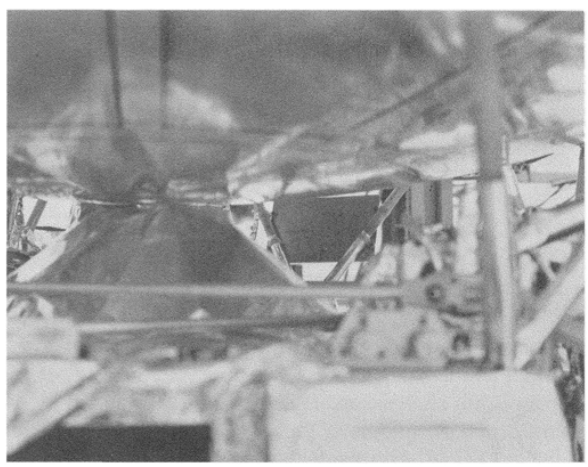
Professor Sagan is the author (with I. S. Shklovskii, a Soviet scientist he met after writing the book) of *Intelligent Life in the Universe* (Holden Day, 1966), a book that weighs the probability and outlines the methods of talking with extraterrestrial beings. Professor Drake's *Intelligent Life in Space* (Macmillan, 1962) is a more general discussion of the same subject. Both books are helpful in gaining some perspective on the mind-challenging project these men have initiated.

(Talking to the Stars) *Cornell Alumni News*, v74n10 (May 1972), pp 9-17:

"This picture is meant to be seen by extraterrestrial beings …
but what if they have no eyes?" by Geof Hewitt '66, pp 10-13.
"Deciphering a Message from Another World," by Prof. Frank D. Drake '51, p 14.
"Deciphering Some of the Deciphering," by the Editor, p 16.

Talking to the Stars

The Cornell astronomers' message (above) was etched onto an aluminum plaque that nestles (at right, dark object at rear) among paraphernalia on the outside of the spacecraft Pioneer 10, launched in March.



This picture is meant to be seen by extraterrestrial beings...

but what if they have no eyes?

By Geof Hewitt '66

SOME FANATICS claim earth was once the insane asylum for an advanced, extraterrestrial civilization: that civilization is even now studying us, bemused by the societies developed by the descendants of its lunatics. More poignant is the astronomer's legendary response to the question: "Is there any life on Mars?" "Oh, a little on Saturday nights," he says, "but the rest of the week it's pretty dull."

Prof. Frank D. Drake would go along, I think, with the astronomer's answer. In spirit, that is. A sense of humor, as well as of imagination, seems constantly at play in what is ultimately very serious work. Meeting Drake in his office at Cornell, I wanted to take as little of his time as possible, knowing that since the launching of Pioneer 10 he's been deluged by reporters.

And letters. "We knew," he told me, "when we did this that we'd be deluged by people second-guessing. First, there's been a deluge of people who want to make duplicates of the plaque and sell them at a profit. A lot of people thought the project was a good idea, and there's another category of letters written by people who would make improvements. Mostly these were good ideas.

"And there's another group of worry warts, the most extreme being the man who insists the man on the plaque is making a Nazi salute. He cites our TV programs, whose beams even now might be actually arriving in extraterrestrial laboratories. Well, our TV shows the Nazis as bad guys and when the plaque comes along with the Nazi salute, the only conclusion possible will be that the Nazis have taken over. And so, he says, we must send a second ship to destroy the Pioneer.

"Some Fem-lib types have complained because: 1) the man is on the left, 2) he is making the greeting and therefore appears to be the leader, 3) the woman is seen as standing behind the man—but this is a wholly subjective way of seeing it—and, 4) the vulva of the woman doesn't show—but we intentionally left it off because we knew magazines and newspapers would want to run pictures of the plaque.

"There's also been some feeling that our mixture of races on the plaque, in which the man appears negroid and the woman oriental, is anti-Semitic. But if you look closely you'll see the male is circumcized. No matter what we did, I doubt such second-guessing could have been avoided.

"I thought we should show the woman in childbirth—this would provide an extremely useful piece of information—but the Sagans thought this would be confusing; maybe the child emerging would appear to be a permanent extremity of the woman. The matter could have been cleared up by showing a separate child, but the confusion could arise that there are two separate species of humans, large and small.

"There was a letter today complaining that the six by nine dimensions of the plaque are not in centimeters, and since the rest of the message is, this may be confusing. Though the basic point is right, he's got it all wrong because the message works with a twenty-one centimeter wave length which is not precisely a centimeter length.

"The people over in Day Hall think we should have put RSVP on the plaque. Surprisingly, NASA didn't suggest an American flag which would have really confused extraterrestrial beings."

The *Cornell Sun* reported what is ostensibly Drake's public reply to the Day Hall suggestion: Pioneer 10 is expected to reach Jupiter by Christmas 1973, and then to travel out of the solar system at 26,000 m.p.h. "At the rate it's going, it will take 80,000 years for it to reach

the nearest star. That's why we neglected to put RSVP on the message."

Drake seems convinced that advanced extraterrestrial civilizations now exist. I asked if his peers consider him a nut. "No. Surprisingly, it's gotten so most astronomers think the same as I do. Those who disagree with the concept of extraterrestrial life are considered the nuts. I think there's a fifty-fifty chance that somebody, not necessarily me, will detect extraterrestrial life within my lifetime. Right now in this room I'm sure are detectable radio waves from another civilization. If we just knew where to look, at what frequency to set our receivers!"

Extreme theories and jokes about the martians may be a form of *reductio ad absurdum* motivated by our human desire, as identified by Sagan in *Intelligent Life in the Universe,* to believe that we are the "pinnacle of creation." Maybe this is why I'd expected Drake to be an odd-ball, the proverbial mad scientist cackling and cooing over new hypotheses. I was surprised to find him so soft-spoken, and calmly sure that his quest is justified. And I had not realized the breadth of knowledge, relating to all categories of existence, necessary for his work. One could wish I'd been prepared with deeper questions, not been so skeptical about the chance of extraterrestrial life. "What do extraterrestrial beings *look* like?" I blurted.

"I don't carry any internal picture of what extraterrestrial beings look like. But my own opinion is that for a planet like the earth they will indeed resemble man, enough that at 100 yards in the twilight you might confuse them with man. At least four extremities seem indicated. I don't know why four seems an ideal, but with this number you develop the ability to use tools with two, and to stand erect with the other two, which raises the eyes to the most advantageous position for locating food and enemies."

An aspect of the Pioneer's message that puzzled me most was the assumption that its finders would be able to perceive it visually. What if they turn out to be possessed of no eyes and gigantic clubby hands, incapable of feeling the fine etching on the metal surface? Drake explained that "it is almost certain that all beings everywhere have sight, because they all live in the vicinity of a star. With radiation everywhere the ability to see will evolve because it is so essential to finding food and to self defense. This is verified on earth where all creatures have eyes. So, assuming extraterrestrial creatures have visual capability, pictures are a sensible means of establishing communication."

I asked if he believed in universal laws. "There are a few. All the laws of chemistry and physics are universal, and the only other law we are sure applies everywhere is the law of economy: because all the planets are round they have limited surface area which requires competition among beings for the limited resources. This means evolution, through the use of eyes, to intelligence, which is the only aspect shown through fossil records to improve. Increasing physical size, as the dinosaurs taught us, has not been of advantage.

Frank Drake is professor of astronomy and director of the National Astronomy and Ionosphere Center, the radio-radar telescope operated by the university in Arecibo, Puerto Rico. He earned the BEP at Cornell in 1952 and the PhD at Harvard, served in the Navy, at the radio astronomy observatory in Green Bank, W. Virginia, and at Caltech, and returned to Cornell in 1964.

"This is an argument that on other planets there is not only evolution but that an intelligent species will develop, given enough time. Increasing intelligence has always been seen as an evolutionary improvement. The only conceivable rebuttal is seen on earth, where we have conceivably evolved too great an intelligence and might pollute ourselves to death, but I believe that the most intelligent creatures identify themselves by coping with the problem, and preventing their demise."

In his *Intelligent Life in Space,* Drake estimates that within the whole Milky Way, one in ten—more than a billion—stars appear to have planets that could support intelligent life. Studies of the earth indicate that approximately five billion years are required for the development of intelligent creatures. Drake portrays Mars as a planet that has not yet developed an intelligent species, and in his book maintains that "all across the galaxy, time after time, intelligent beings and civilizations have probably

arisen and may be arising today."

The binary code on which Drake and his associates rely for communication beyond the earth, he says, the most efficient method of establishing communication short of sending pictures with corresponding earth-words. "We knew a terrestrial language wouldn't work because we have hieroglyphics we couldn't translate until we found the Rosetta stone. You have to give some way of associating the language with something the other guy is familiar with. This is the basis for our using binary code, which carries more information than the laws of information theory allow, because the messages do make use of common information in terms of the laws of physics and chemistry.

"But the binary system is also meaningless unless you have something to show its use. This is the same way a baby is taught to talk. If you received a terrestrial TV program you could probably reconstruct the language used because the language is juxtaposed with certain objects and actions. But given the conversation without pictures, you're helpless."

In 1960, Drake initiated "Project Ozma," named for the mythical land of Oz, by training a special receiver he'd developed, at 21 cm. wavelength, on two nearby stars, Epsilon Eridani and Tau Ceti. He used the 85-foot radio telescope at the National Radio Astronomy Laboratory of Greenbank, West Virgina, as an antenna. Such "eavesdropping" on the stars, Drake maintains, is one method we might employ more persistently to locate distant civilizations. "For less than it costs to send a man to the moon, we can construct radio telescopes capable of receiving radio and TV waves from great distances in space.

"Project Ozma was a failure, and we knew full well it was a limited search. At the time it was thought possible that every star in the universe was radiating. But we only had time in the two months of telescope time allotted us to try these two stars, and in a very narrow range of frequencies. After our two months, the telescope was made available again to more conventional studies."

Because of the distance between Earth and other potentially advanced civilizations, inter-planetary communication could take tens, hundreds, or even thousands of years. But, as Sagan points out in his book, some of our AM radio and all television signals have interstellar potential; earth has been transmitting signals, then, for over forty-five years. Sagan speculates that any civilization less than half forty-five light years away may have received our first radio programs and have beamed some response that right now is in our air.

Drake entertains various notions of the fate of Pioneer 10. One hope—and on this the communicative function of the plaque largely rests—is that a civilization will be able to intercept the capsule without damaging it. Success for the message relies heavily on a civilization at least as advanced as we are. "We communicate right now with natives in Brazil who have no technology, but there are certain things we do have in common. The binary code, however, requires someone as advanced as us so they can receive the message. There is a *remote* possibility that if the plaque crashed on a planet in its equivalent to our 15th Century the beings there might still break the code, but a 10th Century civilization would miss it completely."

I asked Drake about afterthoughts, and he acknowledged there were many, since he and the Sagans had only a week in which to design the plaque. "If we had a bigger plate, and more time, we could have shown the capabilities of the human brain, nerve endings, the DNA molecule, and maybe something of our reproductive method, but there wasn't time. There's another such shot in a year; maybe then.

"No one knew the space craft would have escape velocity; this was a wholly unreported fact until Eric Burgess at the *Christian Science Monitor,* who has since left there, was snooping around and discovered and mentioned this escape velocity to Sagan. Sagan and I met in San Juan a couple of days later, and he brought this up —we discussed the idea and convinced NASA to let us have a couple of ounces for the plaque. Extra weight at such a late date in planning is difficult to allow for. A microfilm encyclopaedia might be enclosed in such a capsule, but of course you have to count on them going out and getting it.

"In all likelihood our [radio and TV] messages of today will get to any star millions of years before our plaque does. It is just possible they can put it all together if they see on TV the launching of the Pioneer 10, with close-up shots of the plaque, and maybe then they'll know it's coming."

Our conversation had been interrupted frequently by telephone calls; in none was I able to hear Drake talking about the plaque on Pioneer 10. I prepared to leave, and he invited me to phone if I had further questions. "What per cent of your work involves inter-planetary communications?" I asked.

"About two," he said.

```
1111000010100100001100100000001000001010 0
1000001100101100111100000110000110100000 0
0010000010000100001000101010000100000000 0
0000000000100010000000000010110000000000 0
0000000100011101101011010100000000000000 0
0000100100001110101010100000000001010101 0
0000000001110101010111010110000000100000 0
0000000000010000000000000100010011111000 0
0011101000001011000001110000000100000000 0
1000000001000000011111000000101100010111 0
1000000011001011111010111110001001111100 1
0000000000011111000000101100011111110000 0
1000001100000110000100001100000001100010 1
0010001111001011 1
```

Is this a message from another world?
Turn the page to learn what it would tell an intelligent being who received it.

Deciphering a Message from Another World

By Prof. Frank D. Drake '51

Professor Drake made up the message on the preceding page a number of years ago. The message would arrive as a series of bursts of energy, received at regular intervals and recorded as ones. Zeros designated intervals in which no energy burst is recorded.

The first step in the solution to the 551-character imitation message from another civilization is to determine, if possible, the number of dimensions in which the message is written. If one dimensional, it will be similar to an ordinary telegram; if two dimensional, it will be similar to a conventional TV picture, although other than cartesian coordinates might be employed, etc. We would not expect the number of dimensions to be large, simply because ease of decipherment calls for few dimensions. To make headway in this, one may see what factors may be divided into 551. This test reveals that 551 is the product of only two factors, 19 and 29, both prime, of course. This is a good indication that the message is two dimensional. Trial and error with cartesian coordinates shows that breaking the message into groups of 19 characters, and arranging these as in a conventional TV raster, gives a clearcut picture, which is obviously the correct decipherment of the message.

The interpretation of the picture is as follows:

1) The figure of the man-like creature at the bottom of the picture is obviously a drawing of the being sending the message. We see that it is a primate, with a heavier abdomen than we have, and that it carries its legs more widespread than we do. Its head is also more pointed than ours. One may speculate from this physiognomy that the gravitational acceleration is greater on the home planet of this creature than it is on earth.

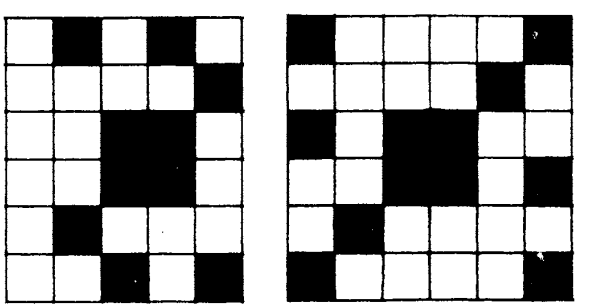
2) The large square in the upper left-hand corner, accompanied by nine smaller objects strung along the left-hand margin, is a sketch of the planetary system of the creature. We see that there are four minor planets, a larger planet, two large planets, another intermediate planet, and one last minor planet. The system thus resembles our own in basic morphology.

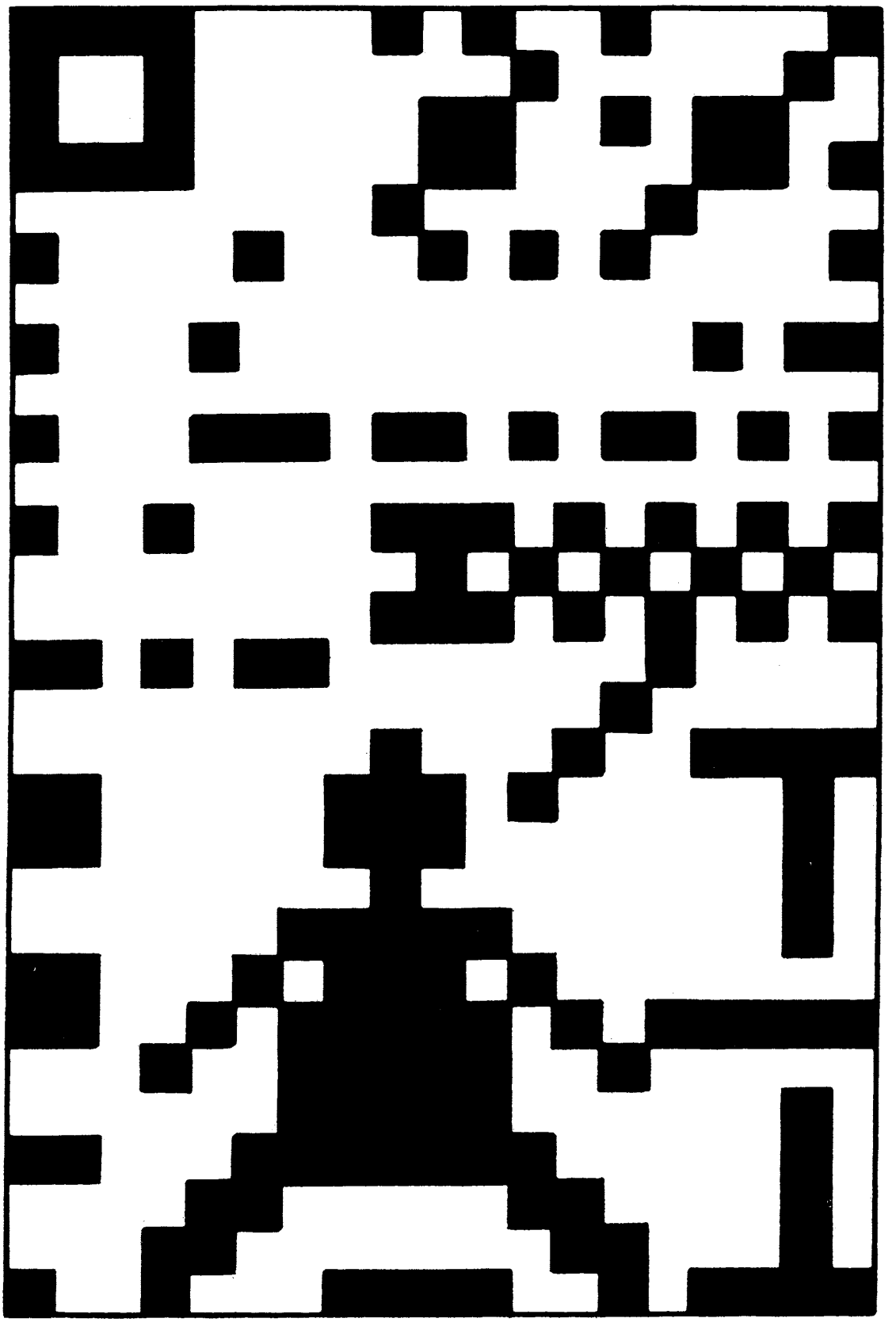
3) The two groups in the upper right hand corner may be recognized as schematic drawings of the carbon and oxygen atoms. We deduce from this that the creature's biochemistry is based on the carbon atom, as ours is, and that the oxidizer used in the chemistry is oxygen, also as with terrestrial animals.

4) A key group of symbols are those occurring just to the right of the four minor planets and the fifth planet. Inspection of these symbols shows that they are simply a modified binary representation of 1, 2, 3, 4, 5, written in sequence alongside the first five planets. The modification made to the basic binary numbers is the addition to the ends of the numbers of parity bits, where necessary, so that the number of 1's in every binary number is odd. This is similar to computer practice on earth. It is

1	1	1	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
1	0	0	1	0	0	0	0	0	1	1	0	0	1	0	1	1	0	0
1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1	1	0	1
0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	1	0	1	1	0	1	0	1	1	0	1	0	1
0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
1	0	0	1	0	0	0	0	1	1	1	0	1	0	1	0	1	0	1
0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0
0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0	1	0	1
1	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1
1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1	0
1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0
1	1	0	0	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0
1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	1	1	1	1
0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	0	0
0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0
1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	0
0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0
0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0
1	0	0	1	0	0	0	1	1	1	1	0	0	1	0	1	1	1	1

At left, *the imitation message is arranged into 29 lines of 19 characters each.* **Opposite page,** *this grid is converted into a picture and series of number and word messages by making black squares of all the number ones.*
Below, *the carbon atom is represented at left. The large square represents its proton nucleus. Two inner-circle electrons are shown diagonal to the proton, and the four second-circle electrons of carbon are shown above and below the inner-circle ones. Oxygen, at right, has two inner-circle electrons and six in its second circle.*





Deciphering Some of the Deciphering

By the Editor

UNDERSTANDING Professor Drake's imitation message from outer space requires knowledge of a language nearly as remote from most of us as a language of another world. It is the binary system, the language of the computer—logical, but using a number system at first glance completely alien to the one we know.

We speak to computers in the same way another civilization might speak to us, in a series of energy bursts and intervals when no energy is transmitted. When the energy bursts are given as 1s and non-bursts as 0s, the result is a signal that reads 1100101000111, etc.

The signals are converted into a number system by the use of base-2 numerals.

We are familiar with the decimal system, which uses 10 as a base. In this system, the righthand digit represents 1s, the next digit represents 10s, the next 100s, etc. Thus the numeral 524 signifies five 100s, two 10s, and four 1s: which add up familiarly to the number 524.

524 base-10 = 524

In the base-2 number system, the righthand digit designates 1s, but the next designates 2s, the next 4s, the next 8s, the next 16s, etc.

So the base-2 numeral 111 means one 4, one 2, and one 1, or the number 7.

111 base-2 = 7

Designation of the numbers 1, 2, 3, 4, and 5 in the base-2 system is as the numerals 1, 10, 11, 100, and 101. These can also be represented as 001, 010, 011, 100, and 101.

001 base-2 = 1
010 base-2 = 2
011 base-2 = 3
100 base-2 = 4
101 base-2 = 5

All this explains the planet numbers 1, 2, 3, 4, and 5 in the imitation message described on these four pages, except for "parity bits." Parity bits are introduced into the number system of a computer to guard against errors caused when one of the computer's components (a resistor, etc.) goes bad, which may cause a burst of energy to appear as no burst, or vice versa, and thus make a 1 appear as 0 or 0 as a 1.

The simplest way to guard against this happening is to feed the computer only numerals that are composed of odd numbers of 1s (010, 111, 10101, etc.). Then if a numeral appears with an even number of 1s, it is clear something is wrong.

To assure that all computer numerals have an odd number of 1s, an extra digit must be added to the arrangement of each numeral, by adding a column to the right of the 1s digit. (Thus the numeral 001 becomes 0010, the numeral 100 becomes 1000.)

001 with parity bit = 0010
100 with parity bit = 1000

When a binary numeral normally has an odd number of 1s, a 0 is added at the righthand end (10 becomes 100). When a numeral normally has an even number of 1s, an extra 1 is added to the right to make the total number of 1s come out odd (the numeral 11 becomes 111).

001 with parity bit = 0010
010 with parity bit = 0100
011 with parity bit = 0111
100 with parity bit = 1000
101 with parity bit = 1011

These, in binary language with parity bits added, are the numbers 1 through 5 and make up the configuration that appears immediately to the right of the first five planets in the imitation message from outer space.

To interpret the three numbers represented at the far right of the message picture, we have to apply binary translation to larger numerals.

The binary numeral at the far right of Planet 2 is 1011, which is the number 5 just translated above. Actually it appears on the message 00000001011.

00000001011 = 5

The Planet 3 numeral is 11010110-101, or the number 858 (one 512, one 256, one 64, one 16, one 8, and one 2).

11010110101 = 858

The Planet 4 numeral requires three lines of eleven units each, which Professor Drake explains to be 3 times 10 to the ninth power or 3,000,000,000.

11101010101010101010101110 10101 = about 3 billion

The only other number in the message is the numeral 11111, alongside the primate figure, and that translates to the number 15.

11111 = 15

As Professor Drake explains, this number represents units of the only length the sending civilization and the receiving civilization could be sure to have in common, the wavelength on which the message is sent. The spectral line of the most abundant element in the universe, hydrogen, is used. Its wavelength is 21 centimeters or about 8 inches.

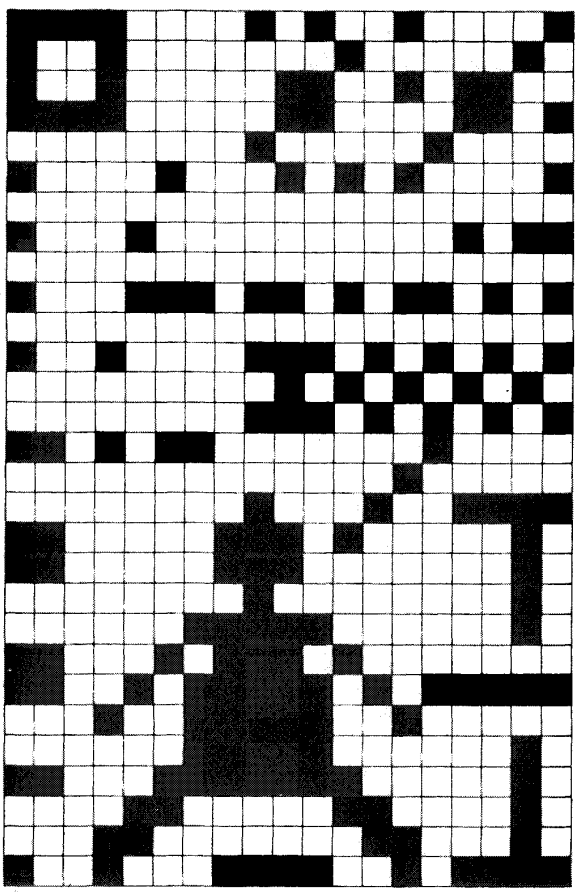
Thus, he says, the primate is 15 times 8 inches or about 120 inches high. "After receiving this message," Drake tells his classes, "we would feel ten feet tall."

At the bottom of the picture is an element of four 1s, to be interpreted as a word because it has an even number of 1s. All other elements we have translated have either contained odd numbers of 1s or been picture likenesses—the primate, the planets, the two atoms, the diagonal to the primate, and the dimensional indicator at the lower right of the picture.

So what is not a picture or a number is a word. And thus ends the lesson for this month.

apparently not used here as a check on transmission, but rather to designate a symbol as a number. In future communications, symbols will certainly also be used for words of language. We may deduce from the creature's careful setting down of the binary number system that he will use this, with parity bits, for numbers henceforth. It follows that we may expect words of language to have even numbers of 1's. In this way, the creature has established a number system, and has enabled us to recognize words of language.

5) Knowing this, the portions of the message located above the creature and below the atoms may be interpreted. We note that there are three groups of characters all having an odd number of 1's. These are then numbers. The lower group is connected to the creature by a diagonal line, signifying that it has something to do with him. The lower group, which was too long to place on one line, is about $3(10^9)$ in decimal. The next is about 800, and the upper group is 5. Noting that these groups are connected to the creature, and written alongside planets 2, 3, and 4, we reach the apparent interpretation that these numbers are the population of the creature on those planets. There are about 3 billion creatures on planet 4, evidently the some planet. There are about 800 on planet 3, from which we can deduce the fact that astronautics is more developed than on earth, and there is a sizable colony on planet 3. Lastly, there are 5 of the creatures on planet 2, evidently a small scientific or exploratory group.



Numerals and words are the dark elements in this representation of the imitation message from space. Planet numbers are at left center, populations right center, height at lower right, and the word at bottom.

6) The figure to the right of the creature contains one binary number, and a symmetric configuration of symbols of even parity, probably not words, and certainly not numbers. One symbol is level with the top of the creature's head, and the other his feet. This is apparently telling us the size of the creature—it is 15 somethings tall. The only unit of length our two civilizations have in common is the wavelength at which the message was sent, so we conclude that the creature is 15 wavelengths tall.

7) Lastly, there is a symbol of even parity, with four 1's, underneath the creature. This is evidently an effort by the creature to use up all the "words" allotted him in his message. We may suspect, in keeping with the discussion in (4), that this is a word of language, and is very likely the symbol that the creature will use for himself in future messages. This behavior would seem to reinforce the conclusions of (4), but we will have to wait for future messages for proof that this conclusion is correct.

A few remarks:

The content of the message was designed to contain the data we would first like to know about another civilization, at least in the opinion of many scientists who have thought about this problem.

In preparing the message, an attempt was made to place it at a level of difficulty such that a group of high quality terrestrial scientists of many disciplines could interpret the message in a time less than a day. Any easier message would mean that we are not sending as much information as possible over the transmission facilities, and any harder might result in a failure to communicate. In trying this puzzle on scientists, it has been true so far that scientists have understood the parts of the message connected with their own discipline, but have usually not understood the rest. This is consistent with the philosophy behind the message.

The use of two dimensions has made possible the transmission of a great deal of information with few bits. This is because it is possible to arrange the symbols of the message in positions relative to one another such that even the arrangement carries information, when we employ logic and our existing knowledge of what may possibly occur in another planetary system. Thus the 551 bits are equivalent to approximately 25 English words, but the information content of the message appears much greater than that. This is because much of the message tells us, by the placement of a single symbol, which of several complicated possibilities is the one that has occurred in the other planetary system, without using bits to spell out precisely the possibility that has occurred.

(Talking to the Stars) *Cornell Alumni News*, v74n10 (May 1972), pp 9-17:
"This picture is meant to be seen by extraterrestrial beings ...
but what if they have no eyes?" by Geof Hewitt '66, pp 10-13.
"Deciphering a Message from Another World," by Prof. Frank D. Drake '51, p 14.
"Deciphering Some of the Deciphering," by the Editor, p 16.

November 1974, Number 2

Astronomy: How complex is the universe?

Exploration of the Unknown

During the past decade we have discovered a bewildering array of new phenomena in the Universe: the quasars, pulsars, cosmic masers, exploding galaxies, and cosmic bursts of gamma rays.

But we must ask ourselves where all these discoveries will end. How much more remains hidden from us? How much more can we learn? How soon will we know every important characteristic of the Universe?

Of course we cannot yet answer such questions, but they are so intriguing that they tempt speculation. In this brief article I will try to outline how these questions might be approached. As I develop the argument we will come to many branch points, places where we will have to decide whether to take one direction or the other. This will make our final conclusions quite hazy. In fact, most of my fellow scientists would feel that we are venturing dangerously far from what we really know, and that our findings might not be just hazy, but actually misleading. For this reason, let me ask you not to consider what I write as a scientific prediction. It is more like a casual exploration of the unknown.

Twenty Questions

The complexity of the Universe can be measured by the number of questions we need to ask to find our way through it. When we were younger most of us played "Twenty Questions"; and our children—or grandchildren—still play that guessing game today. Once we had settled on "Animal, vegetable, or mineral," we were off on a chain of twenty questions which could be answered only by a "Yes" or "No;" and at the end of that chain, if we had budgeted our questions properly, we might identify the object that the other children had thought up.

Did you ever wonder why it should be twenty questions? Why not ten—or perhaps fifty?

The answer is slightly mathematical. If we are allowed only one "Yes—No" type of question, we can readily identify one object, given a choice of two. We ask "Is it the one on the right?," and if the answer is "No," then we know that it has to be the object on the left. Similarly, as Fig. 1 shows, we can identify one object among eight with three questions. With ten questions we would be able to make the correct choice only if we were faced with fewer than about a thousand—that is, 2^{10}—items. But since most children can think of many more than a thousand objects, ranging all the way from "New York City" to "the red marble on the kitchen table," a guessing game called "Ten Questions" could never be won. By the same token "Fifty Questions" would be much too easy because that many questions would suffice for identifying one among a thousand million objects. Since the average child probably can think up only a few hundred thousand items for us to guess, twenty

"Astronomy: How Complex is the Universe?" by Martin O. Harwit (The Arts College Observer, n2, Nov 1974); in *Cornell Alumni News*, v77n4 (Nov 1974), pp 33-36.

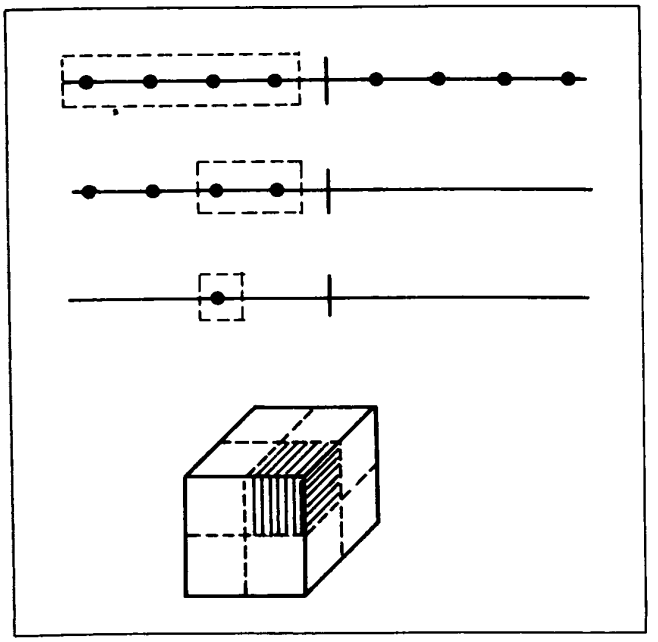


Fig. 1. *If we have eight objects, we can identify a chosen member of this group with three 'Yes-No' questions. The top three rows show how this is done if we can arrange the objects in a line. With the first question, we can decide whether or not the object is among the group of four to the right of the center line. With the next question we can similarly narrow the number down to two. And the final question identifies the object—uniquely. The bottom figure shows the same process when there is no single property among the objects that permits us to array them along a line. With three properties—say, site, hardness, and transparency as criteria—we could arrange the eight objects in a cubic array and then ask whether the object is in the upper half, the front half, and the left half of the array. Again three questions would suffice to identify one among* $2 \times 2 \times 2 = 2^3 = 8$ *objects. With twenty questions, one among* 2^{20} *or about a million objects can be identified.*

questions will usually suffice, provided we do not aimlessly squander too many questions.

How Much Can We Learn About the Universe?

Given then that a child's world probably comprises less than a million (or 10^{20}) objects, how many such objects would the astronomer's world, the Universe, contain? Is it an infinite number or is it finite?

This second question is readily answered. It is clear to us now that the amount we can learn about the Universe must be finite.

How do we know that? Because the world is not infinitely hot!

I realize that I had better explain this puzzling answer:

In order to learn anything about the Universe, we must—in some fashion—receive information about it. We obtain information about the distant stars, the galaxies and the quasars, by means of the light that

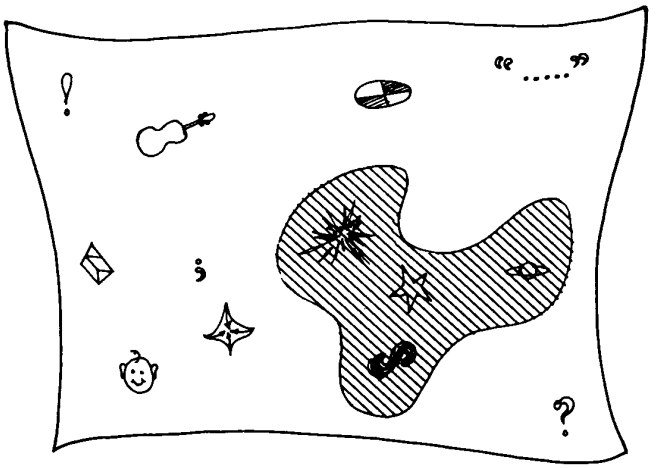


Fig. 2. *The boundary of this diagram is meant to illustrate the bounds on the realm of possible astronomical observations. The shaded area represents those types of observations that we know how to make. These have enabled us to discover stars, planets, galaxies, and supernovae as sketched. But there must be many phenomena outside this area—those that remain to be discovered with new techniques, new ways of looking at the Universe.*

they emit. This light consists of quanta, small packages of energy that we call photons. Each of these photons can carry only a limited amount of information. For example, if we wanted to send a Morse code message with a blinking light, we would need to send at least one photon for each dash.

But the photons from distant galaxies carry more than just information about the source from which they come. They also carry energy with them. This means that if we wanted to learn an infinite amount about the Universe, we would have to receive an infinite number of photons, and even if each photon carried only a small amount of energy, that would still mean that an infinite amount of energy would have to be pouring down onto the Earth, and it would become infinitely hot. Since the earth's temperature is quite moderate, this in itself implies that no more than some maximum amount of information can be reaching us from the surrounding Universe.

Could we have known all this fifty or a hundred years ago? After all, we knew perfectly well even then that the Earth was cool. For two reasons the answer has to be "No." First, the science of "information theory" is only some twenty-five years old, and the idea that information must be accompanied by heat is therefore rather recent. We used to think that the transmission of information could be accomplished without paying the price of heat.

There is a second reason. We have found in the last couple of decades that the energy of photons reaching us from large distances in space falls into a well-defined range. Above and below this range of

energies, the photons are extinguished during their travel and never reach us with the information they were to convey.

This minimum energy level precludes the sending of information by a boundless number of near-zero energy photons in order to increase the total information that can be conveyed. Consequently, there remains a well-defined limit on the rate at which we can learn more about the Universe. Of course, we can always learn more by observing for longer periods. But the Universe is evolving on a time scale of ten billion years. And if we were to study it for much longer than ten billion years we would no longer be studying the same system; it would have changed.

Cosmic Phenomena

While we may not be able to learn an infinite amount about the Universe, there may be no real need to. What we have learned about the world in the past century or two seems to show that we deal with certain major types of phenomena. There are ordinary main sequence stars like the sun, other stars that pulsate (periodically grow and shrink in size), galaxies like the Milky Way or the Andromeda Nebula, and exotic objects like pulsars, quasars and supernova explosions. Essentially everything we observe falls into one or another of such classes of objects, or phenomena.

Right now we probably recognize no more than some forty to fifty different types of phenomena in the Universe, although of course each phenomenon tends to show a variety of subclasses. For example, we recognize some five slightly differing classes of supernova explosions. At the moment, however, the observed differences are small, and we consider all these different subtypes as representative of only one supernova phenomenon.

By the word *phenomenon*, I mean something very specific. It is a cosmic object or event which differs by many orders of magnitude—at least in some respect—from other types of objects or events. The differences between different phenomena are vastly greater than the differences found in the different subtypes. To illustrate what I mean, let me again use the supernova as an example: We know of no phenomena that compares in explosive energy output, but we

Aerial photograph of the thousand foot radio telescope at Arecibo, Puerto Rico.

can recognize cosmic explosions that are thousands of times weaker. These are involved in ordinary nova outbursts. We also recognize explosions involving entire galaxies. But the nova, supernova, and exploding galaxy phenomena differ from each other by many orders of magnitude, and are not even approximately similar to each other.

Astronomers like to use the phrase "order of magnitude." It is somewhat vague, but very useful. A simple example of orders of magnitude is the difference in the budgets of a child, an adult, a city, a state, and a country. Each of these budgets differs by factors of many hundreds or thousands from any of the others on the list: They differ by many orders of magnitude.

The differences between the various cosmic phenomena are at least as big as the differences between these budgetary scales. They comprise events on vastly different scales with completely different quantities and character.

The Number of Cosmic Phenomena

I mentioned earlier that we are probably aware of some forty to fifty different cosmic phenomena. But we have discovered a few new phenomena in every recent decade. Does that mean that we will ultimately find an endless number of these phenomena, and that we can never come close to recognizing all of the principal features that characterize our Universe?

I think not. The reason for the many new discoveries is that we are making so many new types of astronomical observations right now. For example, at Cornell alone, Prof. Kenneth Greisen in the Physics Department is looking at gamma rays emitted in cosmic events. These gamma rays are light quanta

millions of times more energetic than visible light. Some years ago we would have flatly—but wrongly—stated that they play no important role in the Universe. Now, just in the past year, a new phenomenon has surfaced. Every few months or so an intense burst of gamma rays reaches us from somewhere in the Milky way or beyond. What types of sources produce these bursts? We really do not know, although Prof. Edwin E. Salpeter and I have conjectured about one mechanism that would involve neutron stars.

These neutron stars themselves are phenomena for which we have had evidence only since 1968. This evidence came from the pulsars which were discovered only after observations became possible on extremely short time scales at radio wavelengths. With this technique a number of astronomical sources were found to emit sharp pulses of radio waves lasting only a few thousandths of a second. Previously, these pulses could not be recognized because radio techniques could not follow their rapid changes.

At Cornell, Prof. Frank D. Drake of the Astronomy Department and his students intensively studied the nature of pulsars using the thousand foot radio telescope at Arecibo, Puerto Rico; and Prof. Thomas Gold, also at Cornell, first proposed that the pulsars are rapidly rotating neutron stars—fantastically dense stars, as massive as the sun, but as small as Ithaca.

Professor Martin O. Harwit, Chairman of the Department of Astronomy, was born in Prague in 1931, and graduated from Oberlin in 1951. His graduate degrees are from Michigan (M.A.) and M.I.T. (1960). He came to Cornell in 1961, after spending one year at Cambridge University as a NATO Post-doctoral Fellow, and progressed through the faculty ranks from Assistant Professor (1962-64), to Associate Professor (1964-1968), to full Professor in 1968. Professor Harwit became Chairman of his distinguished department in 1971.

If we looked at the entire list of recently discovered phenomena, each discovery would reflect a set of observations that resulted from a radically new observing technique, in fact an observing technique that was able to sense events orders of magnitude different from anything we could previously detect. But we can now show that we are approaching the end of the line of new observing techniques—that is of all the independent ways of looking at the Universe—and that we may therefore also be coming to the end of the line of newly discovered phenomena. We know that there are limits on the energy range that cosmic photons can have. We know that there are intrinsic, well-defined limits on how well we will be able to resolve observed radiation into its spectral and polarization components, and these limitations will curb our ability to draw ever finer scale maps of the cosmic objects we observe.

We have probably already discovered a small but significant fraction of the cosmic phenomena that make up the Universe. I would guess that we will ultimately recognize at least a hundred phenomena—more than twice the number we now know. But I would also estimate that the total will be less than a thousand. If we make progress at our present rate, we should know for certain within a century.

What does this tell us about the complexity of the Cosmos? The Universe contains billions upon billions of stars. We would need to play a game of Eighty Questions to correctly identify any one among them. In that sense the Universe is truly large and complex. But in terms of its wealth of distinct phenomena, the Universe should prove to be reasonably simple—certainly simple enough to fit into any game of Twenty Questions.

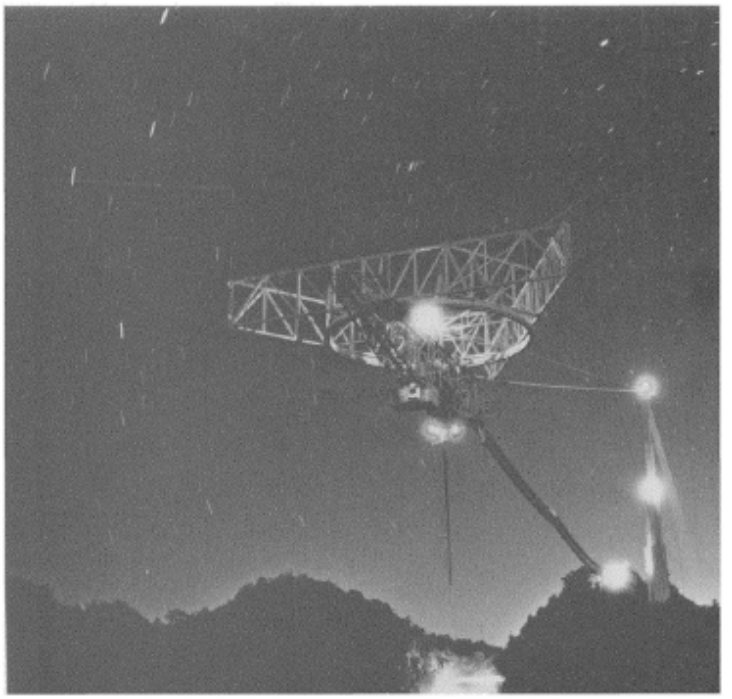
The Arts College **Observer**

The Arts College Observer is published four times a year by the College of Arts and Sciences, Cornell University.

Editorial offices are in Room 133, Goldwin Smith Hall, Cornell University, Ithaca, New York 14853.

Funds for this issue were provided by an alumna.

"Astronomy: How Complex is the Universe?" by Martin O. Harwit (The Arts College Observer, n2, Nov 1974); in *Cornell Alumni News*, v77n4 (Nov 1974), pp 33-36.



Caribbean stars wheel above the 600-ton suspended receiver operated by Cornell University at Arecibo, Puerto Rico. Beneath it is a 1,000-foot bowl covered with new aluminum panels that make the world's largest radio telescope 2,000 times more sensitive than it was when completed in 1963.

Cornell scientists are studying radio signals that took 10 billion years to reach the earth. Others are examining happenings in a space measuring 2.3 millionths of an inch.

The first group operates the largest radio telescope in the world, set among the mountains of Puerto Rico at Arecibo. According to astronomy Professor Frank Drake, Director of the National Astronomy and Ionosphere Center, they have been able to map distances on Venus with accuracies better than the length of a city block, and have studied quasars at the edge of the Universe.

(Caribbean stars wheel above the 600-ton suspended receiver) *Cornell Alumni News*, v77n3 (Oct 1974), p 64.

An exhibition of photographs taken at Cornell's Arecibo Observatory in Puerto Rico by Barrett Gallagher '36 (above) opened Sept 9 at the Overseas Press Club in New York. At the opening program, sponsored by the Alumni Assn of NYC, color slides by Gallagher were shown and Prof Frank Drake '51, astronomy, dir of the Natl Astronomy and Ionosphere Ctr at Arecibo, talked about the 1,000 ft radio telescope and the recent 'face-lift' that increased its sensitivity 2,000 fold.

(A photograph of Barrett Gallagher) *Cornell Alumni News*, v77n4 (Nov 1974), p 43.

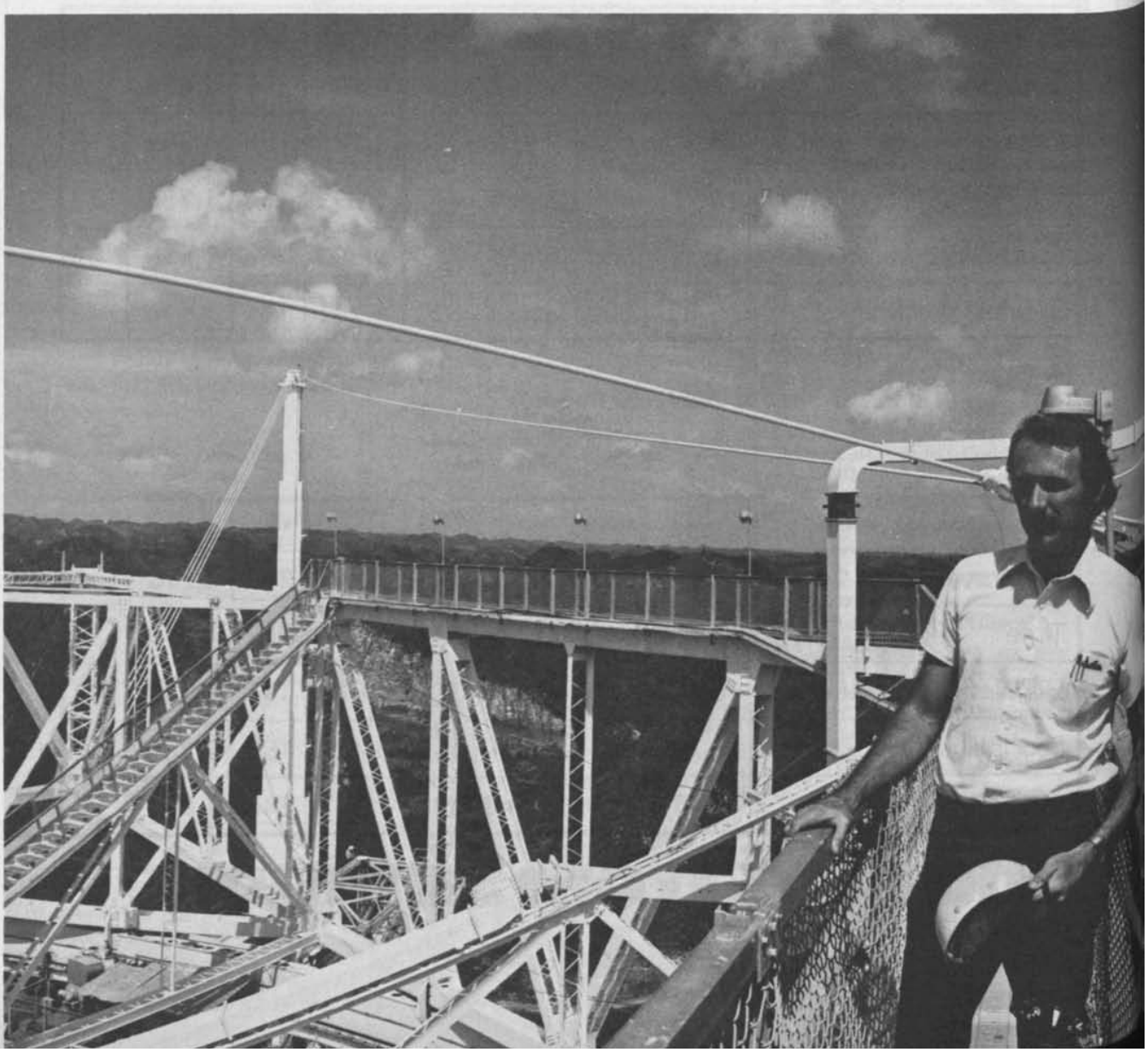
"Tuning the Big Ear," *Cornell Alumni News*, v77n5 (Dec 1974). Cover: A workman holds one of 38,000 panels of aluminum mesh that make up the reflector of the world's largest radio radar telescope at Arecibo, Puerto Rico; photo by Barrett Gallagher '36.

The discovery of mountains on Venus, thick dust on the Moon, Mercury's spin, a new superdense form of matter, a number of pulsars, and the nature of the ionosphere are among the achievements made possible by the radio radar telescope at Cornell's Arecibo Observatory in Puerto Rico during it first eleven years.

The telescope can reach farther into deep space than any other instrument built by man: its reflector bowl has collected radio signals emitted by quasars, the mysterious star-like objects that appear to exist at the very edge of the universe. And recent adjustments, improvements, additions, and innovations have now increased the instrument's sensitivity two-thousandfold. Prof. Frank D. Drake '50, astronomy, and director of the observatory's parent National Astronomy and Ionosphere Center at Cornell, explains, "We can now map distances on Venus with accuracies better than the length of a city block. There are areas of Earth we don't know as well as that."

The whole project had been pretty extraordinary from the outset—the idea of learning more about objects and gases in space by bouncing radio waves off them and interpreting the return waves. Some of the scientists who worked with radar during World War II had wondered

The director of operations of Cornell's giant radio radar telescope, Harold D. Craft Jr., stands atop the signal feed platform that is suspended above the telescope's 1,000-foot reflector.



"Listening to the Stars," *Cornell Alumni News*, v77n5 (Dec 1974), pp 10-15.

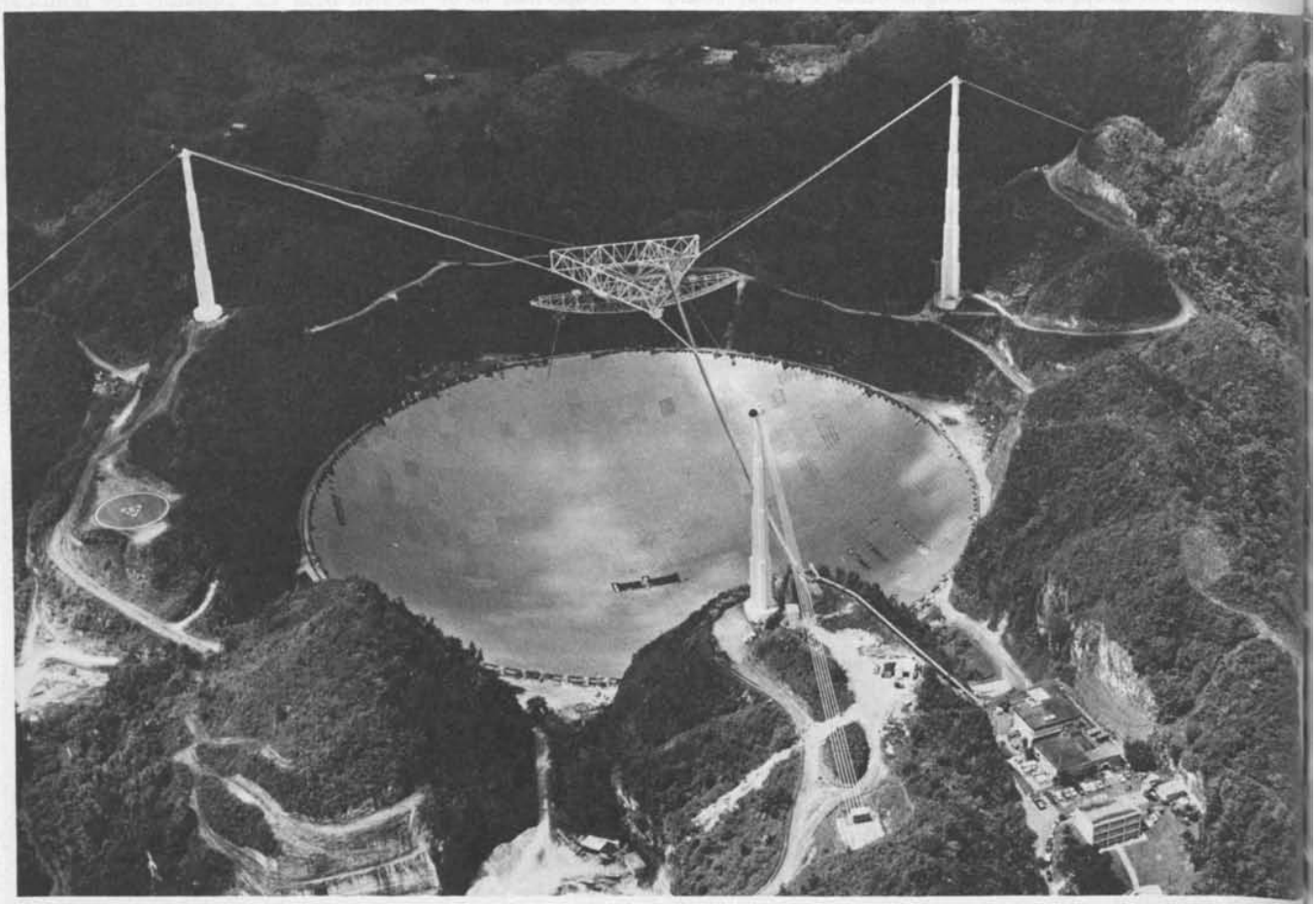
Listening to the Stars

at the time if the new technique might be of use to astronomers, but dropped the thought because radar could detect objects only within a hundred or so miles.

By the 1950s, the technology of radar had grown in sophistication to the point where more powerful senders and more sensitive receivers would permit radar to reach Earth's outer atmosphere, and far beyond. There was a feeling as well that a radar reflector could be used as a sensitive radio receiver for identifying and analyzing energy coming from distant stars.

Several of the early radar scientists had never abandoned the idea entirely. In due course they convinced the US government to pay Cornell University to build and operate a radio radar telescope for use by astronomers.

For reasons of the geography of the sky, such a telescope had to be located near the equator. For political reasons, it had to be in territory friendly to the United States. And, in addition, the exceptional design proposed by Cornell's Prof. William Gordon required a location with a particular topography. (The conventional radar sender-receiver has a moveable reflector of the sort seen turning slowly on ships and at airports. Gordon proposed instead to make the reflector stationary—so it could be large and thus more sensitive—by fitting it into a natural hollow in the earth. Aiming would be achieved by suspending a moveable signal-emitter and receiver above the giant reflector.) The search for a site that met all these requirements led to a bowl-like depression in Puer-



to Rico, eleven miles from the town of Arecibo and well away from man-generated electrical interferences.

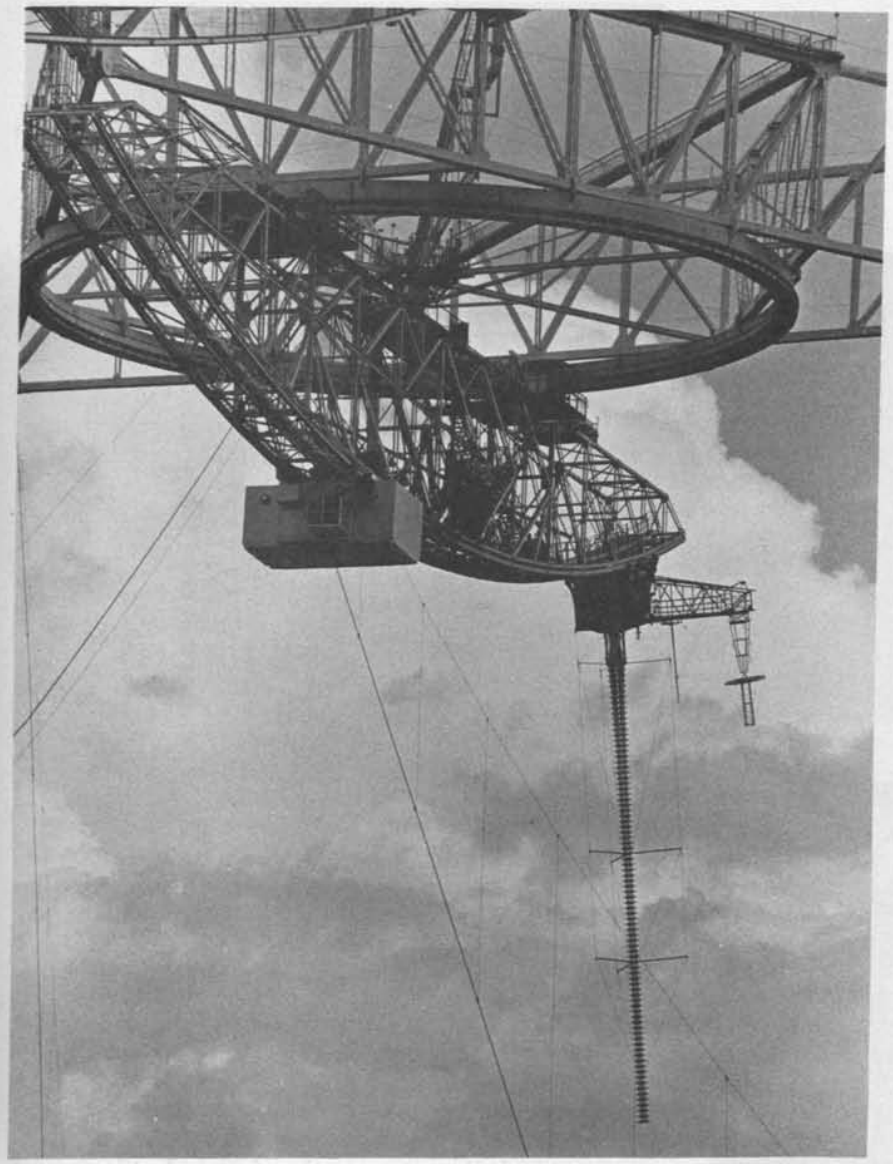
The project cost $9 million, and went into operation on November 1, 1963. The telescope consisted of a dish reflector of wire mesh 1,000 feet across, suspended from cables slung from the edge of the bowl. The sender-receiver was a rod nearly 100 feet long, suspended from a platform held aloft by immense cables strung from three concrete towers that also stood at the edge of the bowl.

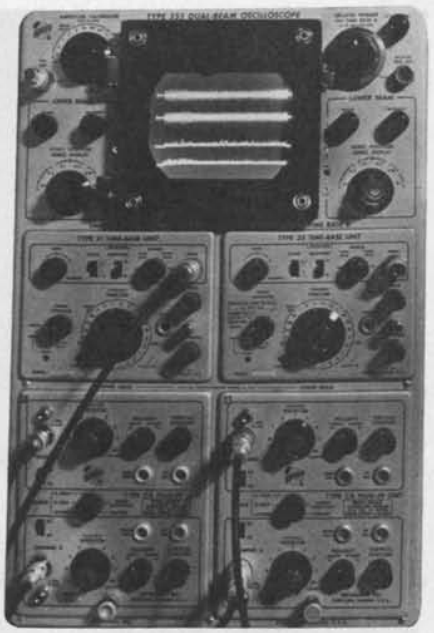
A radio radar telescope can "see" objects in space because radio signals, like light, are emitted by stars and galaxies, and can be bounced off the surfaces of planets in radar experiments. Unlike light, these signals can be observed right through clouds or dust with equal strength in daytime and nighttime.

Radar "maps" of planets are in fact maps of the radar reflectivity of the planet's surface. A visual map of the Moon has been found to coincide very closely with a radar map, leading scientists to conclude that radar reflectivity is an accurate gauge of light reflectivity.

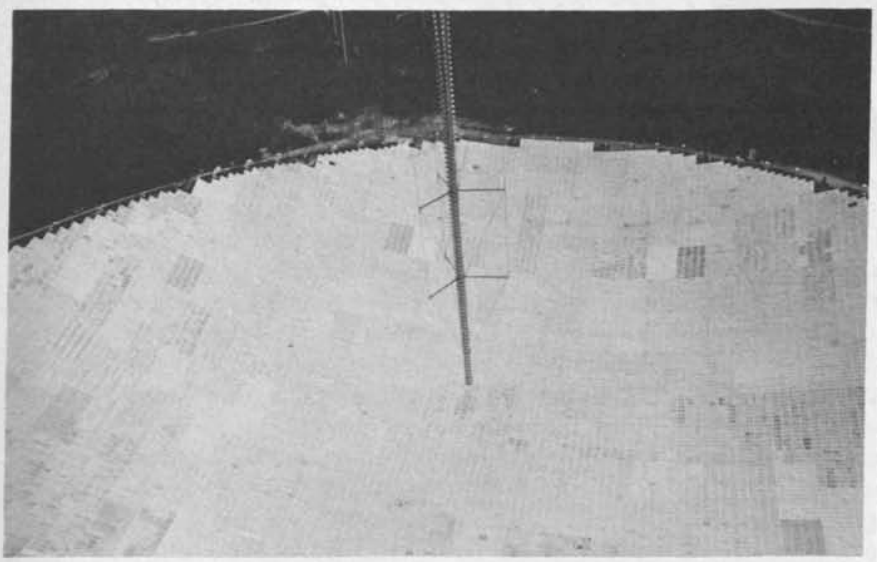
Radio astronomers are working with amounts of received energy so small that all the energy collected from celestial radio signals in the forty-year history of radio astronomy is about equal to the energy released when one snowflake falls on the ground (nowhere near as much as when that snowflake melts). Radio energy from some sources requires more than 10 billion years to reach the Earth.

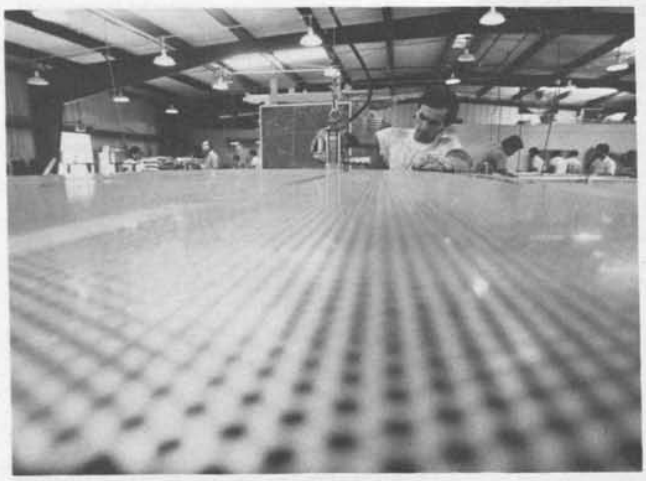
From the beginning, uses for the telescope proved to be many, including study of the ionosphere—that little understood area of Earth's atmosphere in which much space travel would soon take place—and of the surface of the Moon, to determine among other things where landings would be safest. Early work at the observatory mapped the surface of the Moon, and discovered a thick layer of fine dust over much of its area. The Arecibo Observa-





Opposite page, *telescope is located in a natural hollow of the earth.*
At left, *signal arm rides a miniature railway above the reflector dish.*
Above, *oscilloscope records several aspects of a radar signal bounced back from Earth's ionosphere.*





tory was able to help the US Moon-landing mission by indicating the best target areas, where the least dust could be expected.

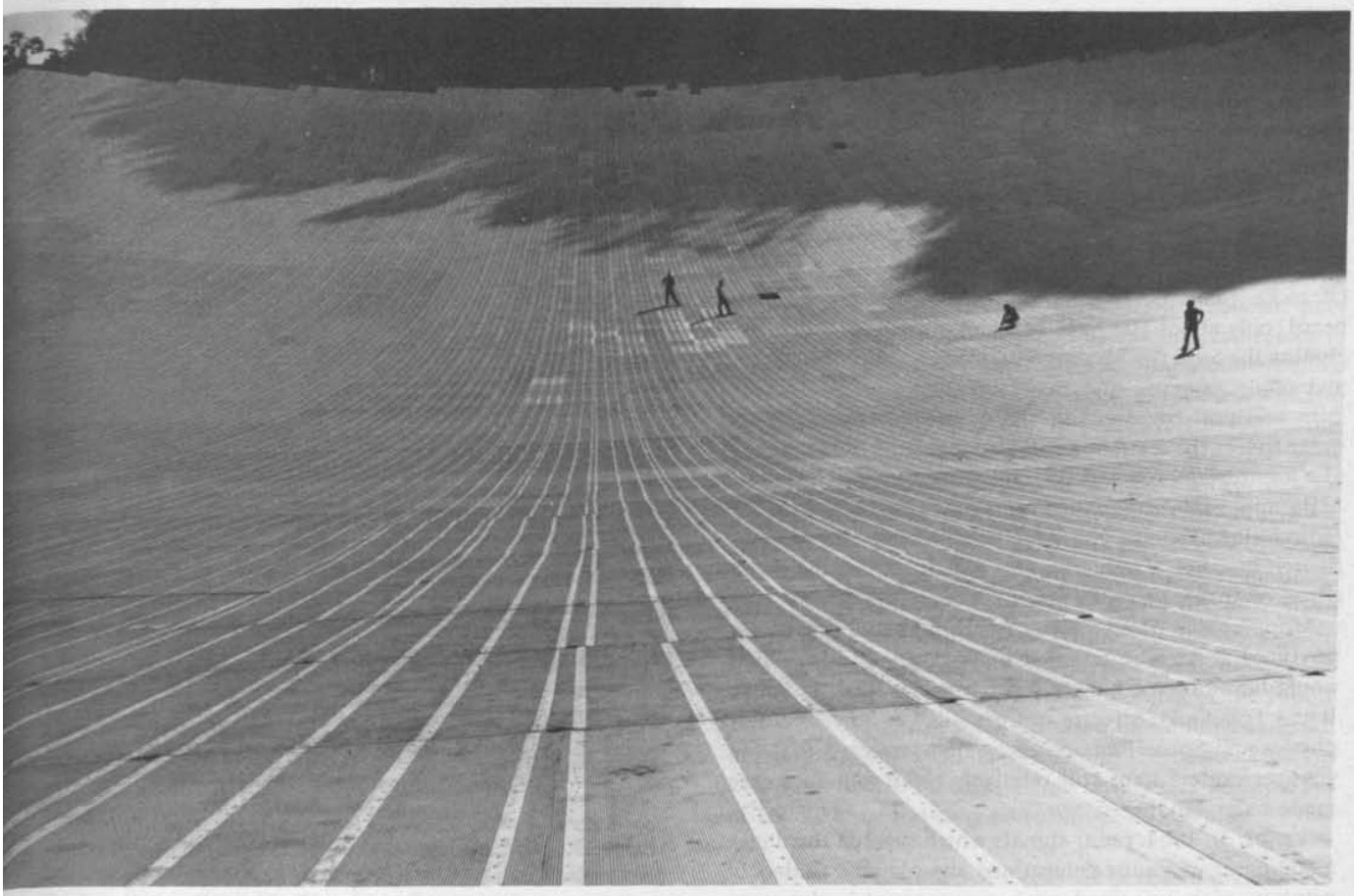
Not only had the wartime invention of radar been improved to where it could map the Moon 240,000 miles away, it could also map Venus 30 million miles away, Mars 40 million miles distant, and Mercury 55-60 million miles away. Saturn is the furthest planet detected by radar, 1.3 billion miles away.

The rather startling idea that Arecibo's telescope—already the largest in the world—could be made two thousand times more sensitive was born during Hurricane Inez, in August 1966, less than three years after the observatory first went into operation. Designers had built the telescope on the assumption that the receiver platform would sway about one and a half inches under normal weather conditions. What happened during Hurricane Inez to change minds at Arecibo was the discovery that the platform was far more stable than expected. Two graduate students, taking surveyors' readings from the telescope control room, observed that the sixty-two-mile-an-hour winds of Hurricane Inez deflected the platform barely half and inch.

This meant that under normal conditions the island's typical trade winds could be expected to budge the platform no more than three-tenths of an inch. "It seemed practical and extremely economical," a recent writer observed, "to reconstruct the rest of the telescope to a precision consistent with the platform's remarkable stability."

The National Science Foundation and National Aeronautics and Space Administration agreed, and nearly $9 million—almost as much as the original cost of the telescope—was allocated to improve the platform and the curvature of the reflector, and to acquire a more powerful transmitter for the radar. The transmitter's output, concentrated into a narrow beam by the reflector, has an effective power 100 times the total electrical production of all the generating plants on Earth. This is the strongest signal now leaving Earth, 100 trillion watts. By contrast, the weakest radar echoes being received are on the order of one-100 million trillionth of a watt.

Work on improving the telescope was finished this summer, and a formal rededication of the Arecibo telescope was to take place on November 16.



Opposite page, *workmen assemble one of 38,778 panels that go to make up the new surface of the reflector dish. Perforated aluminum is stapled to frames, manufactured at the observatory to avoid transporting the delicate panels over rugged mountain roads.*
Above and left, *workmen attach the panels to cables suspended from the edge of the bowl, wearing big discs on their feet to distribute their weight.*

"Listening to the Stars," *Cornell Alumni News*, v77n5 (Dec 1974), pp 10-15.

Learning by Listening

By Dava Sobel

Of more than 3,000 radio sources the telescope has heard, only about 100 have been identified optically, including the Sun, the Moon, some planets, the Milky Way and other galaxies, and many nebulae and quasars.

In addition to receiving radio waves originating in outer space, the telescope can also transmit radar pulses at a given frequency and then measure the return signal.

Because of its size, power, and precision, and its dual radio-radar capacity, the Arecibo telescope has already figured in a list of achievements ranging from the outer edges of space to Earth itself.

Mapping the Moon: Early radar maps of the Moon produced at Arecibo revealed thick layers of dust which would have posed a hazard for astronauts landing there. It was Tom Gold, director of Cornell's Center for Radiophysics and Space Research, who first proposed that the younger craters were still relatively clean and therefore made safer landing sites.

Venus: In 1964, radar signals which pierced the dense cloud cover of Venus determined the planet's period of rotation with unprecedented accuracy and also confirmed the theory about its retrograde rotation. (Venus spins on its axis in a clockwise direction. Earth and all the other planets spin counter-clockwise.) Later studies revealed the phenomenon of "earth lock," whereby Venus turns the same face to the Earth each time it swings by.

Arecibo produced its first radar map of Venus in 1968.

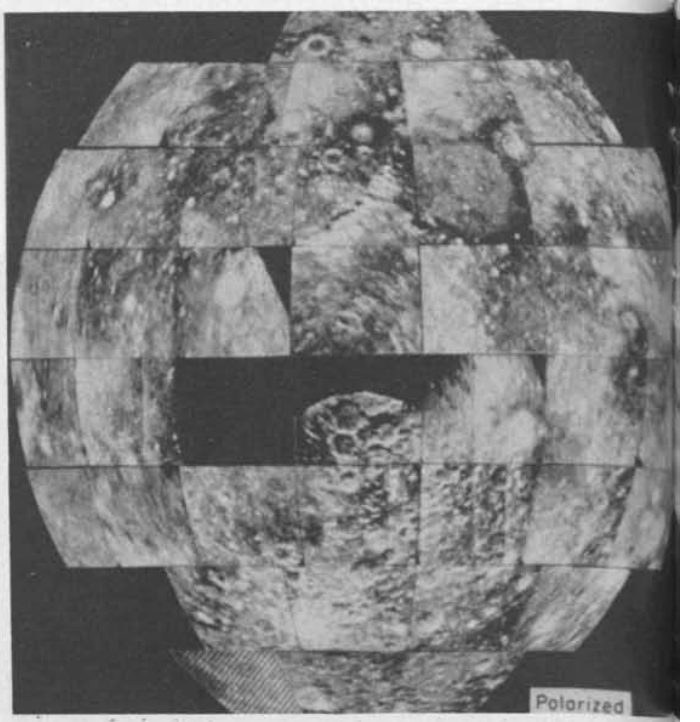
Mercury: Astronomers at Arecibo found in 1965 that Mercury, the closest planet to the Sun, did not always keep the same face to the Sun as it made its eighty-eight-day orbit. Textbooks and encyclopedias which had stated that the Sun's tremendous gravitational pull had stopped the planet's free rotation had to be revised accordingly.

In 1970, the Arecibo radar was used to map a portion of Mercury, showing the planet's surface to be rougher than Venus but not quite as rough as the Moon.

Long-Baseline Interferometry: In 1966 a team of astronomers which included David L. Jauncey, adjunct associate professor of astronomy at Cornell, developed the technique of long-baseline interferometry for use in radio astronomy. The process makes use of two widely separated radio telescopes to measure extremely small angles, such as those associated with the size and rate of expansion of very energetic explosions in very distant quasars. In some instances the telescopes are stationed at almost opposite sides of the Earth. For these contributions, the four-man team later received the American Academy of Arts and Sciences' Rumford Award for 1971.

The Arecibo telescope was paired at different times with telescopes in Australia, at Danby near Ithaca, and at a site near Arecibo itself.

Pulsars, Neutron Stars, and Black Holes: In 1968 Arecibo scientists identified a pulsar in the Crab Nebula—the still-glowing remnant of a supernova, or stellar explosion, which was observed and recorded by the Chinese in 1054. Professor Drake rejected an earlier theory that the pulses were an intelligent signal because they



Comparison of radar 'maps' (at left) and visual maps of the Moon and one of its craters demonstrates the similarity of radar reflectivity and light reflectivity.

"Learning by Listening," by Dava Sobel, *Cornell Alumni News,* v77n5 (Dec 1974), pp 16-19.

were coming in over all frequencies (an inefficient way to communicate) and they were extremely intense (trillions of times greater than all the electrical energy generated on Earth).

Very careful measurements (accurate to millionths of a second) timed the arrival of pulses from the Crab and led to the conclusion that pulsars are actually fast-spinning neutron stars. This idea was first proposed by Prof. Franco Pacini of Cornell and later pursued by Professor Gold.

Neutron stars, which had existed only in theory before this time, are giant stars that have collapsed into a dense ball a few miles wide because of the depletion of their nuclear fuel. Crushed together under tremendous pressures, the atoms become a compacted mass of neutrons with an estimated weight of as much as ten billion tons per cubic inch. An explosion of the magnitude assumed to produce the Crab could well result in the formation of a neutron star. If Cayuga Lake were compressed to the density of neutron star matter, it would be the size of a sugar cube—and bore a hole right through the earth.

Theoretical work on pulsars continues today, as does the discovery of new pulsars and other mysterious objects known as X-ray sources (because they are sources of X-ray emmissions), and the search for a black hole. Still undetected, a black hole is theorized as the densest material possible, a body whose gravitational attraction is so great that nothing—not even light—can leave its surface.

The Earth Itself: In 1972, Arecibo astronomers were able to turn their telescope on Earth by achieving a radar triple bounce between Earth and the Moon. This experiment opened the way for radar studies of Earth by Earth-based scientists working as though they had a radar telescope placed on the Moon. Radar studies performed aboard the Skylab are now amplifying and supplementing these data.

New Horizons

The recent improvements to the Arecibo telescope have not only made it more powerful and more precise, but, through the introduction of new radio frequencies, have opened the way to the study of atoms and molecules in space through spectroscopy. The new capabilities enable the Arecibo scientists to refine many of their current studies and to undertake new and even more exotic searches.

Mapping the Solar System: By applying all the new facilities of the observatory, Arecibo radar astronomers will produce the first detailed picture of the surface of Venus when its orbit brings it closest to Earth, next summer. The radar will penetrate the planet's fifty-mile-thick cloud cover and return photograph-like images of most of the surface with a resolution better than one mile, rivaling the best Earth-based radar pictures of the Moon. Early radar bounces have glimpsed mountains, canyons, and enormous craters on Venus, but the new equipment will fill in details on these rough outlines to an accuracy of 150 meters, and may reveal much of the planet's history.

Beyond Venus, the telescope will probe to make maps of an almost equal quality of Mercury and Mars—planets that are already well known from spacecraft missions. Information gleaned by the new radar system will pinpoint the low-level rigid soil regions on Mars best suited for the landings of the Viking spacecraft in 1976.

The telescope will also provide new data on the composition and rotation of the asteroids between Mars and Jupiter. Fifty or more of these bodies should be detectable.

It will be possible to make crude radar maps of the surfaces of the four major satellites of Jupiter—those moons which Galileo first recognized and used to start modern astronomy on its correct course. Radar echoes from these satellites can be used to probe the structure of the Jovian atmosphere, by measuring minute changes in the character of the echoes as the satellites move toward eclipse behind the giant planet.

The rings of Saturn will also be probed, and will return strong radar echoes, containing the first detailed information on their nature.

The Search for New Moons: Astronomers believe that

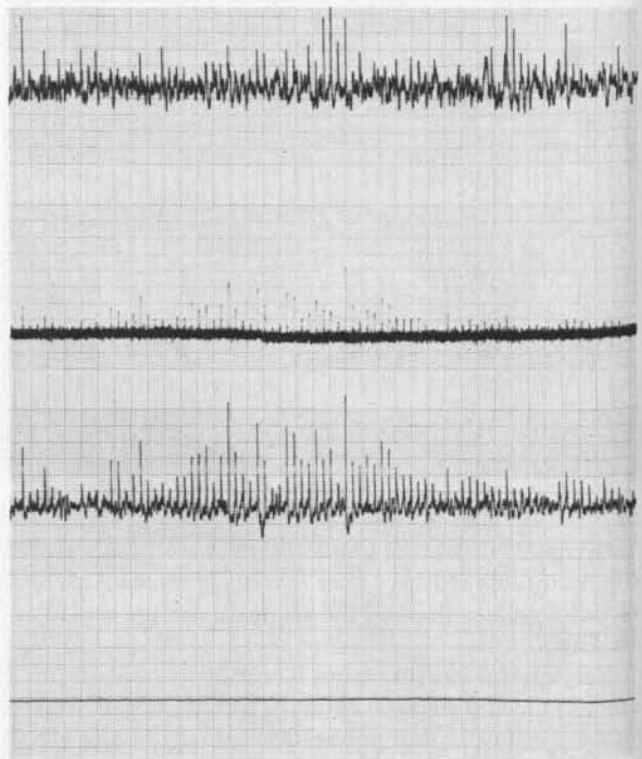
undiscovered satellites, though probably very tiny, may be orbiting Earth, and the new radar will search for them. Of particular interest are the so-called Lagrangian points L-4 and L-5, located in the orbit of the Moon but 60 degrees from it, where celestial debris can accumulate. Material from the earliest history of the solar system, as well as from its recent past, may lurk there, possibly creating a hazard for spacecraft. Such objects would be prospective targets for sample-return space missions. Recently, the construction of very large space stations at these points has been proposed.

Further Study of Pulsars: New information for the study of pulsars, in which Arecibo has played a key role, will come from new high frequency investigations of the physical effects inside these dying stars. The telescope will also produce high-time-resolution observations of the intensity and polarization of flares on other stars, which Arecibo astronomers hope will aid their understanding of the atmospheric structure of stars and the origin of flare phenomena. In the process, they may solve some of the more challenging puzzles associated with the star of this solar system, the Sun.

Cosmic Radio Sources: The narrow beam of the Arecibo telescope at its new wave lengths, coupled with the enormous collecting area of the dish, will enable radio astronomers to detect and distinguish clearly some 100,000 cosmic radio sources, including rather faint emissions coming from the edge of the observable universe. They hope that, by studying such a large sample of data never before available, they will not only learn more of the origin of strong radio emissions in space but be able to trace out the history of galaxies from the time they first apparently congealed from remnants of the primordial fireball.

The Search for Other Life Forms: The question of other life forms is a recurrent theme in astronomy. Statistically, given the number of other stars like the Sun that probably have solar systems quite like this one, it is almost reasonable to assume that some form of life does exist elsewhere in the universe.

Cornell astronomers observing Saturn in 1972 with the Arecibo telescope found a level in the planet's atmosphere where temperatures are suitable for life of the kind found on Earth. Using the new Arecibo frequencies that permit spectroscopic analysis of atoms and molecules in space, scientists have already identified bits of atomic neutral hydrogen, OH and CH radicals, formaldehyde, and methyl alcohol floating through the interstellar regions. The quest to learn the temperatures, abundances, velocities, and distributions of these molecules in space is motivated, at least in part, by the knowledge that the very same materials exist in living organisms on Earth. Their spectroscopic analysis is a prospecting mission through deep space in search of the seeds of life.



A graph traces three aspects of a single signal being received by the Arecibo telescope from a distant pulsar. The central tracing is the unrefined signal. The two more pronounced tracings result from mathematical analysis of the signal by the computer.

Listening for Life: Other programs will be aimed at approaching that most ill-defined but fascinating threshold: the detection of radio transmissions from other intelligent life in space. It is indeed tantalizing to think that, right now, like an inaudible whisper, radio messages from light years away are falling into the valley of the Arecibo reflector bowl—messages that could be heard if their direction and frequency were known.

The Arecibo telescope is now the premier instrument in the world for such studies. Given careful planning and an adequate observing program, there is a genuine probability that this most important of frontiers will be crossed for the first time.

"Learning by Listening," by Dava Sobel, *Cornell Alumni News,* v77n5 (Dec 1974), pp 16-19.

Books Geof Hewitt '66

Astronomical Possibilities

In *The Cosmic Connection—An Extraterrestrial Perspective* Cornell Professor of Astronomy Carl Sagan leads the reader very carefully through a basic understanding and acceptance of astronomical possibilities: writing for the layman, he outlines current hypotheses and patiently disassembles numerous false ones that effectively retard mankind's search for cosmic understanding, that mental equivalent to the place Archimedes wanted to put his feet so he could move the world.

Citing research as recent as 1973, Sagan contemplates a wide variety of human scientific concerns. Though interrelated, the chapters are short and selfcontained; the book is divided into three major sections. In the first section Sagan emphasizes that man is just a form of life on a 4½-billion-year-old planet that circles a middle-aged star that is one of 250

"Astronomical Possibilities," by Geof Hewitt '66, *Cornell Alumni News*, v78n2 (Sep 1975), pp 18-20. Review of *The Cosmic Connection—An Extraterrestrial Perspective* by Carl Sagan.

Prof. Carl Sagan, astronomy, is surrounded by representations of the Moon in his department's 'Moon Room.

billion stars in the Galaxy. That galaxy is approximately 1/250-billionth of the Universe. Sagan stresses that evolution is not a remarkable process—here or elsewhere in the Universe. But, given an exact duplication of conditions, Earth would probably not develop a species much like us again; intelligence would surely evolve, but our physical features might develop quite differently. This is why we're not likely to encounter extraterrestrial beings who are just a tad different from us.

The second section of *The Cosmic Connection* explores what is presently known about our own solar system, with special reference to Earth, Mars, and Venus; section three is given to the possibilities of extraterrestrial communication and the mysteries of gigantic black holes, which presumably may provide our only means of crossing the Universe. The whole book contains a good blend of social science, a sense of Sagan's concern for his fellow-worldlings, and a cosmic humility that comes from knowing man's insignificance beyond this solar system.

Sagan's explanations of scientific phenomena are detailed but not cumbersome, and a layman's questions are usually anticipated. The author postulates that our first contact with another civilization will come in the form of radio messages; this is a popular theory, one stressing that man has developed sophisticated radio "listening devices," like that at Arecibo, only within the last twenty years. We couldn't very likely pick up messages sent by a civilization with less technology than we have, because radio transmission requires at least as much sophistication as that required to catch the signals. The reasoning follows that it took Earth 4.5 billion years to develop radio astronomers: another civilization would have to be at least this old to have parallel capabilities.

Next, Sagan attempts to analyze the sort of language (possibly similar to that used on the plaque he and Frank Drake designed for *Pioneer 10*?) [*Alumni News*, May 1972] such a civilization would invent for inter-space talking. It would be a language using the least bits to carry the most information. Perhaps the arrangement of radio "blips" could even be decoded into a picture.

A book like this is hard to read for any stretch of time because its imaginative demands are immense to someone whose knowledge of space exploration and theory is casual. For this reason, the chapters in which the author investigates the earthly phenomena that touch his astronomical work are welcome and enlightening. Sagan writes of his attempts to communicate with a Soviet scientist in the presence of an "interpreter" who is, he soon learns, working for the Air Force Intelligence, hoping to glean Communist secrets. Sagan claims that such intelligence activities are common on the part of both the US and Soviet military, and he bitterly denounces these invasions (which are made in the name of "national security" of course) of the communications among members of an interest group whose concerns are not divided along nationalistic lines. "In fact," Sagan writes, "the military establishments in the US and the Soviet Union owe their jobs to each other, and there is a very real sense in which they form a natural alliance against the rest of us." Nevertheless, Sagan sees space exploration as a legitimate military activity, hopefully one that would usurp the militarys' current destructive role.

Sagan's experiments in communication lead him to a study of the mysterious vocal patterns of cetaceans (dolphins and whales are in this taxonomic class). Do their "songs" contain elaborate codes of social interaction? Are whales and dolphins like human Homers before the invention of writing, telling of great deeds done in years gone by in the depths and far reaches of the sea? Is there a kind of Moby Dick in reverse—a tragedy from the point of view of the whale, of a compulsive and implacable enemy, of unprovoked attacks by strange wooden and metal beasts plying the seas and laden with humans?

At the end of the chapter, Sagan writes of the narrow thinking that allows man to destroy any being different from himself, animal or human. "Contact with another intelligent species on a planet of some other star—a species biologically far more different from us that dolphins or whales—may help us to cast off our baggage of accumulated jingoisms, from nationalism to human chauvinism. Though the search for extraterrestrial intelligence may take a very long time, we could not do better than to start with a program of rehumanizations by making friends with the whales and the dolphins."

Earth and Human Chauvinism, patterns of thinking based on our own, relative experience, may be as great a block to extraterrestrial exploration as distance. In a chapter titled "Chauvinism," Sagan outlines such patterns and explains how organisms evolving on other worlds might adapt to conditions that would kill earthings immediately. "Extraterrestrials will be the product of billions of years of independent biological evolution, by small steps, each involving a series of tiny mutational accidents, on planets with very different environments from those that characterize Earth." A separate biology suggests, as well as a "hostile" environment, the possibility of fire-breathing, aluminum-eating spacefolk; Sagan maintains that organisms will evolve that best utilize the special environment. There is no reason to disbelieve the possibility of wheeled beings, inhabitants of a rather smooth planet.

With an awareness of chauvinism in mind, it is fun to rethink our feelings about the planets in our own solar system, places close enough that some of us may some day visit them. Could there be life on Venus, where the surface temperature is now believed to be at least 900 degrees F? Could Mars, where liquid water is not possible because of insufficient atmospheric pressure, support life on a periodic basis, and be presently enduring a 12,000-year winter?

This is a possibility based on the observation of channels which, Sagan writes, "there seems to be little doubt . . . were cut by running water. . . . The channels revealed by *Mariner 9* speak eloquently of the possibility of massive climatic change on Mars. In this view, Mars is today in the throes of an ice age, but in the past—no one knows just how long ago—it possessed much more clement and Earth-like conditions." Perhaps hibernating organisms are locked in its polar cap, awaiting "summer." They have adapted to a year that is 12,000 Earth-years in duration.

Further, in four billion years "the Sun will be sufficiently brighter that there will be a greatly enhanced runaway greenhouse effect on Earth, just as there is today on Venus. Our oceans will boil . . . When the Earth becomes uninhabitable, Mars will gain a balmy and clement climate. Our remote descendants, if any, may wish to take advantage of this coincidence."

The wide realm of possible space scenarios explored by Sagan, from radio communication to "cultural homogenization of the Galaxy," is kept within a certain perspective by a scientist who is keenly aware of human foibles. Sagan's hope that mankind will let space take the place of terrestrial militarism is inspiring. Yet in the name of science man has ruined more than a few environments and I cringe when I think of space garbage, golf balls on the moon, or hear Sagan intoning, "There is a bare possibility of re-engineering Venus into a quite Earth-like place, a possibility I suggested with some caution in 1961. . . . The idea is simply to seed the clouds of Venus with a hardy variety of algae. . . ."

The trouble with reading books like this is that the imagination finally has to back off and reconsider just the immediate, airy possibilities. It hurts somewhere to visualize our own Sun as just one of 10^{11} stars in the Galaxy, and 10^{11} galaxies in the Universe at that! And now they're beginning to say there may be more than just the Universe. Perhaps it is just one of who knows how many black holes.

The visual experience of *2001*, or walking through blown snow knowing each flake is unique and as common as stars, involves the kinds of perceptions that ultimately entail a mental "backing off" that suggests to me brain incapacity and/or fear. A grain of sand might well be the Universe to some beings an awful lot smaller than we; it's even more likely that our Universe is as a grain of sand to whatever lies beyond.

Switching the mind from this perspective back to the trials of earthly endeavor is like driving at 60 mph and shifting to low gear. When you realize how tiny we are and what a pip-squeak civilization compared to any that would care to talk with us—you feel for an instant the horrible inconsequence of our daily stupidities. If man could assimilate how little difference it's gonna make in the scheme of things when he's gone, he might make a more vigorous attempt at keeping Spaceship Earth afloat.

"Astronomical Possibilities," by Geof Hewitt '66, *Cornell Alumni News*, v78n2 (Sep 1975), pp 18-20. Review of *The Cosmic Connection—An Extraterrestrial Perspective* by Carl Sagan.

UL
LIBRARY

Cornell alumni news

April 1981 $1.50

A Gallagher Portfolio

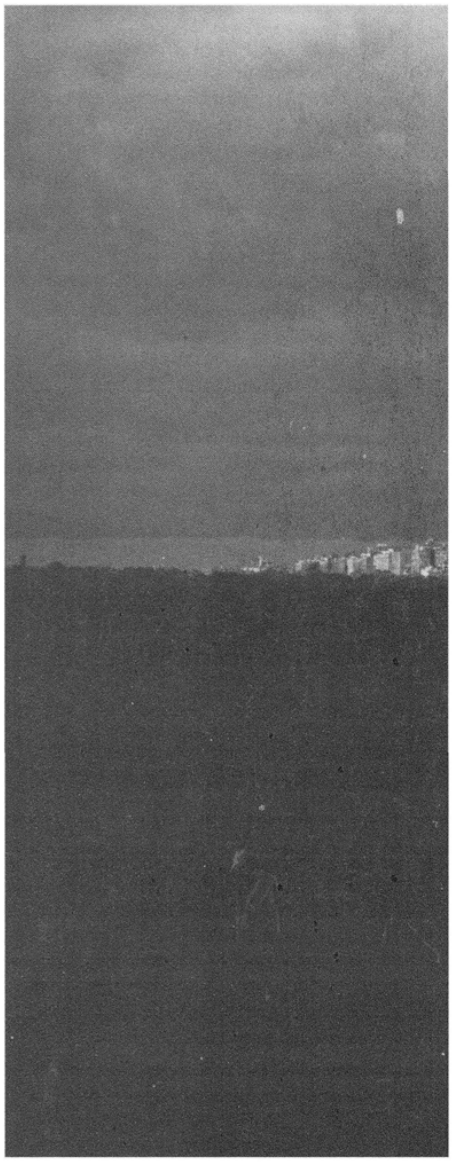
COVER

A fireworks display in Central Park, Manhattan, from the apartment window of Barrett Gallagher '36, whose work is found in this issue.

Camera Work

Except for a brief sabbatical during World War II, Barrett Gallagher '36 has made his living since graduation as a photographer. He is best known for more than two hundred assignments shot for *Fortune* magazine, story-telling series of pictures on a single subject that are the mark of the photo-journalist.

Within each series taken for *Fortune* and a variety of other periodicals are one or several photos that stand on their own as self-contained pieces of art. Some three hundred of these are included in a retrospective of his career that will be on display at the Johnson Museum of Art on campus from late next month through Gallagher's Forty-fifth Reunion in June and until July 5. Pictures on the next eight pages are from that exhibition.

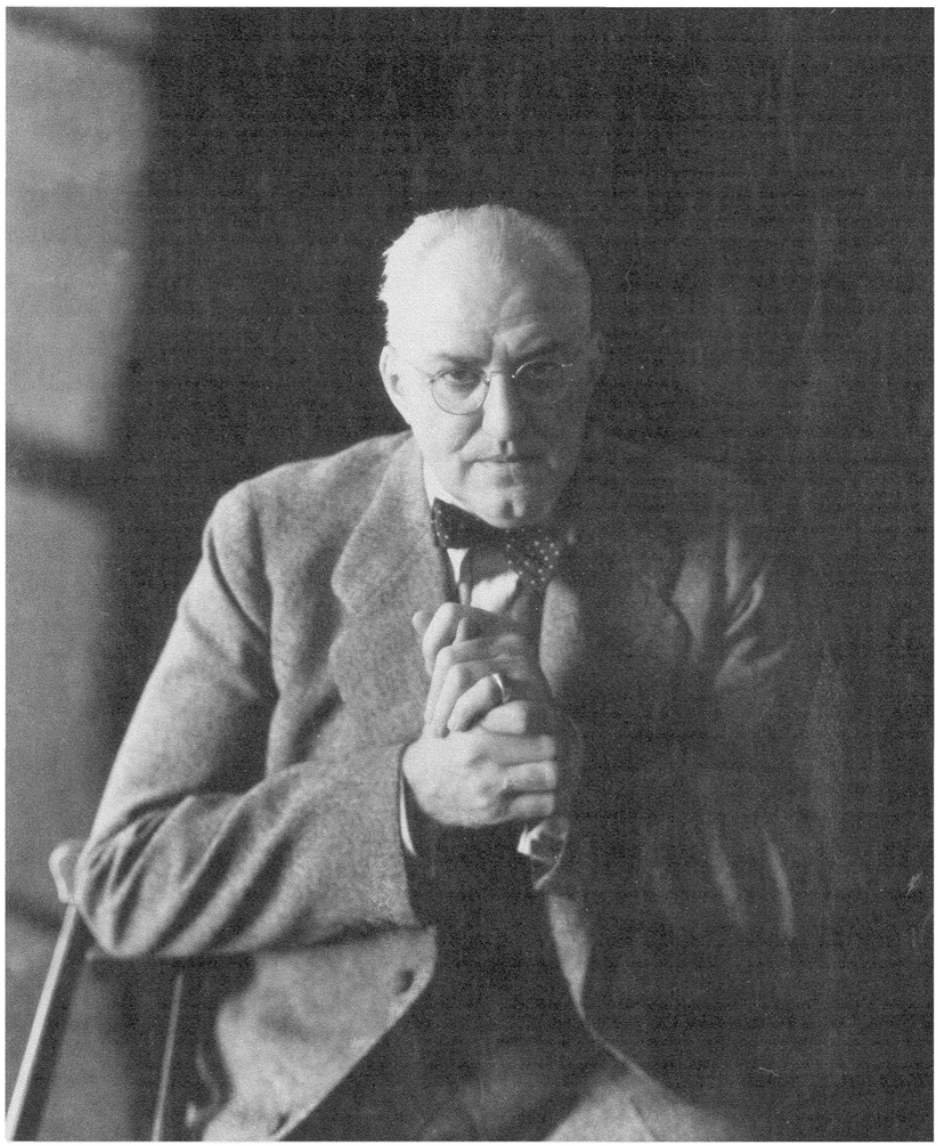


"Camera Work," *Cornell Alumni News*, v83n8 (Apr 1981), pp 24-31. On the exhibit by photographer Barrett Gallagher '36, in the Johnson Museum of Art.

Above, *the elegant structures along Fifth Avenue, Manhattan, in 1960 before glass-faced skyscrapers intruded. The view is across the treetops of Central Park, taken from the apartment of the Gallaghers on Central Park South.*

Opposite page, *a confident William Zeckendorf in front of his Park Village West development on May 11, 1960. Although the Gallaghers were with him on assignment for* Fortune *throughout the day when the tycoon's real estate empire was crumbling, he showed no sign of feeling the successive blows, word of which was relayed by car telephone as he toured his New York holdings. Photographer Gallagher notes that such overheard information is, of course, privileged.*

At left, *Leonard Bernstein of the New York Philharmonic in rehearsal in 1966.*



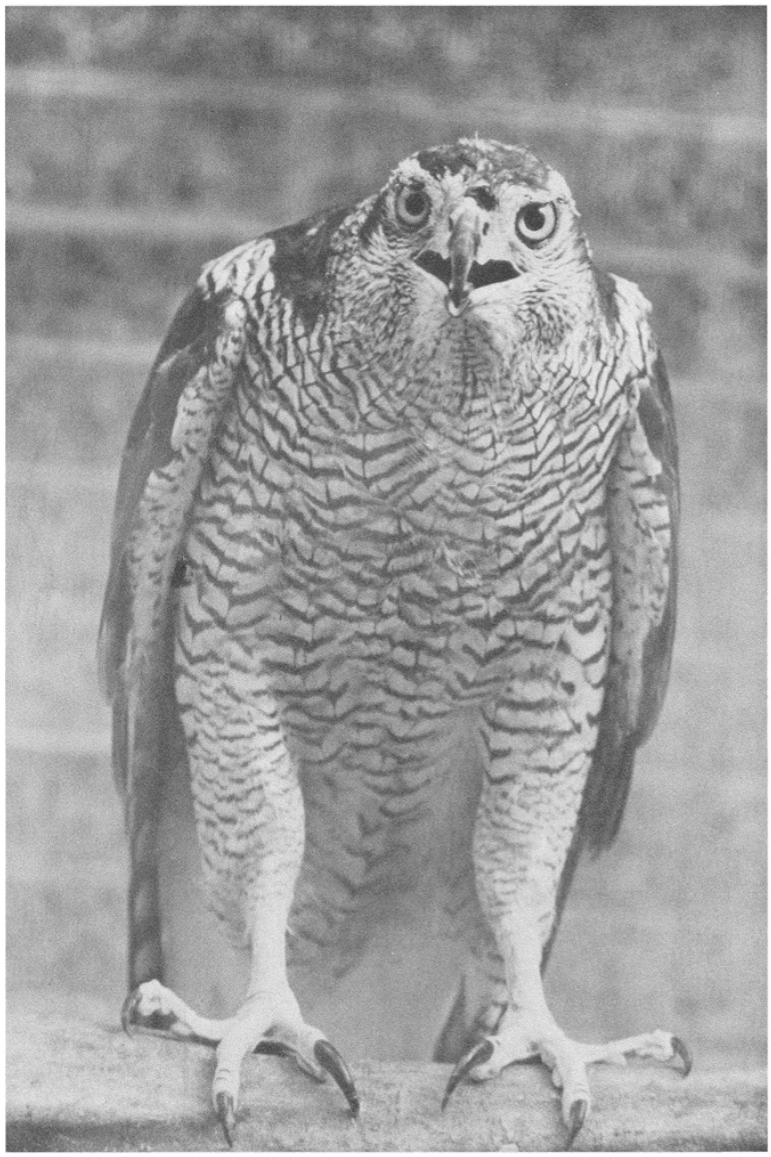
Barrett Gallagher came to Ithaca in 1931 from Troy in Upstate New York, by way of Staunton Military Academy in Virginia, and followed the lead of his father, Francis Gallagher '06, and sister Catharine '30 by majoring in chemistry, rather than following his mother, the former Frances Coons '02, MA '04 into the classics.

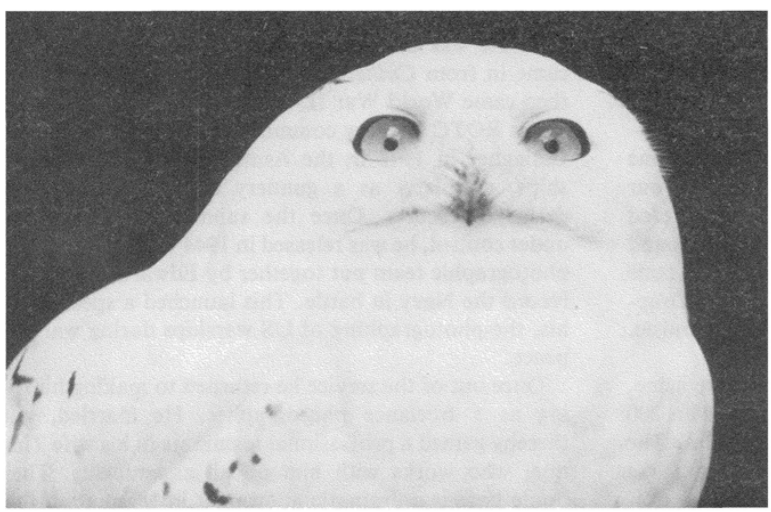
Soon, though, he was attracted from the sciences to the arts, in particular the Dramatic Club and its legendary mentor, Prof. Alex. Drummond. Gallagher threw himself into the club wholeheartedly, working on productions, acting, and using an ability at photography to set up and execute the club's publicity shots. The latter talent led in due course to service with yearbook.

As photo editor of the *1934 Cornellian,* he explains, he captured the likenesses of President and Mrs. Livingston Farrand, as well as "all the college deans, many faculty characters, snow storms, and visiting celebrities —Eleanor Roosevelt, Big Bill Tilden, Lawrence Tibbett, Margaret Bourke-White '27, and the Budapest Quartet. Equipment consisted of [my] 8 x 10 camera, a tripod, two light bulbs in reflectors (the original photofloods), and a gray background blanket. There were no light meters. Flashbulbs appeared, and my experience with flood lighting was helpful. Synchronization came later; the rule then was, 'Open the shutter, flash, close shutter.' "

He notes that he spent any available spare time in Manhattan and its theater district. After graduation in 1936 he made the journey for good, by now equipped with a 2 x 2 Rolleiflex with an unchangeable 75 mm. lens, trudging the sidewalks of New York in search of work as a photographer.

As he recalls, "A Dramatic Club friend, Monty Hellinger '34 (he wrote the Berry Patch in the *Cornell Daily Sun*), was the younger brother of Mark Hellinger, Broadway columnist. Monty offered access to 52nd





Opposite page, *the university's legendary teacher of drama Prof. Alex. Drummond, in 1934, to whom the* 1934 Cornellian *was dedicated. Gallagher was the yearbook's photo editor, and the portrait was its frontespiece.*

Above, *a goshawk photographed in the Bronx Zoo in 1970 using a 400 mm. lens on a Leicaflex camera.*

At left, *a snowy owl photographed in the same year with the same camera and lens, at Barrett Park, Staten Island, New York City.*

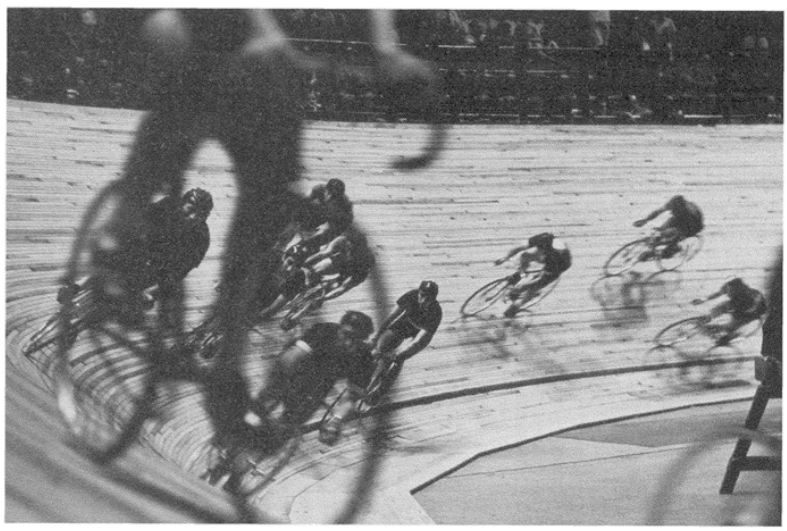
Street, Stuff Smith, Maxine Sullivan, Cozy Cole, Benny Goodman, and Martin Block.

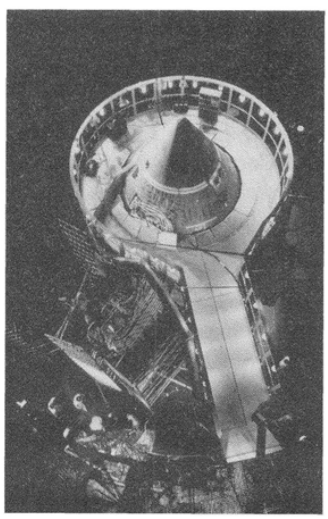
"Burgess Meredith, a friend from Hoosac School, opened the door to radio and theater. Famous for *Winterset,* he was MC of several big radio shows—*The Spirit of '47, Cavalcade of America.* We became partners later in New World Films, producer of our 1950 Cornell film *Spring in Ithaca.* I was almost offered the part of the photographer in *Lilium* with Burgess and Ingrid Bergman in her American debut. Franchot Tone '27 was Meredith's friend and house-mate. Paul Draper, starting his career, tap dancing to classical music, lived conveniently across 57th Street."

Then in 1938 he caught on with *Fortune* magazine, carrying out the first of what would be more than 200 photo assignments over the next several decades. The trade quickly came to recognize his ability to make crisp, well-composed pictures that taken together conveyed the meaning of a complex activity or organization. He was on his way. In due course, assignments came in from *Collier's, Life, Time,* and *Esquire.* And then came World War II.

His ROTC artillery commission from Cornell landed Gallagher in 1942 in the Armed Guard on merchant ships, and later as a gunnery officer aboard Navy destroyer escorts. Once the submarine menace was under control, he was released in 1944 to the blue ribbon photographic team put together by Edward Steichen to record the Navy in battle. This launched a specialty of his, the photographing of US warships during war and peace.

Once out of the service he returned to making his living as a freelance photographer. He married, and thereby gained a professional teammate in his wife Timmie, who works with him on all assignments. Their home base is a dramatic apartment in Manhattan that



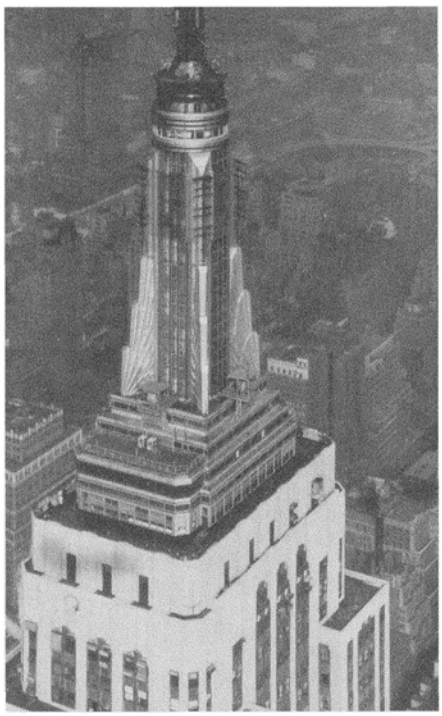


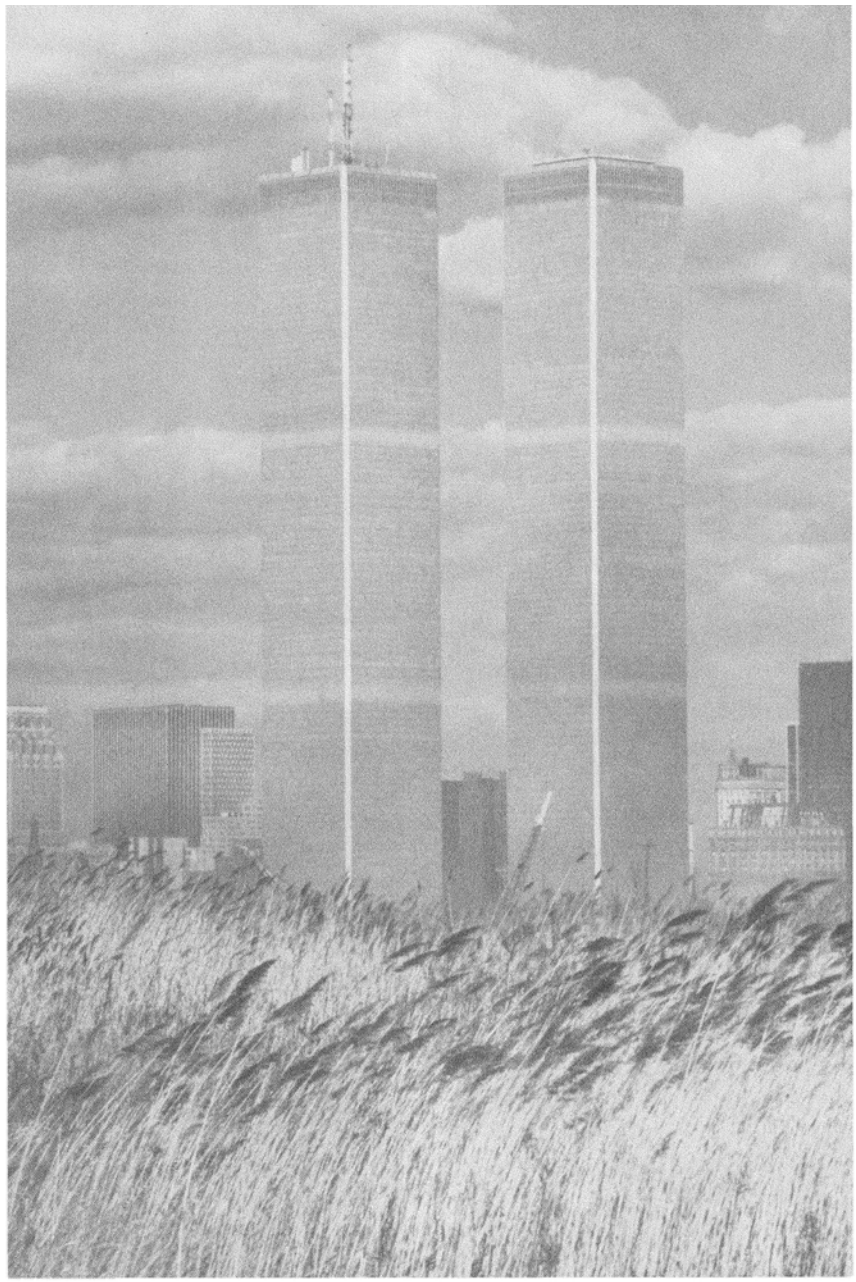
Opposite page, *sailors aboard the USS* Lake Champlain *put out fire in a warplane in June 1953, a month before the end of the Korean War.*

At left, *the space simulation chamber with command service module on NASA's Saturn V Apollo in Houston, Texas in September 1966, on assignment for* Time.

Above, *a warplane lands on a carrier deck during World War II in the Pacific where Gallagher was part of the Edward Steichen team that recorded the US fleet in battle.*

Immediately above, *a six-day bicycle race in Madison Square Garden, New York, shot for the old* Saturday Evening Post *in 1961.*





looks north across the treetops of Central Park.

By 1954, he says, "The 35 mm. camera replaced my Rolleiflex. The rangefinder M3 had a viewfinder through which I could see the full frame, wearing glasses. Fast lenses, wide angle and telephoto, extended the photographic possibilities. In time, the Leica M3 was supplanted by the M2, the M4, finally in 1970, by the SLR Leicaflex. Electronic flash arrived in heavy units, making it possible to freeze dancers in action."

Gallagher returned to combat to cover aspects of the Korean war aboard the USS *Lake Champlain*. *Life* published the results.

Nearly all his stories are assigned, but occasionally he pursues a special interest beyond a sure sale. Such was the case with the Verrazano-Narrows Bridge in New York Harbor. He received one limited assignment to photograph the bridge, then followed it to completion on his own. The result was a chapter for a book about the engineering profession. He has also published a book on US aircraft carriers, and worked with scientist Robert Jastrow on books on the evolution of stars, planets, and life.

In addition to the earlier movie for the university, Gallagher photographed Cornell for the pre-Centennial Campaign booklet "In excellence and diversity" in the 1960s, and the radio-radar telescope at Arecibo, Puerto Rico in the '70s. He has contributed prints of his to the University Archives, and found time amidst his professional activities to be president of the Alumni Association of New York City and serve on the Federation of Cornell Clubs and the University Council.

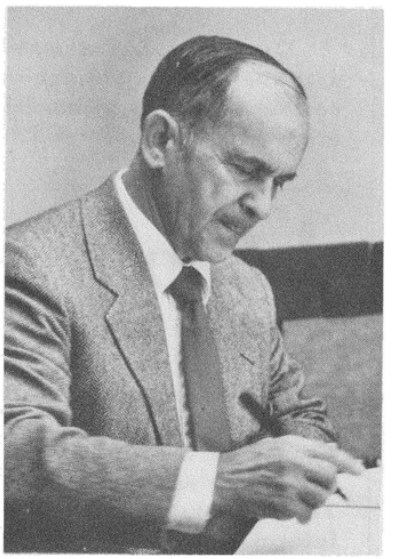
If some of his photographs at this spring's exhibit on campus seem familiar to alumni, it may be because he has been represented in the *Alumni News* over the years, with picture essays on his career, an East African safari, and Cornell's Arecibo and synchrotron installations.

Opposite page, left, *the Empire State Building, shot from the air in 1963 for an advertisement for* Fortune *on New York City as corporate headquarters for the US.*

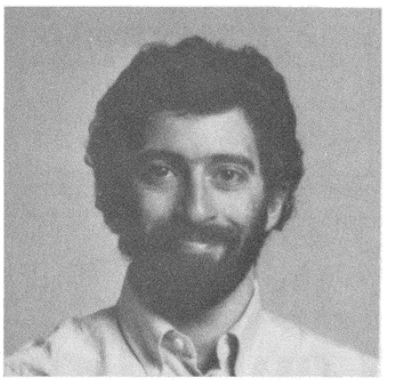
Opposite page, right, *the twin towers of the World Trade Center in lower Manhattan pick up eery reflections of sunlight and clouds in 1979, standing across the Hudson River from the Jersey swamps. The Gallaghers captured this view as part of a personal record they made of the effort of Jersey City to carve Liberty Park out of the smoldering, garbage-strewn swamplands.*

Above, *Gallagher photographs his bride, the former Timmie Hyler, and himself in a mirror on their wedding day, January 22, 1946, a picture he used subsequently for their wedding announcement.*

"Camera Work," *Cornell Alumni News*, v83n8 (Apr 1981), pp 24-31. On the exhibit by photographer Barrett Gallagher '36, in the Johnson Museum of Art.



Administrator Robert Matyas '51



Photographer Jose Azel '76

Etcetera: contributors

We carry the professional work of Jose Azel '76 for the first time in this issue. When he was an undergraduate and a work-study student under Sol Goldberg '46, the university photographer, Azel's coverage of track, a sport in which he also competed, appeared in these pages.

Azel was born in Havana, Cuba, in 1953, lived in the northeastern US from the age of 8, and after earning a Cornell degree went on to the U of Missouri School of Journalism for a master's. He started as a staff photographer for the *Miami Herald,* then was a free lance before settling in New York City in 1982 when he joined the international photojournalism agency Contact Press Images.

He covered the 1984 national political conventions and the summer Olympics. A photo of the visit of Pope Paul II to Guatemala won him first prize for news feature in the 1984 World Photo Press Holland Contest. His work has appeared in *GEO, Time, Sports Illustrated,* and *Newsweek.*

Pictures by Azel in this issue were taken for Robert Matyas '51, vice president for facilities and business operations at Cornell. Bob earned his bachelor's degree in Architecture in 1952 and did graduate work in administration before serving as a supervising engineer for nuclear submarines, surface ships, and a nuclear power station at the Westinghouse atomic power lab in Pittsburgh from 1954-62. For the next three years he was supervisor of nuclear core contracts for Westinghouse, then came to Cornell as director of operations supervising construction of the Wilson Synchrotron at Upper Alumni Field. He served a year as executive officer of the Laboratory of Nuclear Studies, then in 1968 was named director of construction for the university, and in 1972 program manager for the upgrading of the Arecibo radio radar telescope in Puerto Rico.

He became vice president in 1974, and, as reported in our December 1984 issue, went on leave late last year to become part of the management team that is planning the proposed largest particle accelerator in the world, at Berkeley, California.

"Etcetera: contributors," *Cornell Alumni News*, v87n6 (Feb 1985), p 26. On Jose Anzel '76 and Robert Matyas '51.

Peter's Principles

A hard worker insists employes are a part of Cornell, too

By Brad Edmondson '81

The current Executive Committee of the Board of Trustees is made up of twelve well-educated Cornellians. A quick scan of the list reveals a PhD, ABs, MBAs, BChEs, and BMEs trailing the names of lawyers, corporate executives, a college president, a prominent editor/columnist, and a foundation executive. And then there's George Peter, who never went to college. Peter is one of the two non-academic employes on the governing board of the university.

George Peter was born in a small farmhouse on poor land in the rural area just south of Ithaca in 1921. His father, Joseph Peter Karamardian, was an Armenian peasant who managed to escape just before invading Turks massacred 1.5 million of his countrymen in 1915. Peter's mother left a small Syrian village near Beirut when relatives wrote her from the east shore of Cayuga Lake promising that good jobs and good prospects for a husband were available at a nearby salt mine.

Peter's life is a classic American success story—through intelligence, perseverance, and ceaseless labor, he has risen from poverty to prominence. But while he has been attaining these heights, Peter has also been opening doors. In a university where the awards, attention, and power have traditionally gone to the faculty, students, and alumni, Peter has long been known as the voice of the Cornell employe. By example and persuasion, he has worked for the causes of greater employe representation, for official recognition of staff achievements, and for a shift in the thinking of faculty, students, and the administrators toward the thousands of people who work at Cornell.

In addition to his role in the politics of the campus, Peter is also a thirty-eight-year employe of the university, who is today lab director for the National Astronomy and Ionosphere Center at Cornell. He still works constantly. He is a short, energetic man who frequently laughs or smiles when telling stories of his early life. He gestures when he talks, often seeming to be doing at least two things at once.

"George can be relentless," says Dominic Versage, who currently serves as the second employe trustee. "Once he decides something is worth fighting for, he gets to work—and I've never seen anyone who works as hard as he does." Peter's tendency to be outspoken and politically conservative has made him a controversial figure at times, but his dogged advocacy for employes and devotion to Cornell have also earned him many admirers.

"He attended the school of hard knocks," Versage says. "He uses experience instead of academic knowledge when he needs to evaluate a situation or a person. And he learned to be conservative because his family had to conserve things. They didn't have anything to waste."

The Route Up

Peter is proud of the back-breaking work his parents, brothers, and sisters did to survive in the new world. He loves to repeat family legends, including the one about his own birth: "My mother said she was digging potatoes when it was time for me to be born. She felt labor pains so she went upstairs in that little Danby farmhouse, plopped me out, cut the cord, and then washed her hands to go downstairs because it was time to fix dinner."

His father farmed the family plot and worked as a baker, a quarryman of Llenroc stone for the construction of Myron Taylor Hall at Cornell, and a foundry worker on the night shift at Morse Chain. Peter remembers that the family ate endless meals of potato stew; he, his five brothers, and two sisters attended a one-room schoolhouse "where we were the only kids with dark hair," and Cornell to them was a place "where you could get a job if you had an education."

He remembers laying the brick pavement on Ithaca's East State Street hill one year after breaking his back in a construction accident, and he vividly recalls spilling a wagonload of hay in the same field where his electronics lab would stand twenty years later.

Peter and many others escaped the Depression by joining the Army. He was drafted into the Army Air Corps in 1942 and spent the war in the Midwest, learning the electrical systems of B-17 and B-29 bombers. When he returned to Ithaca after the war he brought with him a wife, the former Gloria Ann Barnell of Lincoln, Nebraska, and enough skill to land a job as a journeyman electrician at Cornell. It was 1947, and he was making $2,000 per year. "The first thing I did was wire the apartments Cornell was building for GIs up by Maple Avenue," he says. "I almost starved to death on that job, but it was probably the best decision I ever made."

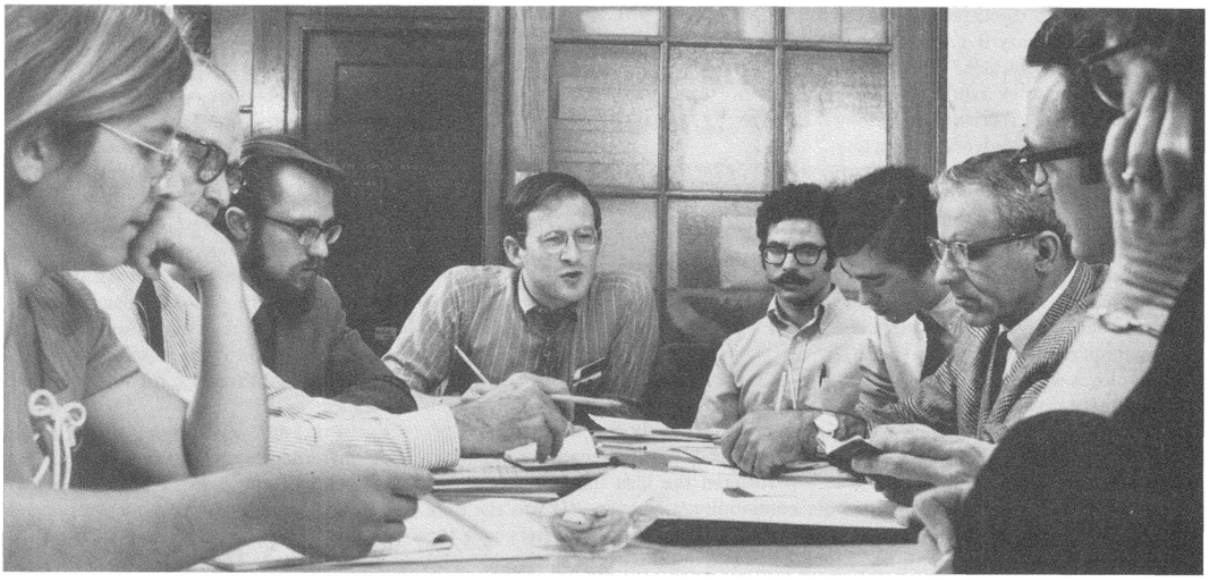
To make ends meet, George and Gloria developed a talent for running dozens of side ventures. He came home from work to tend to a yard full of chickens. He set up and operated a television sales and service business in 1952 with his brother Mitchell, and he recalls the special status a TV repairman had in the early days: "We were kept hopping. TV in those days was like some kind of miracle—people would come by to watch one and they'd be dumbfounded. You know, 'How can this *happen*?' If their set ever broke down, it was like they'd *die* if you didn't come fix it.

"One night Mitch and I were up on top of this snowy roof setting up an antenna. Mitch has this gruff voice. You had to have been there. To hook up the last guy wire I had to hold on to it and slide down the roof in pitch blackness. So I was doing that, and Mitch yells at me from the other side of the roof. *'George! Do you have any children at home barefoot?'* 'No.' So Mitch says, 'Then what the hell are we *doing* up here?' "

Peter was working double-time, driven by the concerns of a man with a wife and four children at home. In 1954, he built a new house northeast of Ithaca for his family. In 1958, he invented and began manufacturing an electronic soap dispenser. He also began an ardent relationship with Freemasonry in 1949. "I was tired all the time," he remembers.

In 1955, he began working on a new

"Peter's Principles," by Brad Edmondson '81, *Cornell Alumni News*, v87n8 (Apr 1985), pp 36-39.
On George Peter, a hard worker on the staff who insisted its nonacademic employees are members of Cornell, too, and who was also involved in designing and constructing the Arecibo telescope.



George Peter, third from right, attends the organizing meeting of the Executive Committee of the University Senate in the spring of 1970. From left, Stephanie Seremetis '72, later to be a trustee; Prof. William T. Dean, Law; Prof. Peter L. Steponkus, Floriculture and Ornamental Horticulture; William I. White, PhD '73, chairman; Arthur Spitzer '71, speaker; Gordon Chang '73, another trustee-to-be; Peter; Prof. Daniel Padberg, marketing; and Mrs. Katherine Anderson, departmental secretary in Industrial and Labor Relations.

project at Cornell, designing and building antennas for the infant field of ionospheric research. "We built three gun barrel antennas and aimed them directly at the North Star," he said. Using the constellation Cassiopeia as a light source, which rotates around the North Star, Prof. Simpson Linke, MEE '49, Peter, and the project team looked at "the composition of the ionosphere—how wide the globs were, and so forth."

Designing and building the antennas and receivers for radioastronomical research soon became the focus of Peter's working life. "Think of a radiotelescope as a fancy television set," he explains. "Both of them receive signals, pass them through a data processing unit, and display them. The difference is that a television receives man-made signals. Radiotelescopes look for cosmic noise, which is that part of the electromagnetic spectrum from less than one to 200,000 or 300,000 megahertz. When the noise is received, it is stored on a strip-chart recorder or magnetic tape. By adjusting the antenna to a different frequency, you can look for different things."

As Peter went from a television repairman to a designer of state-of-the-art scientific equipment, he became more than just a technician. In 1960 he moved his family to Arecibo, Puerto Rico for two years. He was one of four people chosen by Cornell to design and construct a 1,000-foot radio radar telescope dish in the mountains. When the Arecibo telescope was finished in 1962, Peter returned to Cornell and began designing and building parts for the big dish in a university-owned lab in South Danby. The project became the National Astronomy and Ionosphere Center (NAIC) and was expanded in 1974, when new offices were built north of campus. Peter was appointed director of lab operations in 1978.

Finding a Voice

His parallel career—representing the interests of employes in university politics—began with the founding of the Cornell Senate in 1970. Peter had joined a trade union and was also a member of the first organized effort by Cornell employes to represent themselves within the university structure—the Technical Employes Association. "It represented employe concerns in informal meetings with the personnel director at that time, 'Dede' Willers ['36]," Peter says. "It eventually died due to its own lack of clout, which I think is really lack of leadership."

When the campus was shaken in April 1969 by the takeover of Willard Straight Hall and subsequent mass meetings in Barton Hall, Peter was not active in campus politics. But the governing system which grew out of those mass meetings—a Constituent Assembly and, later, the University Senate—brought a new, egalitarian spirit to campus governance. Two non-academic employe members were allowed on the Constituent Assembly. "It was token representation at best, but it was a beginning," Peter said.

In 1970, Peter was elected to a seat on the first Senate, and he remembers being swept up in the ideological debates of the day: "I made a real ass of myself in the early days arguing that everything we did was invalid because of token representation." There were originally 140 Senate members—60 each of students and faculty, 5 other employes, and 15 people appointed by the administration. In contrast, the population on campus is about 17,000 students, 1,500 faculty, 6,600 full-time staff, and many part-time staff. Full-time staff members comprised roughly one-quarter of "the Cornell community," but at the time they were almost totally unrecognized. This was Peter's main arguing point, and it worked—slowly.

"One of the strongest opponents I had at that time was a kid by the name of Gordon Chang ['73]," Peter remembers. "If you want to use labels, he's about as ultraliberal as you can be. And I was branded as the ultraconservative, of course. Chang was vehemently opposed to the idea of increased employe representation because he thought that all the employes would be as conservative as I was . . . and he was probably right too, because I think most of the employes are fairly conservative in nature."

Chang and Peter finally wrangled out a compromise increase in the number of

employe-elected Senate members; George wanted twenty-five, but Gordon made him settle at thirteen. "People saw us agreeing and they couldn't believe it," he recalls. The experience of arguing with "ultraliberal" students and faculty was as memorable to Peter as the Puerto Rico project, and he has never been far from university politics since those days.

"Working with the students was a great experience," he says. "But I think that the students may not have the same long-term perspective or the same sense of community as faculty and employes." Employes stay the longest and they know the place best in many ways, he argued, and he believed they were being ignored. "When they talked about 'the Cornell community' they meant faculty and students," he says today. "Employes were here but they weren't here. They didn't get any of the credit.

"I think that if I have done anything in my years here, it has been to try to change that image. The employes began saying that when they are not included, they feel insulted in a way. And in the last ten years you can see that the staff are mentioned alongside the faculty in most writing about the university as a whole. That's very important—much more important than most people realize."

Because the entire community was forced to consider university policies for the first time during the Senate years, Peter says it was usually easy to convince people of his position. "Some would immediately say it was unfair as soon as they thought about it," he says. "For example, faculty got reduced rates on athletic facilities but employes did not. That was struck down immediately. It was just a question of raising consciousness." In an age informed by the civil rights movement, the message was easy to understand.

"George was a shop steward," says Harold Levy '74, who watched him and argued with him constantly while a student Senate member. "I can't think of one time we ever agreed on anything, but I liked him from the beginning. He was diligent—he would do his homework. And when he disagreed, he would work on that person until they reached a resolution."

Students and faculty tended to vote in blocs, Levy recalls, and Peter was skilled in "working the margins. He didn't speak often, but when he did he was incredibly eloquent and persuasive. He had the ability to rise above factions, so everyone would listen."

Peter remembers the Senate experience fondly, and he contends that the Senate was the closest Cornell ever came to creating a truly representative university council. "If the Senate did anything, it fostered the idea that Cornell is one community," he says. "It was the only time I've ever seen the Peters and the Levys and the Changs of the world really communicate."

'I still think the university desperately needs a system of governance'

He served for four years and was then required by Senate rules to take a year off, so he took over the chairman's seat of a committee he had designed, the Committee on the University as an Employer. During a fourth term in 1975, he argued for and got an employe-elected seat added to the university's Board of Trustees. He says that because students were gaining access to the top governing board of the university at that time, it seemed only natural to extend the privilege to non-academic employes. Levy disagreed because, he explains, "I thought it would take away from the pressure to form a union, which I saw as the only real way for them to protect their interests." But the seat was approved, and Peter won the ensuing election.

In 1976, a presidential Commission on Self-Governance chaired by Prof. Geoffery Chester recommended that the Senate be dissolved. Dissatisfaction had grown over the size and the unwieldy decision-making processes of the Senate. The commission's report argued that it was unreasonable to expect so many people would be willing to devote so much time to campus governance.

The body was disbanded in 1977, and in 1978 a Campus Council was formed. It was smaller and its assembly had a more limited function, but the role of independent advisory boards for specific aspects of the university was expanded. Then in 1981, three assemblies—one each for non-academic employes, faculty, and students—were formed to debate issues within the three sectors.

Peter chaired the Employe Assembly in 1982-83. How well does he think campus government is working now? "Fairly well, and I think there are advantages to the present system," he said. "I think the Personnel Department at Cornell takes the Employe Assembly much more seriously now. But I can still see this system dying, and for the same reason—a lack of participation creating a lack of leadership. When we raised the number of employe members of the Senate to thirteen, we never once had an election where more than thirteen people were running. Until we get enough people convinced that the system is viable, we'll never have the kind of mass participation it takes to create a good, effective leader.

"But I still think the university needs a governance system desperately. It's very important that there be some mechanism in place which can take a stand and question the administration's policies."

Serving the Whole

After he was first elected a trustee in 1976, Peter's perception of his own role changed. In the Senate, he says, he was very careful to represent the views and interests of employes. As a trustee, however, he says he must first take the welfare of the entire university into consideration. "But those aren't mutually exclusive," he adds. "This is very important. If the whole university is going to be seeking the kind of excellence [Presidents] Corson and Rhodes have spoken about, we're going to have excellence in every area—staff as well as faculty. In a place which puts as much emphasis on research as Cornell does, staff quality is crucial.

"It's been said that what's good for General Motors is good for the country. Well, I would also say that what's good for Cornell employes is also good for the university. Enhancing the work environment is an immediate and tangible way of enhancing the quality of the university. And because I feel so strongly about this, my work is most effective when I am serving in this area."

In addition to the Chester Commission, Peter also served on the Personnel Policy and Planning Board (PP&PB) which looked at general and specific areas of concern to staff. It was through this committee of deans and administrators that Peter developed some new employe-related institutions.

One of his personal projects—"my idea, although I don't run it"—is the Cornell employe newsletter *Networking,* which celebrated its fifth anniversary in March. "It's an amateur production, but the spirit and the concept is there,"

George Peter at right talks before a Board of Trustees meeting with fellow trustees, from left, Bernard Potter '43, Judge Aubrey Robinson '43, LLB'47, rear, and Dr. Edward Wolfson '48, MD '53.

he said. "The purpose is communication. Communication is the key to the life of any group, and Cornell employes are no different."

Another of his projects is Cornell Employe Day, begun in 1974. All faculty and staff, and their families, are invited to a varsity football game and a chicken barbecue at Barton Hall. For many employe children, who may live in Danby or Newfield or Trumansburg or Candor, it is their first opportunity to see that the university is more than the office or shop where their parents work. Last fall the Big Red Band played, cheerleaders performed, the Cornell vocal group Nothing But Treble sang, and top university administrators served the chicken barbecue to the staff and their children.

The idea of President Frank Rhodes, Senior Vice President William Herbster, the personnel director, and other Day Hall luminaries cooking a chicken dinner for employes was Peter's, and it has become a tradition which generates much publicity and good feeling. In the beginning, though, the idea was sometimes viewed with reluctance. "Dede Willers thought it was just a terribly Mickey Mouse idea, and so did some others," Peter said. "But once it got rolling, it was too popular to turn down."

For the first time last year, busloads of employes from the Medical College in New York City joined in. Some of them went to the football game, but more took the opportunity to tour campus. For many it was a first visit.

The PP&PB was "probably where I did the most good," Peter says. "We looked at specific and general things. For example, long before the union started organizing I was pushing for an attitude survey of employes. It took me two years to convince Herbster to get it done. When it was finally completed, it turned out that 60 per cent of the employes were generally satisfied. Willers saw that and said, 'See George, it's not so bad,' to which I replied, 'When I went to school 60 per cent was a failing grade, dammit!'

"I told them that they'd better look closer at the survey—there were pockets of dissatisfaction which needed immediate attention. Well, they didn't do it. And they got a union."

The university's service and maintenance workers voted 483-375 in February 1981 to accept the United Auto Workers (UAW) as their official bargaining agency. In the long battle for the hearts and minds of the workers which preceded the vote, Peter actively supported the administration's position that a union was unnecessary and an outside intrusion on university policy.

He was and is roundly denounced by UAW supporters for being too partisan, and many say that his conception of Cornell is outdated and unrealistic. "He has access," said Alan Davidoff '80, president of the UAW local at Cornell. "Because of this, he has a certain small influence. But because he can speak directly to the administrators, he has gotten the delusion that he can really represent the concerns of employes. . . . We're saying that only a union is up to that task."

Peter says he fought the union because he believes that the university should act as a family with a common purpose. He is pained at the trend he sees toward autonomous, self-interested groups, which he calls "factions," running the university and determining policy. "The union gets to me because it's so negative about Cornell," he says. "They're always saying, 'We're the good guys and they're the bastards.' "

Such an orientation, he says, is counterproductive to the spirit of the university. "I make a lot of the concept of family, because it's been such an important part of my life in so many ways," he said. "I talk about the Cornell family as an important thing. And I think that when people say that family is not important, they're really missing the boat. Family is really all there is . . . it's the model we should use in almost any organization." In fact, he says, there is a direct connection between pride in one's family and pride in one's job.

"A job is like a marriage," he says. "You can't have a satisfying job or marriage if you only put in the minimum amount of effort. It takes a lot of hard work on everyone's part. I started *Networking* to try to communicate the message to all the staff that anyone can be a leader and take pride in Cornell, no matter what they do. And if the message is getting through from the top, employes will have pride.

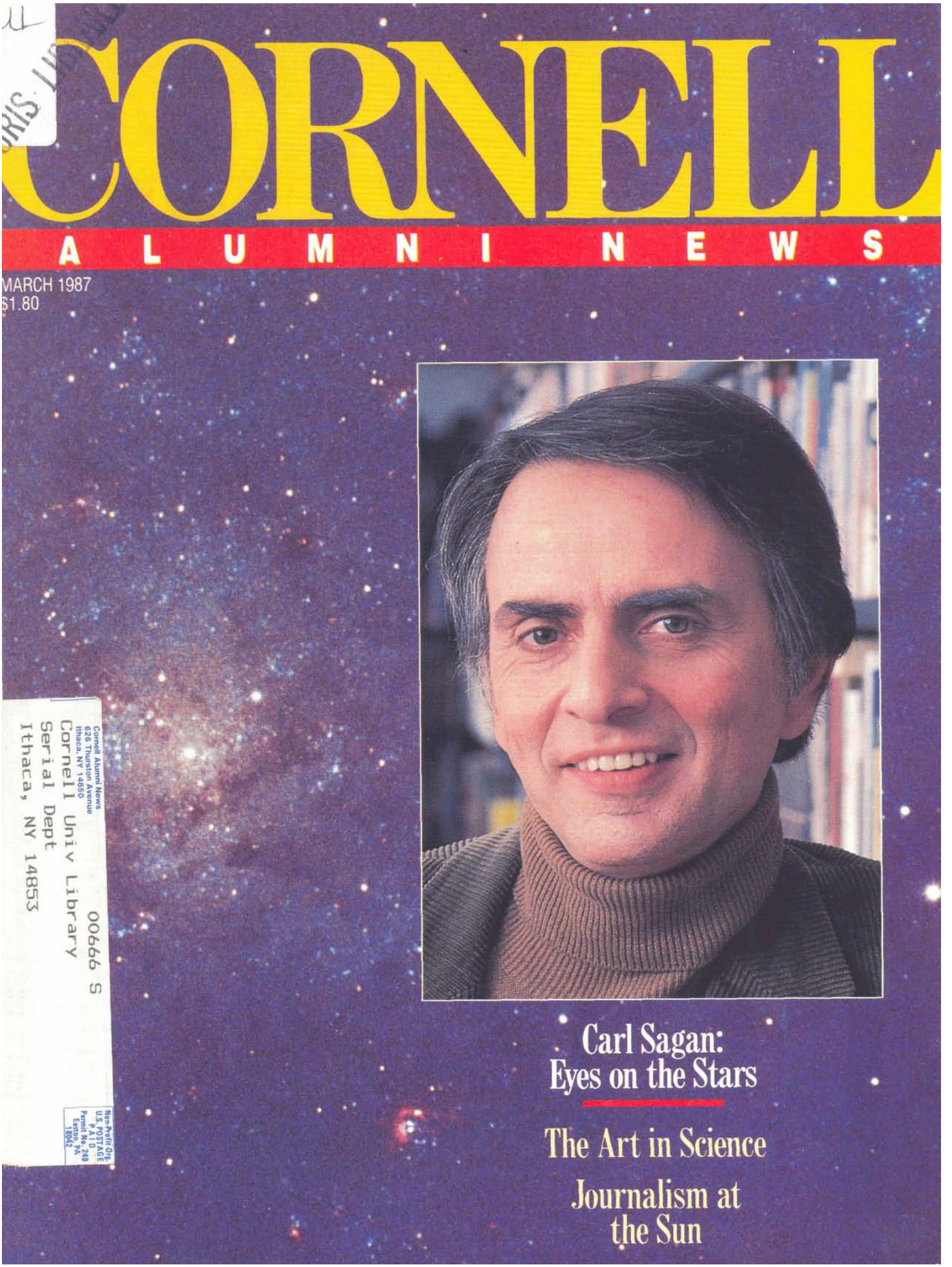
"See, I don't feel at all that Cornell is ready *not* to have a union," he says. "I've always felt that if the employes feel so strongly that the union is the only alternative they have, then dammit, the *administration* has done something wrong . . . .

"In a perfect system, there would be perfect communication; the leaders would know the concerns of every employe and the employes would know the problems the leaders face. Such a thing is impossible to achieve, of course, and so we have these representative systems which provide an imperfect mechanism for communication. I sometimes think I've had a false calling, because I think I would love to devote my time to systems analysis and designing the perfect system for organizational communication.

"I think the bottom line is that every injustice done to an employe is a direct responsibility of the administration. Where there is bad management and poor communication, union activity will flourish. I sent a paper to Bill Herbster once called 'The Root of the Peter Principle' [by Prof. L. J. Peter, no relation].

"I was making the point that the Peter Principle, which states that people rise through the ranks to a level where they are incompetent, will only apply in organizations whose hierarchies refuse to acknowledge that leaders are not born. See, they need to be *developed*. That takes a lot of hard work." And hard work is a familiar subject to a man like George Peter.

"Peter's Principles," by Brad Edmondson '81, *Cornell Alumni News*, v87n8 (Apr 1985), pp 36-39.



"Sagan's Universe: Beyond Venus, Jupiter, and the clouds of Titan," by William Steele, *Cornell Alumni News*, v89n7 (Mar 1987), pp 20-25. Astronomer Carl Sagan explores life in outer space while crusading to save life on Earth.

Beyond Venus, Jupiter, and the clouds of Titan

Sagan's Universe

BY WILLIAM STEELE

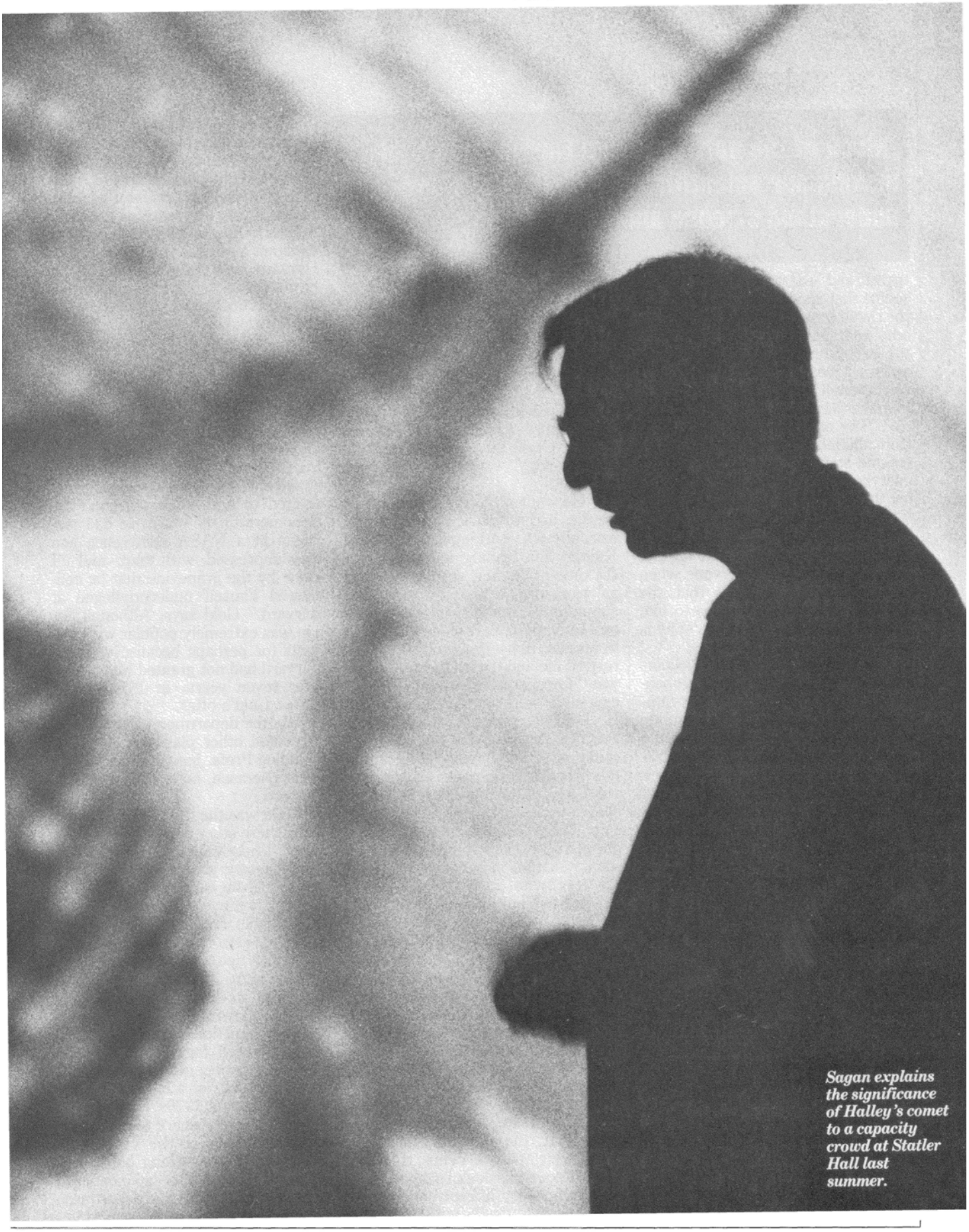
Carl Sagan is known to many as a novelist, talk-show guest, popularizer of science, and peace activist. Almost forgotten by the public is Carl Sagan, the scientist, who drives all those other personalities. Like most scientists, Sagan is passionately in love with his work. Unlike most scientists, he is the sort of lover who will shout the virtues of his loved one from the housetops and feel bitterly disappointed if others fail to find her as beautiful as he does.

If the shouting sometimes irks his colleagues, it has nevertheless accomplished much of its purpose, bringing both the wonder and promise of science and some of the technological problems that threaten humanity to public attention. The television series "Cosmos," which Sagan helped to create, was seen by 10 million people—more than any other PBS series in history. Sagan's testimony has enlightened Congress on such matters as the nuclear winter, Star Wars, and the greenhouse effect, at least two of which he would have been unprepared to discuss had he not spent a good part of his life studying the atmospheres of Mars and Venus.

Out of his string of awards and prizes far too long to publish here, only about a third are for scientific accomplishments; the rest are for promoting peace and for excellence in "communicating science." Among the latter are the Peabody Award for "Cosmos" and a Pulitzer Prize for *The Dragons of Eden,* one of his twenty books so far. The citation for one of his most recent honors, the Federation of American Scientists Annual Award for Public Service, seems to combine all three areas of achievement: "The most visible spokesman of the scientific community of the planet Earth . . . Sagan has ever greater potential for leading humans away from destruction."

Sagan is disturbed by the suggestion that he may be the only living scientist the person on the street could name. "To the extent that that's true," he says, "it's just another indication of how poorly we communicate science. I think the average person ought to be able to come up with a list of scientists at least as long as the list of basketball players. And I'm a big basketball fan."

Like many legendary love affairs, Sagan's began in childhood: at about the age of 6 he became fascinated by the stars, and the idea that they represented other worlds like ours. At about 12 he ran across *Astounding Science Fiction* magazine (now called *Analog*) with its tales of space



Sagan explains the significance of Halley's comet to a capacity crowd at Statler Hall last summer.

'Much of the battle to save Earth depends on making our scientifically untrained leaders understand science and technology.'

travel and extraterrestrial life. It seems that inside Carl Sagan, who is the David Duncan professor of astronomy and space sciences, director of the Laboratory of Planetary Studies, and president of The Planetary Society, the small boy is still around, trying to make the stories come true.

"The only thing I wanted to do from childhood was learn about planets and stars," Sagan says. "I think everybody is born a scientist. Knowing things and building things is what human beings are good at. Unfortunately so many kids get turned off. Parents and teachers tell them it's not practical, or they get nervous when kids ask deep questions that the adults don't know the answers to, like 'Why is the moon round?' or 'Why is grass green?' "

Sagan's parents didn't discourage his interest, though it was probably outside their experience. His father, a Russian immigrant, was a cutter in the garment industry, his mother a traditional housewife. They were cultured people, but not involved in science or technology. "They never told me that being an astronomer was an impractical thing, that they'd never heard of such a thing," he recalls.

He attended public schools in Brooklyn, skipping a few grades. After his father was promoted to factory manager the family moved to New Jersey, where Sagan graduated at 16 from Rahway High School.

He went on to the University of Chicago, which attracted him with a brochure that promised an emphasis on learning in preference to sports and social life. He had planned to major in astronomy, but discovered Chicago didn't believe in specialization. "The premise was that if you arrived there you were confessing ignorance," he recalls, "because if you knew stuff you wouldn't be there, and if you were ignorant you were in no position to say what you wanted to specialize in." Completion of fourteen year-long courses earned a BA "in nothing." You could, if you liked, take additional courses and get another degree, so Sagan graduated with an additional BS in physics. "I am eternally grateful to them," he adds, "because I learned about all sorts of things I never even knew existed, [like] art, architecture, Freud, music, Russian novels, Greek playwrights, cultural anthropology. I was phenomenally ignorant."

He went on to get a master's in physics and a PhD in astronomy and astrophysics, working under Gerard Kuiper, the leading astronomer at the time in the new specialty known as planetary science. During the summers he studied biology at Indiana University, part of a careful plan to prepare himself to study extraterrestrial life and the origins of life. He was "fortunate," he says, to be accepted to work in the laboratory of H. J. Muller, winner of the Nobel Prize for the discovery that radiation could cause mutations. Significantly, the first scientific paper Sagan ever published, at the age of 22, was in biology, with a little physics on the side. Titled "Radiation and the Origin of the Gene," it suggested that solar radiation might have provided the energy to form the first DNA molecules in our planet's youth.

Sagan was in the right place at the right time. It was the early '50s and NASA's great push to explore the planets was just beginning. Kuiper was not only the leading planetary scientist, but practically the *only* one, and his students were in demand. While still a graduate student, Sagan was asked to consult with NASA on the design of spacecraft. He went on to work on Mariner II, the first interplanetary probe, which flew to Venus, then the two Mariner missions to Mars, and practically every interplanetary mission since.

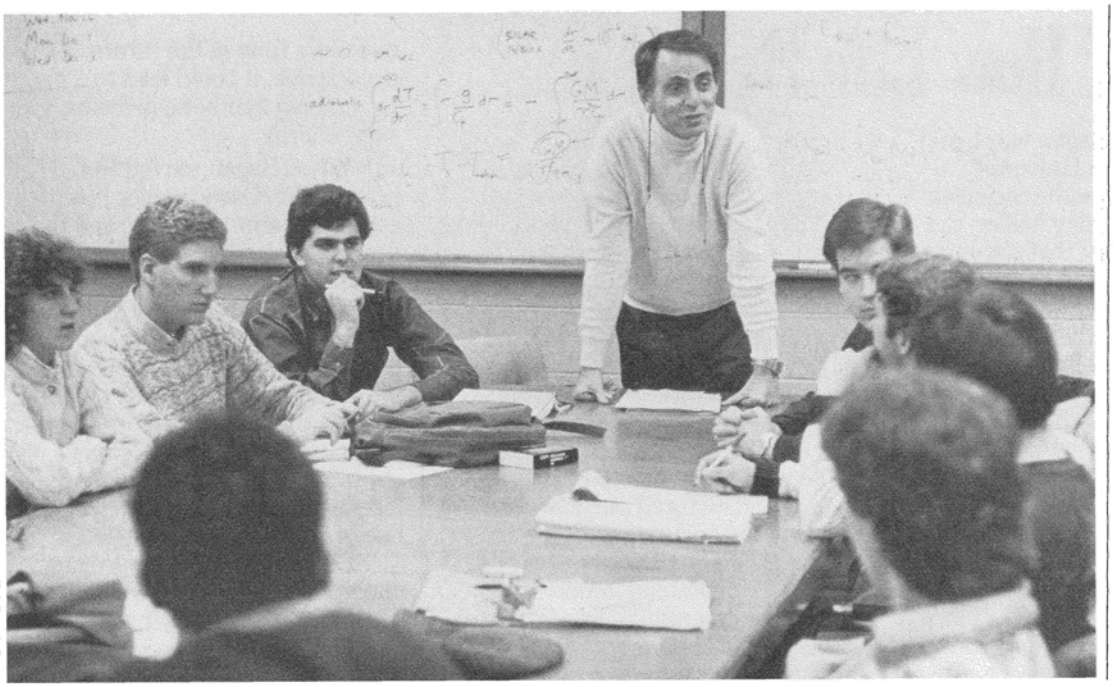
He spent two years at the University of California as a research fellow in astronomy, then jumped to Stanford University School of Medicine as a visiting professor of genetics, studying and teaching about the origins of life. In 1962 he became an assistant professor of astronomy at Harvard and a researcher at the Smithsonian Astrophysical Observatory in Cambridge.

Meanwhile, Cornell had hired Prof. Thomas Gold away from a full professorship at Harvard and given him a mandate to develop his dream of the Center for Radiophysics and Space Research, an interdisciplinary program which included construction of the radiotelescope in Arecibo, Puerto Rico. Like Sagan, Gold was aware of NASA's research push, and wanted to add some planetary astronomers to the staff. He had met Sagan at a NASA conference and was impressed with him, and "I knew by the grapevine that he considered himself underprivileged at Harvard," Gold says. Although Sagan was extremely popular with students (or perhaps because of that), Harvard had not granted him tenure after seven years. In 1971 he accepted Gold's offer.

As the department grew, Sagan suggested other planetary workers, including Profs. Joseph Veverka and Peter Gierasch, both also trained at Harvard.

"He was the driving spirit in enticing these other people here," Gold says. "There's no question but that the planetary group gained a lot of strength from his presence."

For many years, Veverka recalls, Sagan remained the "senior" planetary astronomer in the department and determined its direction. But, he adds, "Some people have a tendency to surround themselves with people who are less competent and can't function on their own. Carl always looked for the best people and most independent people. He wasn't looking for a bunch of flunkies." In the late 1970s, when Sagan took a leave of absence to go to California and work on the Viking program and began writing books and television shows, that independence asserted itself and the department became more diverse. (For an exam-



JON CRISPIN

◀ ***Professor Sagan and his class on critical thinking, part of his battle against pseudoscience.***

ple of some of the recent planetary work, see "Picturing the Universe," October 1985 *Alumni News*.)

Sagan also brought from Harvard an intriguing research effort into the origins of the chemicals of life on Earth and the possibility that such chemicals exist on other worlds (see page 24). Most of the rest of his work has focused on the atmospheres of Venus, Mars, and Jupiter. He was the first to suggest that the thick carbon dioxide atmosphere of Venus might trap heat by a "greenhouse effect," raising the temperature of the planet to a previously unlikely 600 degrees. A Russian space probe eventually proved him right.

A study of the opposite effect —how Martian dust clouds might block the sun and cool the planet— led to the prediction that dust and smoke from the fires following a nuclear war might drastically alter the Earth's climate and perhaps even wipe out all life. The prediction, based on computer modeling of Earth's atmosphere, was published in 1983. The "nuclear winter" report was written by Sagan. Richard P. Turco of R & D Associates, Marina del Rey, California, and four workers at NASA's Ames Research Center in California, O. Brian Toon, PhD '75, Thomas P. Ackerman, and James B. Pollack. Toon is a former graduate student of Sagan's, and Pollack worked with him as a post-doctoral research associate in the early 1970s. From the initials of the authors, the study has come to be known as the "TTAPS Report."

Nuclear winter, Sagan points out, was "an entirely unexpected finding that the defense establishments of the United States and the Soviet Union completely missed. It raises the uncomfortable question: what else have they missed?"

The TTAPS Report's conclusions have been challenged, with most of the challenges on the order of "Well, it won't be quite that bad, some people will survive." Starley Thompson and Stephen Schneider of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, argue that the TTAPS model is too simple, not taking into account such matters as the capacity of the oceans to store heat. Using a different computer model, the NCAR researchers predict more of a "nuclear fall," with an average temperature drop of only about 12 degrees C for a short period of time, and with not all parts of the earth suffering extreme cold. Sagan responds that just a 4 degree C drop would devastate Canadian agriculture, and that areas of the world that escaped extreme cold would still be in big trouble without the agricultural and technological support of the superpower nations.

The TTAPS group is working to support and refine its predictions, but Sagan nowadays spends much of his time trying to convince the government and the military that the possibility of a nuclear winter calls for policy changes. He agrees there is uncertainty on the subject, but argues that where the future of the human race is concerned, policy ought to be based on the worst possible case. Much of this battle depends on making our scientifically untrained leaders understand science and technology.

Meanwhile, Sagan has been working at the other end of the scale to combat the spread of non-science. He is one of the founders of the Committee for Scientific Investigation of Claims of the Paranormal (CSICOP), an organization devoted to exposing phony psychics, faith healers, and other exponents of pseudoscience. "I was drawn in by the utter credulity of the news media on subjects I knew something about— UFO's, ancient astronauts, astrology, and so on," he explains. "People don't see the distinction between science and pseudoscience," he adds. "I blame the media and the scientists for not doing a better job of explaining what science is all about." As a

Hints of How Life Began

While Carl Sagan was a student at the University of Chicago another scientist there, Stanley Miller, did an experiment that shook the world of biology—and perhaps the worlds of philosophy and religion as well. Miller mixed the gases that were believed to be in the atmosphere of the Earth shortly after it was formed—mostly methane and ammonia—zapped them with high-voltage sparks to simulate primordial lightning, and got amino acids, the chemical building blocks of the protein essential to living creatures. (Ideas of what the primitive atmosphere was like have changed since then, but other experiments have shown that many different mixtures of gases can produce amino acids, as well as the chemical building blocks of DNA, the material that carries the genetic code. How all these chemicals got together into organisms that could reproduce themselves is still a mystery.)

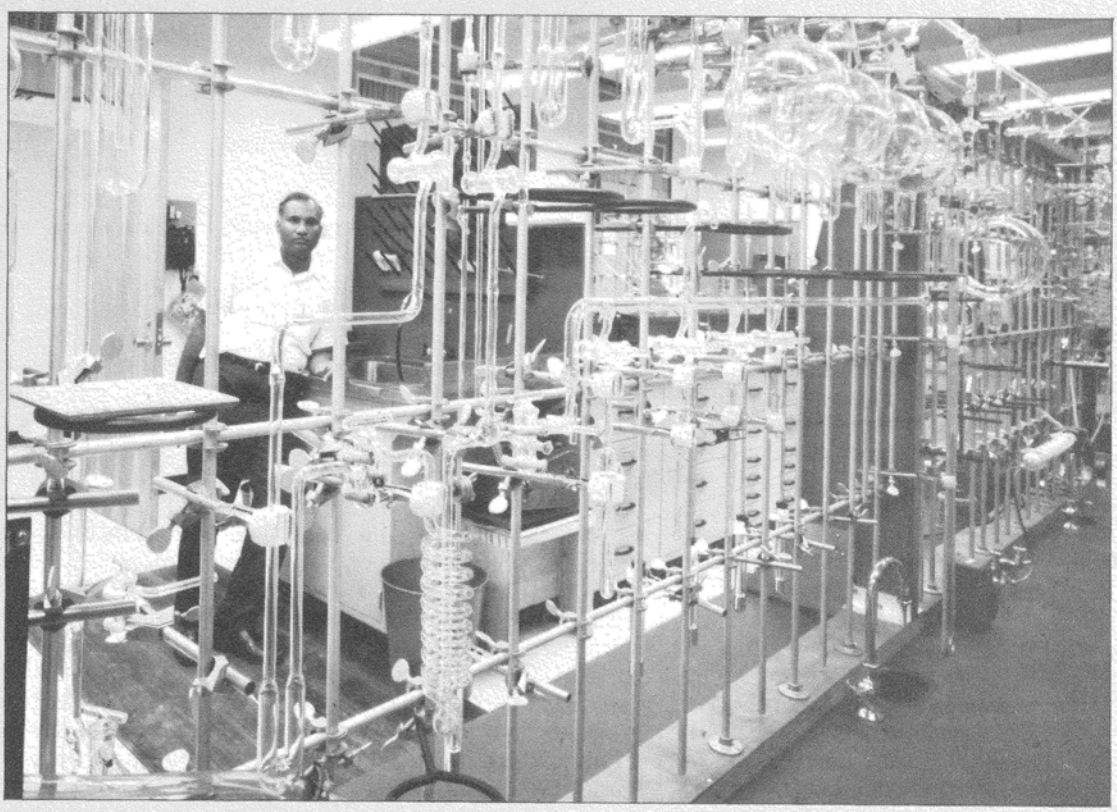
When he joined the faculty at Harvard, Sagan decided to repeat and expand on Miller's experiments. Through an advertisement in *Physics Today* he recruited Bishun Khare, a physicist experienced in working with gases and vacuums. Where Miller had supplied energy from homemade lightning, they used ultraviolet light, with which the Earth had been bathed generously before it developed a protective layer of ozone, and charged particles like those in the solar wind. They added hydrogen sulfide to the gases and got sulfur-containing amino acids which are essential to life. They calculated that under conditions existing on the primitive Earth, the ocean might have contained a 1 percent solution of amino acids, a surprisingly high amount.

Sagan and Khare took out a patent on this method of manufacturing amino acids; it's of little value now, but some time in the future, if the need arises, it could lead to a process for making synthetic proteins with solar energy.

When Sagan moved to Cornell he brought Khare, senior research associate James Pollack, and the entire research effort with him, dubbing it The Laboratory of Planetary Studies. Later joined by W. Reid Thompson, another post-doc, they began applying the same techniques to the study of conditions on other planets, including Jupiter, Uranus, and some of the moons of those planets. Their most successful work has focused on the atmosphere of Titan, one of Saturn's larger satellites.

Photos taken by the Voyager spacecraft show Titan's atmosphere filled with an orangey-brown, smog-like haze. Sagan's group prepared a mixture of methane and nitrogen similar to what astronomers believed to be the atmosphere of Titan, exposed it to the kinds of radiation believed to be there, and got an orangey-brown powder which absorbs the same bands of light as Ti-

HERMAN ECKELMANN



▶Bishun Khare in the Laboratory for Planetary Studies. This experimental set-up simulates planetary atmospheres, comets, and the interstellar medium.

tan's atmosphere. "We claim to have bottled the clouds of Titan," Sagan says.

The stuff resulting from these experiments consists of very large, complicated molecules, the sort of thing a chemist might call "tar" if it appeared unwanted in the bottom of a test tube. Somewhat to the annoyance of some chemists, Sagan and Khare coined the name "tholins," from a Greek word meaning "mud," which is what the material looks like.

Once again, when you add Titan-style tholins to water, you get amino acids. "And suddenly," Sagan says, "there's the prospect that the kind of chemistry happening on this remote outpost in the outer solar system is relevant to the origin of life on this planet!"

There's no liquid water on the surface of Titan; it's so cold there that water would be hard as granite. But there may be oceans of hydrocarbons, and Thompson visualizes vast quantities of tholins raining down from the atmosphere and collecting as sediment on the ocean bottoms. There, he says, water and ammonia may be blown from inside the planet by volcanic action, or the sediments may be pushed down into watery regions by movements of the planet's crust. "We're getting a picture of a very exotic world," Sagan says.

Other work in the laboratory has produced tholins in frozen gases, like the methane-water frost that may exist on the surface of some of the outer planets and moons, on comets, and in interstellar space. According to Thompson, spectral measurements suggest that tholins may exist in interstellar dust and in comets, including Halley's, that have their origins beyond the solar system.

Now, the group is trying to find out more about the chemical structure of tholins, and particularly what gives them their color. That in turn will provide something for the next space missions to look for, to confirm that what's seen on Titan is really the same as what's been made in the lab.

small step in this direction he has begun teaching a course on "critical thinking."

From the beginning of his career, Sagan was crusading to make science accessible to the public. While still a graduate student at Chicago he wrote popular articles for the alumni magazine and organized a lecture series on cosmic evolution, and he continued such activities at Harvard and Cornell. "All of these quite amateurish attempts on my part were wildly successful," he recalls. "It wasn't because I was good at it, it was because there was a great hunger."

But although seeking publicity was a natural part of that work, his rise to celebrity status was largely an accident. It began, he says, when he delivered papers at scientific conferences and reporters zeroed in on him because they found his subject matter interesting. He was interviewed for television documentaries and invited to appear on talk shows. Johnny Carson, an amateur astronomer, saw him on one of those and invited him to the "Tonight Show," where he still appears regularly. Carson probably helped to make his name a household word by doing impressions of him. (Just as Cary Grant never said "Judy, Judy, Judy," Sagan claims never to have uttered the reverberant "Billions and billions.")

"I don't want to blame Carson for any of this!" Sagan says quickly.

But it all made "Cosmos" easier to sell. The television series grew, Sagan says, out of "immense frustration" over poor network coverage of space research. Mariner IX photographed Mars from pole to pole, and later the Viking spacecraft actually landed on the planet's surface, and network television gave the events only a few minutes on the evening news. "At that point it was clear we had to do it ourselves," Sagan says.

He was in California at that time, working on the Viking program, and was able to interest a Los Angeles Public Broadcasting Service station in the project. What had first been envisioned as a one-hour special on space exploration grew into a series embracing, in a way, all of science. (Despite its success, there is still almost no prime-time coverage of science on the commercial networks; a recent attempt at a science series hosted by Walter Cronkite was dropped after two or three episodes.)

Sagan's popularity and his ability to make science interesting and understandable caused publishers to beat a path to his door. Repeatedly he was invited to write fiction as well. After resisting for a while he succumbed and produced the science fiction novel *Contact* in 1985, because, he says, "I'd written a lot of non-fiction about [the search for extraterrestrial intelligence], and here was a chance to present it to a much broader audience." With a movie deal signed, the audience will soon become broader still. Sagan reports with satisfaction that the screenplay is being written by Ernest Thompson, writer of *On Golden Pond,* which means that the movie should end up being about people, "not just gadgetary razmatazz."

The Martians Sagan read about as a child in the works of Ray Bradbury, H. G. Wells, and Edgar Rice Burroughs have not materialized, but Sagan still believes the "contact" he envisions in his novel may come about some day. As president of The Planetary Society, the largest private organization supporting space travel and research, he oversees a project by Prof. Paul Horowitz of Harvard to scan the skies for radio signals from intelligent inhabitants of other star systems. Horowitz uses a sort of super version of the familiar police-band scanner; this one covers 4 million separate channels over most of the radio spectrum, and methodically scans the sky one small area at a time. Sagan has also helped to get federal support for an even more extensive search by NASA.

It's fair to ask how all this extracurricular activity benefits Cornell. "First of all," Sagan replies, "there's very little I do that's outside of teaching and research; I consider the public lecturing and public writing that I do to be teaching. And I hope it gives a kind of intellectual vibrancy that attracts students. A lot of youngsters write to me and say that they're applying to Cornell University because I'm here."

Sagan's Universe: Beyond Venus, Jupiter, and the clouds of Titan By William Steele. *Cornell Alumni Newsletter* v89n7 (March 1987), pp 20-25.

A Space First

The university's 1,000-foot radio telescope in Puerto Rico has led to discovery of the least massive objects ever found outside the solar system. The objects, a furiously spinning pulsar and a "featherweight" companion star, were spotted circling one another in outer space.

Prof. Tor Hagfors, director of the center that operates the telescope at Arecibo, Puerto Rico, described the phenomenon as "a completely new type of object. It will allow astronomers to study for the first time a plasma sphere around a remote star."

Pulsars are collapsed, superdense remnants of stars that have undergone immense explosions. They emit rhythmic flashes of radio waves. The discovery is expected to give astrophysicists an unprecedented look at the turbulent corona, or atmosphere, of a star other than the Earth's own Sun, as they measure how the precise strobelike radio pulses from the pulsar are eclipsed by the companion star.

"A Space First," *Cornell Alumni News*, v91n2 (Sep 1988), p 13.

Black Holes

Yervant Terzian seems to move as quickly as the expanding cosmos, but the chair of Astronomy and Space Sciences and James A. Weeks Professor of Physical Sciences slowed down long enough to talk about space, stars, and science.

OUT THERE WITH THE BEST. "Most scientists agree that we're one of the leading departments in the world, along with a few others. It suggests how serious we are about what we do."

"What astronomers do" is: *theoretical astrophysics*, applying theoretical physics to complex astronomical problems; *radio and radar astronomy*, using radio waves to study everything from asteroids and galaxy halos to quasars and pulsars; *infrared and optical astronomy*, looking at the universe as it appears in infrared and optical wavelengths; *planetary sciences*, investigating the surfaces and atmospheres of solar system objects; *space and atmospheric physics*, studying space plasmas, the ionosphere, and the lower atmosphere.

It's quite enough to keep 20 faculty members–and their research associates and graduate students–very busy.

THE HIGH COST OF SKY WATCHING. Cornell astronomers and students have access to telescopes at the Fuertes observatory on campus; at Mt. Pleasant, in the town of Dryden; to the world's largest radio-telescope at Arecibo, Puerto Rico; and at Mt. Palomar, near San Diego. Whether a freshman is taking her first look at the Taurus star cluster from Fuertes or a senior researcher is settling in for a night at Mt. Palomar, Cornellians can find what they need–at a price. "The association with Palomar is tremendous–but it is expensive to jointly operate that facility. Arecibo? Invaluable, incomparable, but very, very expensive."

A WAITING LIST FOR THE UNIVERSE. "Teaching doesn't take a second place to research here. We have a strong undergraduate program, where we prepare scientists, but we also educate non-scientists about the fascinating world of astronomy. About 450 students sign up for our introductory courses–there's always a waiting list! We don't scare off non-scientists with a lot of complex math, we just open their eyes to the beauty of critical astronomical thinking. We're also proud to be a part of the Pew Undergraduate Program in Science Education, which enhances teaching for science and non-science students alike. It's an exciting collaborative effort with other liberal arts colleges."

CAN YOU TELL A STAR FROM A PLANET? The concern for teaching isn't only at the university level. "Surveys have shown that about 94 million US citizens don't understand why there are seasons or know that the earth revolves around the sun once a year. We should all get involved at the local and state level to urge the use of astronomy as a way of teaching science to young people, to help foster analytical and critical thinking. Who hasn't been thrilled by a view of Saturn's rings or a star cluster?"

BROWN DWARFS AND MORE. Cornell astronomers are very active in research, discovering the first protogalaxy, a "nearby" hydrogen cloud little changed since the beginning of the universe. Other faculty members are part of the Magellan project to map the surface of Venus. Some are studying brown dwarfs, bodies without enough heat to achieve nuclear burning, whose discovery could yield insights into the birth of stars and planets. Still others use large-scale computations on the supercomputer to explain the formation of black holes.

STARS IN YOUR EYES? If you'd like to know more, call 1 800 331-0650 and we'll put you on the "Friends of Astronomy" mailing list. You'll receive a color brochure, which includes faculty bios and research activities. You might like a selection of national news articles about Cornell astronomy or the annual report, with its close look at the department and its activities.

Which are truly out of this world.

Arts & Sciences

This series is sponsored by the Office of Alumni Affairs and Development of the College of Arts and Sciences.
We welcome your comments by letter, phone, or fax. We're at 726 University Avenue, Ithaca, NY 14850 and our telephone is 607 255-7225 or 800 331-0650 (8 A.M. till 5 P.M. Eastern time). Our fax is 607 255-6585 and it's on duty all the time.

(Arts & Sciences) "Black Holes," *Cornell Alumni News*, v93n8 (Apr 1991), p 11.

METAL ASTEROID

University scientists have found the first firm evidence of the existence of near-Earth metallic asteroids—a discovery that could have an eventual economic payoff. Researchers say the asteroid could contain some ten billion tons of iron, one billion tons of nickel, 100,000 tons of platinum and 10,000 tons of gold.

The discovery was made using the giant Arecibo radio/radar telescope and the findings were published in the June 7 issue of *Science*. The researchers are Donald Campbell and Alice Hine of the National Astronomy and Ionosphere Center at Cornell; Steven Ostro and Keith Rosema of the Jet Propulsion Laboratory of the California Institute of Technology; John Chandler and Irwin Shapiro of the Harvard-Smithsonian Center for Astrophysics; and Scott Hudson of Washington State University.

"Metal Asteroid," *Cornell Alumni News*, v94n3 (Oct 1991), p 14.

Gold Strikes Oil

Conventional wisdom holds that when the dinosaurs and the ancient jungles decomposed, their remains turned to the oil that is now pumped up from sedimentary rock below the earth's surface.

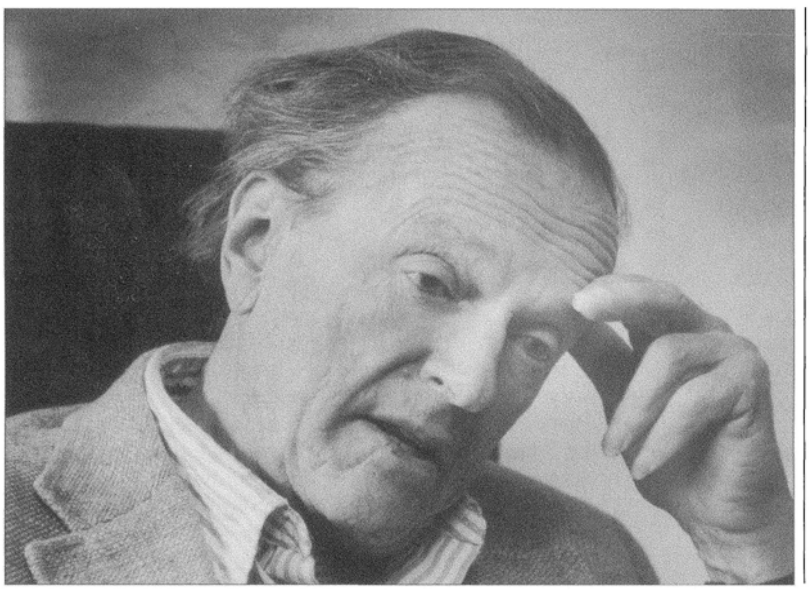
On the contrary, says Thomas Gold, emeritus professor of astronomy.

For the last decade, Gold has insisted that oil and gas come not from organic matter but from a primordial brew of hydrogen and carbon—called hydrocarbons—that were deposited as the planet was formed and have seeped up into the earth's mantle, just below the usual reach of drilling.

Now a crew has struck oil beneath a meteor crater in central Sweden—in the just the spot where Gold said it would be—and he claims the discovery proves he is right. But the skeptics are still skeptical, as they have been for most of the maverick scientist's career, making this yet another Gold hypothesis that is slow to win popular acceptance.

"I think the world at large will need a commercial production of oil from this well before it is convinced," he says, "although that is really an unfair and improper demand. They would not have expected *any* oil to be down there."

Gold, now 71, came to Cornell in 1959 and was director of the university's Center for Radiophysics and Space Research, heading research at the Arecibo radio telescope in Puerto Rico. But his infinitely curious mind has tackled questions in a variety of disciplines—electrical engineering, audiology, biology, astronomy and geology—and he has made contributions in all of them. Many of his theories also have the common feature of having been denounced, having drifted in ignominy for years, before finally being recognized as valid.



JAY REITER / ITHACA JOURNAL

Astronomy Prof. Emeritus Thomas Gold

In 1967, for instance, he was among the first scientists to claim that pulsars—sources of pulsating energy in the distant universe—are actually rotating neutron stars that have spent most of their nuclear fuel and are collapsing. Mainstream astrophysicists balked at his idea and would not let him present it at a scientific conference. Then they realized he was right.

Similarly, in 1948, fresh from a stint building radar equipment for the British Admiralty, Gold wrote an elaborate theory of how the inner ear works, arguing that not all its cells are passive receivers. Some, he wrote, are like little muscles that actively respond to sound. "It was much too sophisticated for the medical profession at that time," he recalls. Last year he was the guest of honor at a conference in England where two scientists presented research confirming his theory.

"Forty-two years I had to wait," Gold mused with a faint accent from his native Austria.

His current oil theory has suffered the same general disavowal. In 1986 a Swedish consortium began drilling in a spot selected by Gold. After spending $33 million on a 6.7-kilometer-deep test hole, the drilling equipment broke and the project stalled, having produced only 86 barrels of oil. Gold claimed the presence of any oil at all proved his point. But critics said the oil was just residue from the lubricants poured down the well. *Forbes* magazine wrote in April 1988, "This is a sad story about a reckless national energy policy, an ambitious American scientist . . . and thousands of Swedish suckers who lost their shirts." *Scientific American* noted his theory in its "Death Watch" column.

Undeterred, Gold kept the project alive and drilling began last year at another site twelve kilometers from the first well. Last fall, having used only water to lubricate the new well, the crew struck oil. "So it's pretty clear that we're right and that they'll go on drilling and making this area productive," Gold says. But skeptics still say the oil could have seeped over from places where conventional theory would place it.

While all the naysayers make Gold disheartened, he is not discouraged. Though he is no longer teaching, he is still researching oil and gas deposits, he says, in collaboration with companies in Oklahoma and with a group of Soviet scientists who endorse his theory. Gold says he also

"Gold Strikes Oil," by Kathy Bodovitz, *Cornell Alumni News*, v94n5 (Dec 1991), pp 5-6.

suspects that minerals like gold, silver and platinum shared similar beginnings deep in the earth. At the same time, Gold would like to see the scientific community become more receptive to unconventional ideas.

Says Gold: "My feeling is that if somebody has a certain background then he ought to be able to get a certain amount of research funds . . . whatever he says, even if it sounds totally crazy to all his colleagues. If he has got a good record in the past, then the stage should come when no one really is able to judge against him. Otherwise you will always destroy the new ideas."

—*Kathy Bodovitz*

"Gold Strikes Oil," by Kathy Bodovitz, *Cornell Alumni News*, v94n5 (Dec 1991), pp 5-6.

OUT OF THIS UNIVERSE

By timing the arrival of radio signals from a rapidly spinning pulsar, a university scientist has found strong evidence of a planetary system outside our own: two or possibly three planets orbiting the neutron star called PSR1257+12.

The discovery involved observations by Alexander Wolszczan, resident astronomer at the National Astronomy and Ionosphere Center's Arecibo Observatory in Puerto Rico, and massive data analysis by the Cornell National Supercomputer Facility. The neutron star under study is a rapidly spinning ball of matter that is squeezed to extreme densities as the result of the collapse of a parent star during a supernova explosion. It is also referred to as a pulsar because the continuous beam of radio energy rotating together with the star appears, to a stationary observer, to be a pulse as it sweeps through space.

Faint signals from the distant pulsar collected by the huge radio/radar dish of the Arecibo telescope were amplified in a receiving system and then digitized and recorded on a computer tape along with timing information from an atomic clock. In almost 1 1/2 years of observations, more than 4,000 accurate pulse arrival times were measured. When the computer analysis revealed a quasi-periodic pattern, the Arecibo astronomer suspected the effects of low-mass objects orbiting the pulsar. He then matched the timing data with a theoretical model based on Kepler's laws of orbital mechanics, named for the 17th-century German mathematician who determined the elliptical orbits of the sun's planets.

PSR1257+12 and its planetary system are 1,300 light-years, or 7,500,000,000,000,000 miles from Earth and too faint to be easily observed by optical or infrared telescopes. The neutron star has a mass about 1.4 times that of the sun, but is only 0.000014 its size, with a radius of about ten kilometers.

Two planets are orbiting PSR1257+12 about 34 million and 44 million miles away from the pulsar—roughly the same distance that Mercury is from the sun.

CHRIS HILDRETH / CORNELL

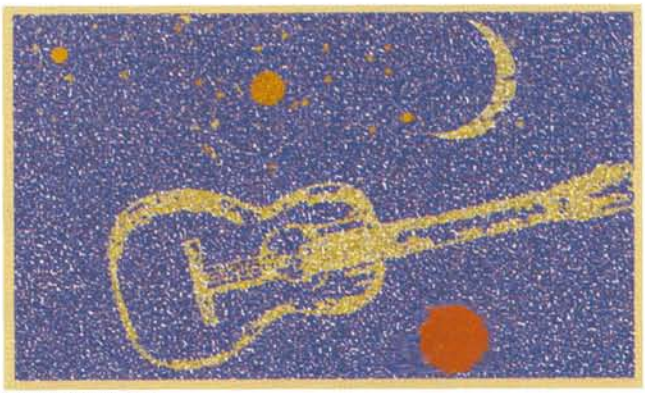
Astronomer Alexander Wolszczan stands before an artist's rendering of the skyline of one of the planets he has discovered.

All this points to the likelihood that planet formation may be more common than previously believed. "Further detections of millisecond pulsars in the solar neighborhoods will help to verify this truly exciting possibility," Wolszczan says.

(Research - Alexander Wolszczan) "Out of This Universe," *Cornell Alumni News*, v94n8 (Apr 1992), p 16.

The Fastest Guitar in the Galaxy

The fastest-moving star in the galaxy—trailed by a guitar-shaped nebula—has been discovered by Cornell astronomers.



STEFANIE LEHMAN GREEN

The galactic speedster actually is a pulsar or neutron star, which is the remains of a star that became very dense and compact after running out of nuclear fuel. Moving through the Milky Way Galaxy at speeds of up to 1,000 kilometers per second and emitting radio waves as it spins, the guitar-shaped nebula of the pulsar was discovered by Prof. James Cordes, astronomy and Scott Lundren, grad, and Prof. Roger Romani of Stanford University.

Named "PSR 2224+65," the pulsar is traveling through space ten to twenty times faster than an average star and is leaving a guitar-shaped wake of debris, or nebula that is so large that it would take PSR 2224+65 up to 300 years to travel from one end of the nebula to the other. The name "PSR 2224+65" is self descriptive in the nomenclature of astronomers: "PSR" stands for "pulsar," and "2224+65" gives the coordinates of the object on the galactic map.

Cordes says that the star creating the huge Guitar Nebula is moving fast enough to break free of the gravitational pull of the Milky Way Galaxy and continue into interstellar space. However, such an event won't take place for at least 20 million years, which is the amount of time needed for the star to move across the galaxy.

Cordes and his colleagues observed the star at the Mount Palomar, California, observatory in a project funded by the National Science Foundation. The Mount Palomar discovery was preceded by work done at the Arecibo Observatory in Puerto Rico, which is run by Cornell for the National Science Foundation. At the observatory, Cordes, who was studying the speed of stars moving through the galaxy, found one star that seemed to be moving much faster than others.

AND NOW, A BETTER CHIP

Cornell researchers, teaming up with IBM, have developed a method of producing computer chips that is more resistant to contaminants than traditional manufacturing processes.

Prof. Jean Frechet, chemistry, working with Grant Willson at IBM's Almaden Research Center, developed a method of producing computer chips using an alkaline-based catalyst instead of the traditional acid-catalyzed process.

The advantage to Frechet's base-catalyzed process is that it is less susceptible to contamination from dust or chemical impurities which are present to some extent in any manufacturing environment. Those contaminants are harmful to the manufacturing process because they can dampen the effects of acid catalysts, thereby slowing or stopping the manufacturing process.

Computer chips, also called microchips, literally are the "brains" of products ranging from personal computers to interval windshield wipers in cars. Their widespread use makes any improvement in their production process very significant.

(Research) "The Fastest Guitar in the Galaxy," *Cornell Alumni News*, v95n10 (Jun 1993), p 20.

CARL SAGAN

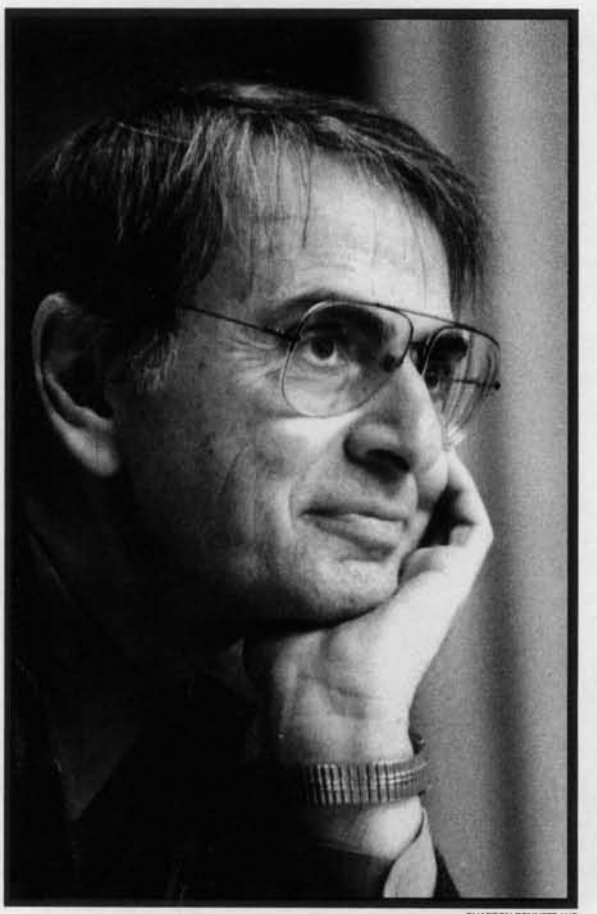
1934-1996

HE WAS PERHAPS THE ONLY LIVING SCIENTIST whose name was a household word. He contemplated the possibility of life beyond the stars and swapped jokes with Johnny Carson. He won a Pulitzer Prize, advised NASA on how to build a better spacecraft, entered the national consciousness with a refrain—"billions and billions . . ."—that he swore he never even said.

The subtitle of Carl Sagan's most recent book, *The Demon-Haunted World,* calls science "a candle in the dark." In the minds of many, the phrase describes nothing so well as Sagan himself. The world-famous astronomer died December 20 at the age of sixty-two, after a two-year battle with a rare bone marrow disease.

"He was, quite simply, the best science educator in the world this century," says Yervant Terzian, chairman of Cornell's astronomy department. "There's a vacuum in talking about science to the public now that Carl is not with us. But that should give us courage to carry on his work."

The son of a Russian immigrant who worked as a cutter in New York's garment district, Sagan made his first trips to the stars in voyages of the mind. As a child he was an avid reader of science fiction—books and magazines spinning tales of space travel and life on other worlds. On clear nights, the young Sagan would lie on the ground, buildings and trees out of sight, and stare at the sky. "The only thing I wanted to do from childhood," he said, "was learn about planets and stars."



SHARRON BENNETT / UP

He graduated from a New Jersey high school at sixteen and went to the University of Chicago, where he earned a bachelor's degree in physics in 1955 and a doctorate in astronomy and astrophysics in 1960. Even as a student he organized a highly successful science lecture series; some faculty dismissed it as "Sagan's Circus," but the crowds were standing-room-only.

Sagan taught at Harvard before Cornell offered him an associate professorship in 1968. In 1971 he was named a full professor, becoming the David C. Duncan professor of physical sciences in 1976. He was a founding father of the university's space science department—and an immensely popular teacher. "He was best known for bringing science to the public, but when it came to deriving the equations, getting down and dirty with the physics, he was great at that, too," says astronomy professor Steven Squyres '78, PhD '81, who took Sagan's Physics of the Planets course as a graduate student.

"He just had this wonderful knack for giving you a clear and elegant understanding of how the physics you'd learned in class connected to what was really going on."

In the late 1970s, Sagan took a leave of absence to work on NASA's Viking space probe (he also contributed to the Mariner, Voyager, and Galileo projects), and while in California began to write books and television scripts. He won the Pulitzer Prize in 1978 for *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*, and would eventually earn twenty-two honorary degrees and several NASA medals for scientific achievement and public service, among other honors.

BUT SAGAN'S PERSONal big bang came in 1980 when public television aired the thirteen-part series *Cosmos*. The show won Emmy and Peabody awards and became the most watched program in PBS history, seen by more than 500 million people in sixty countries. An accompanying book was on the *New York Times* bestseller list for seventy weeks, the best-selling science book ever published in English. He even made a foray into fiction with *Contact*, a novel about Earth's first alien

"Carl Sagan (1934-1996): A Special Tribute," *Cornell Magazine*, v99n6 (Jan/Feb 1997), pp 19-20.

encounter. At the time of his death he was co-producing a Warner Brothers film based on the book.

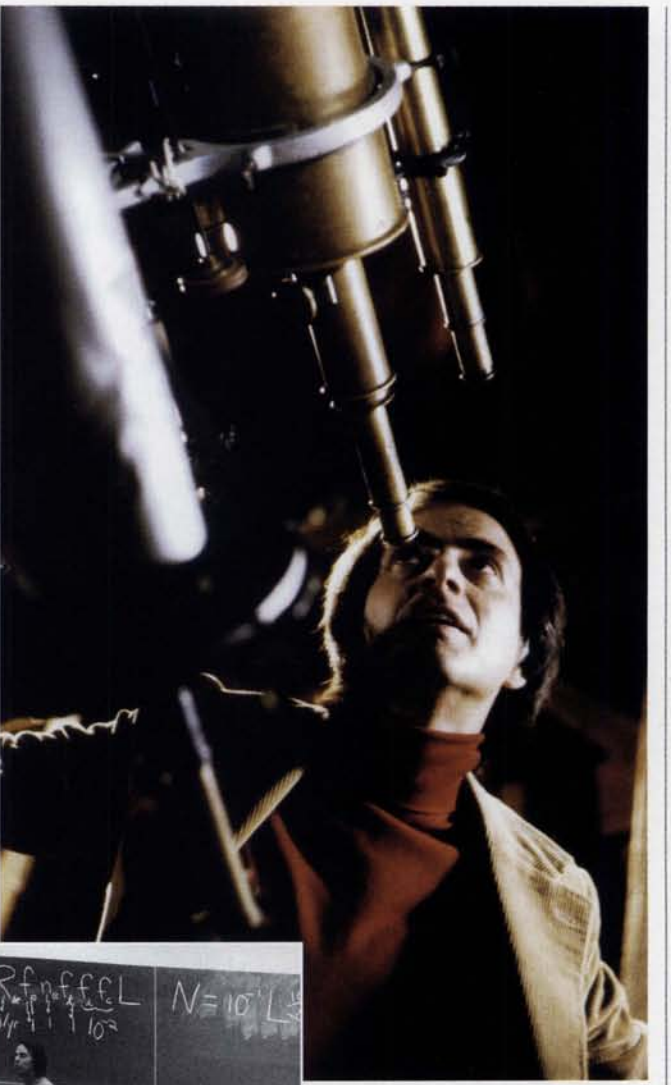
But nothing cemented Sagan's position in popular culture so much as his frequent appearances on Johnny Carson's couch. Carson, an amateur astronomer himself, brought Sagan into millions of living rooms. Appearing more than twenty times, he became a fixture—astronomy's answer to Joan Embry of the San Diego Zoo. In addition to his role as science's informal ambassador, Sagan became known as an environmental watchdog, warning of the danger of "nuclear winter," among other issues. "He was a pioneer in great ideas about humanity," Terzian says. "He was an explorer of the Earth, of the solar system, and of the universe. He believed he had a message, and he worked very hard to explain it: for the love of humanity, let's preserve ourselves by learning our place in the universe."

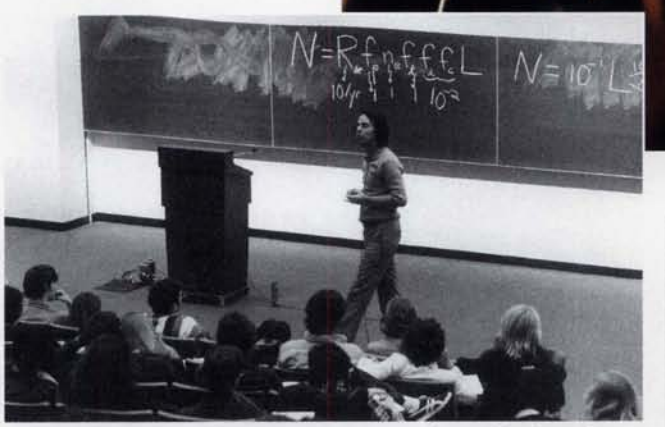
He also waged a one-man war against "pseudoscience," devoting *The Demon-Haunted World* to debunking phenomena like faith healing and alien abduction. "My candidate for planetary ambassador can be none other than Carl Sagan himself," said Oxford science professor Richard Dawkins in a book review. "He is wise, humane, witty, well-read, and incapable of composing a dull sentence."

Cornell feted Sagan in 1994 with a two-day symposium in celebration of his sixtieth birthday. "Most people, in their heart of hearts, still believe they are at the center of the universe, either physically or in some other form," he said in his keynote address. "It's a delusion that we have some privileged place in the universe." Sagan had long advocated the possibility of life on other planets, helping formulate the universal greeting beamed to the stars by Cornell's Arecibo radio telescope in Puerto Rico.

EARLIER THIS YEAR, thanks to a fallen meteorite, scientists discovered the first evidence that life may once have existed on Mars. For Squyres, the fact that such a potentially monumental leap came in the year of Sagan's death is a bitter irony. "At this pivotal point when we may be discovering life in the universe, Carl is gone," he said. "We may be on the verge of finding out things he wanted to find out his whole life, and he's not going to be around to see it."

By the time of the Mars discovery, Sagan was one year into his battle with myelodysplasia, which destroys red and white blood cells. He underwent a bone marrow transplant and chemotherapy in 1995, pondering the surreal experience of taking seventy-two pills labeled "biohazard." While the treatment was initially successful, the disease recurred early last year.





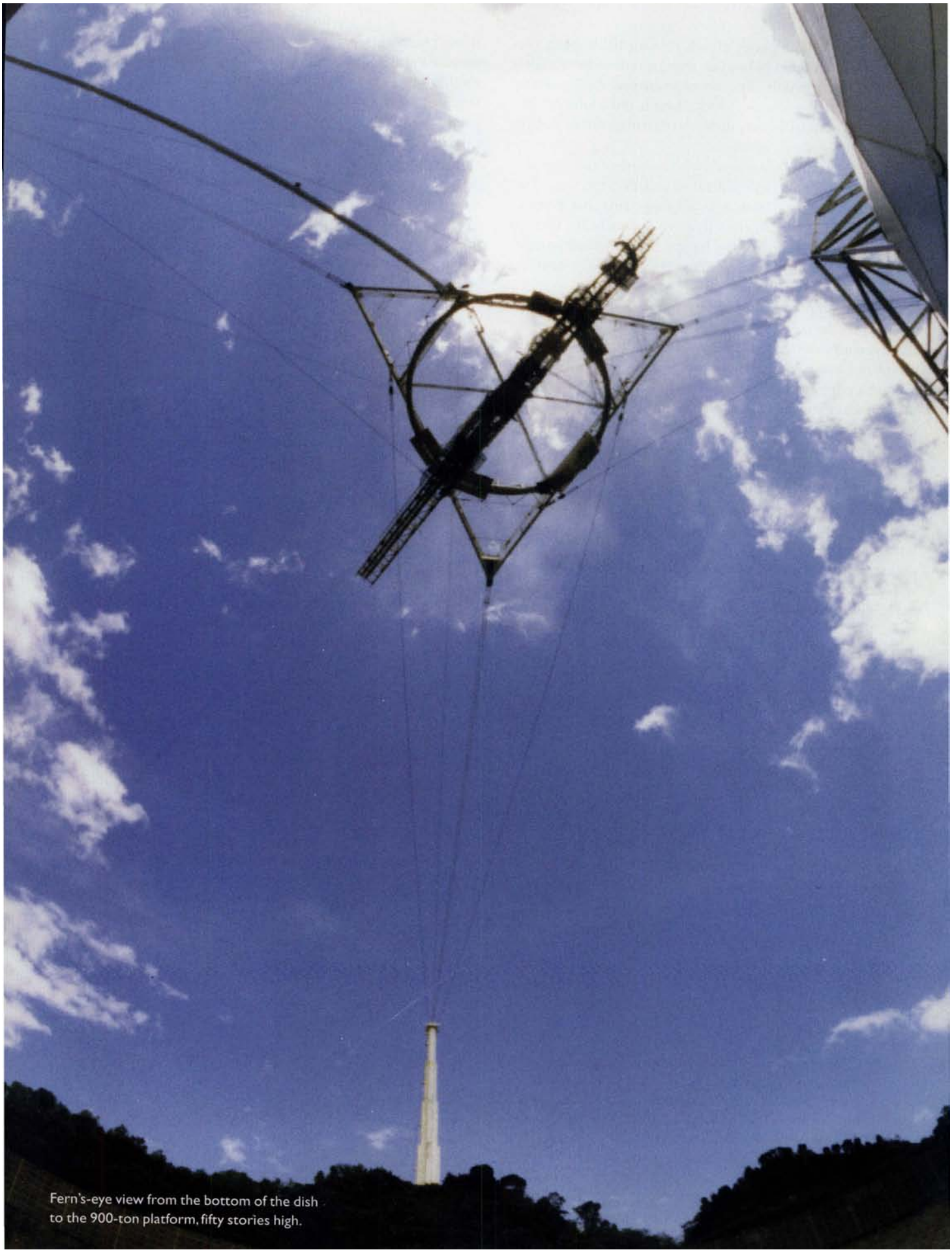
BILL RAY (ABOVE) AND BRUCE CRISPELL (LOWER LEFT)

"He was best known for bringing science to the public, but when it came to deriving the equations, getting down and dirty with the physics, he was great at that, too," says a colleague.

True to character, Sagan turned his illness into an opportunity to educate the public about the need for bone-marrow donors. In March, he wrote an essay for *Parade Magazine* describing his ordeal and reaffirming his skepticism of life after death. "The world is so exquisite, with so much love and moral depth, that there is no reason to deceive ourselves with pretty stories for which there's little good evidence," Sagan wrote. "Far better, it seems to me, in our vulnerability, to look death in the eye and to be grateful every day for the brief but magnificent opportunity that life provides."

Sagan is survived by his wife and collaborator, Ann Druyan, a sister, five children, and one grandson. Memorial donations may be sent to The Children's Health Fund, Attn: Donald Kingston, 317 E. 64th St., New York, NY 10021; and The Planetary Society, Carl Sagan Memorial Fund, 65 N. Catalina Ave., Pasadena, CA 91106.

"Carl Sagan (1934-1996): A Special Tribute," *Cornell Magazine*, v99n6 (Jan/Feb 1997), pp 19-20.



Fern's-eye view from the bottom of the dish to the 900-ton platform, fifty stories high.

"Eye on the Universe," by Beth Saulnier, *Cornell Magazine*, v99n8 (May/Jun 1997), pp 38-45. The Arecibo radio telescope is getting a new lease on life with a $30 million upgrade. A visit to the university's tropical outpost, where astronomers explore the cosmos as they dodge the occasional vampire.

eye on the universe

BY BETH SAULNIER

Arecibo, one of the world's best observatories, just got better.

AS DARKNESS FELL ON THE PUERTO RICAN HINTERLANDS, TWO astronomers gazed at a speck in the southern sky. It must be Fomalhaut, they thought, the star that makes up the mouth of the constellation *Piscis Austrinus*, the Southern Fish. "No," said a third voice. "It's Canopis." And with a pajama-clad arm pointed at the brightest star in the Ship's Keel, two-year-old Pia Salter-Ghosh toddled off to bed. Her babysitters both have PhDs in astronomy. But they were still pretty impressed.

Then again, the doe-eyed child's knack for star-gazing is probably as inevitable as the rising moon. Pia has spent her life at the Arecibo observatory, where her parents are staff scientists studying the cosmos with the world's most powerful radio telescope. Isolated in its mountain paradise in northwestern Puerto Rico, the observatory is to astronomers what a good particle accelerator is to a high-energy physicist—or maybe what Stonehenge was for your average Druid. "Here, you're breathing astronomy all the time," says University of Michigan graduate student José Francisco Salgado. "Breathing, but not suffocating."

Operated by Cornell under an agreement with the National Science Foundation, Arecibo is home to the biggest single-dish radio telescope on the planet, a monstrous aluminum punchbowl 1,000 feet wide. It works like a backyard satellite dish, reflecting signals off its curved surface to a central point. But at Arecibo, that central point is a 900-ton platform, suspended nearly fifty stories off the ground by three massive cement towers. You could fit the Astrodome in here and still have plenty of room for parking. "When I go out there and look at it, I'm still impressed," says senior research associate John Harmon, who's been doing radar astronomy at Arecibo for the past nineteen years. "You never get tired of the size of the thing. You never get jaded."

Arecibo was the first of its kind when it was built more than three decades ago under the direction of a Cornell electrical engineering professor. And with a long-awaited $30 million upgrade scheduled to be completed within the next few months, the telescope will be able to see farther, and in much better detail, than ever before. "It really is getting a new lease on life," says Arecibo director Daniel Altschuler. "We expect it to be one of the best instruments in the world. Way into the next century, we'll be finding ways of using the new power we've got. We hope to enter the next millennium with the keenest eye on the universe."

In the observatory gift shop, across from the astronaut ice cream and the glow-in-the-dark constellations, there's a wall of cotton-poly T-shirts bearing the Arecibo logo. It's a circle divided into three slices—clouds, planets, a spiraling galaxy—representing Arecibo's tripartite mission to study atmospheric science, radar astronomy, and radio astronomy. The observatory was originally designed to explore the ionosphere, the upper part of the atmosphere that filters out harmful solar and cosmic radiation. In 1958, while egos were crashing all over the western world in the wake of the Sputnik launch, Cornell's William Gordon realized that a radar beam could be used to study electrons in the ionosphere—if, that is, you could manage to build a big enough antenna. "In the beginning," says chief telescope operator Reinaldo Velez, "it was one big experiment."

And in radio astronomy, bigger really is better. The more surface area you have, the more radiation you can gather; like a larger camera lens, a bigger dish can see the universe in better detail. To minimize building costs, the observatory's designers looked to geography. Flyovers found several sinkholes in Puerto Rico's Karst region, a lunar landscape of valleys and jutting mountains covered in shaggy vegetation. The island had several advantages: it was a U.S. territory, and it was located close enough to the equator to allow for the study of planets passing overhead and for a partial glimpse of the southern hemisphere. Construction was completed in 1963 at a cost of $8 million, funded by the Defense Advanced Research Projects Agency. "Society was a little different in those days," says Paul Goldsmith, director of the National Astronomy and Ionosphere Center (NAIC), the observatory's parent organization. "If you had a good idea, somehow the government was able to find the money and

get it done very quickly."

Times have changed—and costs have skyrocketed. The recent replacement of one of the platform suspension wires, for example, cost $800,000. If Arecibo were destroyed tomorrow, it would cost more than $100 million to replace. "The Arecibo venture," says transmitter engineer Robert Zimmerman, "was a bargain of the Space Age." With a $10 million annual budget, Arecibo is open to scientists around the world, who apply for telescope time through a rigorous peer-review process. The facility, funded by NASA and the NSF, employs 140 people. And all of them, from the resident astronomers to the electronics technicians to the guards at the gate, are Cornell employees. "They don't have to pay parking fees," Goldsmith says. "That's just about the only difference."

'It is getting a new lease on life,' says observatory director Daniel Altschuler. 'Way into the next century we'll be finding ways to use the new POWER we've got.'

From the air, the telescope looks like a solid bowl sitting directly on the ground. It's not. The dish is actually suspended two stories in the air by pillars underneath, and its eighteen-acre surface is a huge, surprisingly fragile screen. During the first Arecibo upgrade in 1975, the original wire mesh, whose half-inch holes were interfering with the telescope's resolution, were replaced by nearly 40,000 panels made of perforated aluminum. Since the telescope has to be precisely located and balanced, erosion would be a disaster, so the dish was designed to allow enough sunlight through to support vegetation. The shade and humidity added up to an enormous fairy-tale fern garden dotted with wild orchids and begonias; all that's missing is the gnomes. "The terrain around here is as wild as anything you see in the world," says Zimmerman, an avid ham radio buff whom everybody calls Zimmo. "It has to be seen to be comprehended. I'm from Illinois, where things are flat. If you stand on the hood of the car, you can see Chicago. But when you look at the telescope, you can't even see the whole thing at one time. Photos never really reflect the grandeur."

If Arecibo looks like something out of a movie, that's probably because it is. The latest James Bond film, *GoldenEye,* was shot here, with the telescope passing as the secret headquarters for a high-tech weapon. (Hollywood took liberal dramatic license: in real life, the dish is neither hidden underwater nor powered by what the astronomers deride as "a big bicycle chain.") In February, scenes were filmed here for the upcoming film version of Carl Sagan's 1985 bestseller *Contact*, starring Jodie Foster as an intrepid astronomer who detects a message from outer space.

Chemists talk about running reactions. Physicists smash atoms. But the operative verb in "observatory" is "observe." Astronomers, in large part, still just watch. And they're a very patient breed. "What actually rotates the dish is the movement of the earth," Velez says. "It might be sometimes a couple of years before you can study a particular object." That patience has been tried by the upgrading process, which was supposed to be finished last year but has lingered on well into 1997. "It was frustrating for a while," says Altschuler, "because it seemed progress was always slower than what we expected." Last year, the project's Texas-based contractor sued the NAIC for an additional $7 million, claiming the upgrade was a bigger job than it bargained for. Although the suit is still pending, construction work continues.

So does research, at least on a limited basis. The telescope's original antenna—a ninety-six-foot dinosaur tail called the "line feed"—has been operational throughout most of the upgrade. And even when construction has hobbled the positioning system, researchers have been using the dish through a scientific method known as "wherever the contractor left it." Says Goldsmith: "You can look at whatever's going by—and that's a perfectly good way to work. The blind search still has a pretty big role in astronomy."

With Puerto Rico's flat-roofed architecture and dominant Spanish, it can be jarring to remember that you're actually in the United States. Similarly, it's rather surreal to think that the observatory, with its lush greenery and outdoor swimming pool, is an outpost of the Cornell campus. To get from the scientific offices to the visitors' quarters, you walk down a gravel path beneath thick vines. In the depths of February, while most Cornellians are swaddled in wool and polar fleece, folks at Arecibo are eating lunch outdoors. Still, there are some similarities. Both places get a lot of rain—although in Arecibo the sun actually comes out afterward—and hiking up Libe Slope is fine training for the observatory's nearly vertical hills.

The night is alive here, and it's loud. The tree frogs are called *coquís*, for the sound they make—and they make it all night long. It's a good thing that radio astronomy doesn't actually involve listening to anything, or UFO hunters would be writing about the invasion of the Budweiser mascots. And unlike the conventional peek-through-a-telescope approach, radio astronomy doesn't involve *looking* at anything either. Think back to Physics 101. Visible light is only one kind of electromagnetic radiation. There's also infrared, ultraviolet, X-rays—and radio waves. The same kind of energy that brings you Garrison Keillor and Howard Stern allows scientists to study galaxies far, far away.

Radio astronomy was born in 1931, when Karl Jansky, a researcher for Bell Labs, was trying to reduce interference in transatlantic phone calls, then transmitted by radio. After building an aerial the size and shape of a merry-go-round, he discovered that the interference was coming not from Earth but from the center of our galaxy; it was the radio waves naturally

emitted by astronomical objects. Scientists had always studied the skies with optical telescopes, which pick up the same light waves as human eyes. Now, astronomers could use radio waves as well. It was like the addition of a celestial sixth sense.

Jansky's serendipity led to an immensely powerful astronomical tool. You can only use an optical telescope on a clear night. But radio astronomers can survey the cosmos all day, every day—and search much farther than their relatively myopic cousins. "With optical telescopes," says research associate Kiriaki Xilouri, "you can only see up to a certain distance, up to a certain age of the universe."

When astronomers talk about looking back in time, they're not being metaphorical. Keep in mind that when you're looking at a star that's 100,000 light years away, you're really seeing light that left the star 100,000 years ago. So by studying far-away galaxies, astronomers can learn about the history of the universe, get glimpses back to the Big Bang. "If something is really far away from you, it's really far back in time," Xilouri says, "and it's close to the original explosion."

Xilouri, a native of Crete who lives forty-six seconds outside the observatory gate with her faithful German shepherd, has spent the past two years at Arecibo studying pulsars. The superdense neutron stars are so named because as they spin, they emit a radio signal whose pulse is so regular it's even more accurate than an atomic clock. "Imagine something bigger than the city of Ithaca, that rotates faster than your kitchen blender—much faster," says Xilouri. "The conditions there are extraordinary. No other physical laboratory, no matter how much money you spend on it, could replicate these conditions for scientists to study."

In 1974, physicists Russell Hulse and Joseph Taylor used the Arecibo telescope to discover the first binary pulsar. The work, which provided evidence to support Einstein's theory of General Relativity, earned the pair the 1993 Nobel Prize in Physics. Other notable Arecibo accomplishments in radio astronomy include the discovery, in 1992, of the first extra-solar planetary system, orbiting a pulsar 1,400 light years away. But though the observatory has had its share of firsts, its focus is the less glamorous bread and butter of basic research. "Not all the research that people do here leads to great discoveries," Altschuler says. "Most of it is just one tiny bit of information about one field."

Xilouri has been able to continue her pulsar studies during the upgrade using the telescope's original line-feed antenna. Once the contractor is finished for the day, she leans over a cobalt-blue computer screen with the heading "VERTEX

Far from a major city, Arecibo is an intense place that gets a lot of rain and is surrounded by near-vertical hills. Sound familiar?

Hector Arce '95, a visiting astronomy student, on his way down from the platform via the catwalk, left.

ANTENNENTECHNIK"—a German firm designed the software—and notes where the antenna is pointed; in case she comes across a pulsar, she has to know where to find it again. "What's happening is the sky is drifting by, and we're just taking data," she says. "I'm just letting the sky drift through my beam."

Once the upgrade is completed, radio astronomers will be able to study the universe at a far wider range of frequencies, essentially being able to tune into many more stations on the cosmic dial. "We're not limited anymore," says research associate JoAnn Eder. "We can look at every frequency the receiver is able to get with equal sensitivity." The most dramatic change to the Arecibo landscape was the installation of two subreflectors inside a 100-foot-wide aerodynamic shield, called the Gregorian dome. The structure, which resembles the golf-ball-shaped sphere at Disney's Epcot Center, both reduces interference and protects the secondary and tertiary dishes from the brutal winds of Puerto Rico's hurricane season.

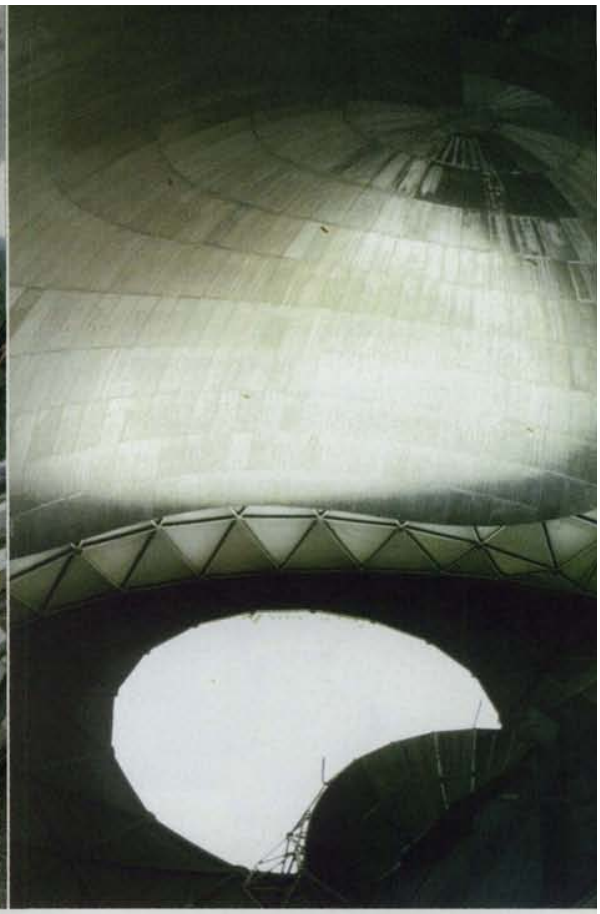
Eder will use the upgraded equipment to study "these little itty bitty galaxies you can barely even see," learning a galaxy's weight, velocity, and size in a five-minute glimpse. Like Xilouri, she is taking a faraway peek at our own past. "We're looking at galaxies like ours, only a long time ago," she says. "It's just like geologists looking at layers of soil." Astronomy before radio telescopes, she says, "was like an ant trying to describe the world."

"In the past twenty years, science has just boomed, blossomed," Eder says, "because we can study the same things, but in so many other ways." Eder first came to Arecibo to attend its highly selective summer student program, while she was earning her astronomy PhD from Yale after raising a family. "I was really starry-eyed," she says of coming to the observatory. "It was the most exciting thing that ever happened to me."

Radio astronomy is consummately passive; researchers just aim their telescopes at the sky. Radar astronomy, by contrast, is a kind of cosmic yodeling in which scientists bounce radio waves off objects in our solar system and analyze the faint echoes. Using this technique, Arecibo astronomers studied the moon's surface to help the Apollo astronauts figure out where to park. They established the rotation rate of Mercury and helped confirm the presence of ice at the fiery planet's poles. Radio astronomers have peered through Venus's dense cloud cover to study its peaks and valleys, measured the moons of Jupiter, and toured the ancient lake basins of Mars.

The upgrade will not only double Arecibo's radar power to one million watts, but make the equipment between three and twenty times as sensitive, depending on what you're using it for. The new "S-band" transmitter is scheduled to be up and running this summer, and astronomers are licking their chops. "The radar gets the biggest improvement," says senior research associate John Harmon. "It was already the most powerful radar in the world. In terms of sensitivity, it will be an order of magnitude stronger, and we'll be able to go about twice as far as we used to."

So what do astronomers expect to find? What will they get for all the time and money that went into the Arecibo upgrade? In fine astronomical tradition, they have no idea; the field has a long and glorious history of serendipitous discovery. There are a few obvious advantages, though. For instance, one of Arecibo's notable accomplishments has been the intricate mapping of asteroids. With the old system, researchers only came across a new asteroid about once a year; with the im-



Platform construction, center, and "Darth Vader's helmet," right, the secondary dish inside the Gregorian dome.

proved radar, they might see one every week. But for the most part, predicting the concrete benefits of the upgrade is a job for an astrologer, not an astronomer. "The things you can describe are things you already know about," Goldsmith says. "We've essentially extended our reach into the universe, and when your view of the universe expands, you almost always find new things. The universe is stranger than we can imagine."

The aliens, of course, have been here. The dish is a perfect landing pad for their flying saucers—when it's not being used as a beam-down point for the *chupacabras,* the drooling vampires who roam the night, sucking the blood out of hapless goats and the occasional chicken. And by the way, the telescope is really a secret military installation where the government... But if we told you that, we'd have to kill you.

Such are the myths that crop up when you build something so enormous—so visually stunning, so simple yet so hard to actually understand—smack in the middle of nowhere. Altschuler is occasionally buttonholed by tabloid journalists and conspiracy buffs, essentially seeking confirmation that the observatory is, in fact, Luke Skywalker's cell phone. Denying it does him about as much good as waving a copy of the Warren Report. "They say, 'I *told* you he would say that,'" Altschuler sighs. "You can't win." And though the facility was handed over to the NSF back in 1969, its early connection to the defense department still dogs it; rumors persist that the observatory is up to something much more sinister than watching the sky. "That's a misconception that we work very hard at debunking," Altschuler says, "because we don't want to be seen as being involved with military work."

While Arecibo has yet to pick up signals from other worlds, it does have an ear to the skies as part of the Search for Extraterrestrial Intelligence, or SETI. Although the search for life on other planets is far from the telescope's main purpose, it's certainly its most glamorous—after all, no one is making movies about millisecond pulsars—and when most people think of Arecibo, they think of SETI.

SETI's modern age began in 1959, when Cornell physicists Giuseppe Cocconi and Philip Morrison published an article in *Nature* about using microwave radio for interstellar communication. About seventy such projects have been undertaken since, scanning the skies for such signs of intelligent life as repeating signals or transmissions using a very narrow band width. "The biggest misconception is that it's easy," says senior research associate Michael Davis. "But we don't know the frequency, and we don't know where to look."

Contrary to rumor, Arecibo has sent a message to the stars only once. In November 1974, a greeting including a simple picture of our solar system, the structure of DNA, and the shape of a human being was beamed toward a star cluster about 25,000 light years away. "It was supposed to be a message that any civilization with the technology to receive the radio transmission could figure out," Goldsmith says. "That message has been traveling along for twenty-three years, and it's almost certain that no one has picked it up yet."

In the effort to make the public understand what really goes on at Arecibo—not to mention what does *not* go on here—the observatory recently opened a $2.6 million education center. It was inaugurated at a gala ceremony in March, attended by luminaries like President Emeritus Frank Rhodes and Charles Rodriguez '76,

majority leader of the Puerto Rican senate. "By making people understand what we do at Arecibo observatory, we're also helping ourselves," Altschuler says. "We're not just aloof scientists. We owe it to the public to tell the world what we really do." The new facility is expected to draw upwards of 80,000 visitors a year. And though that might sound ambitious for such a remote locale, consider that 40,000 people a year were showing up when there was nothing to see but the dish. "Before, they came in, they looked, they watched a homemade tape, and they went home," Altschuler says. "It really was a shame for a national research facility which had visitors from around the world."

Kiriaki Xilouri studies **PULSARS.** 'Imagine something **bigger than Ithaca** that rotates faster than your kitchen blender. **No other lab** could replicate these conditions.'

Now, astronomy buffs can roam 3,500 square feet of exhibition space in a sleek, modern building. Visitors are greeted by statues of Jansky and atmospheric science founder Sydney Chapman, who chat in English or Spanish at the push of a button. "I like the idea that they're here, reincarnated," says Altschuler, a Douglas Adams fan who came up with the exhibit's name, "The Cafe at the End of the Universe." Behind the Jansky-Chapman kaffeklatch is a mock-up of famous scientists hanging out together in an imaginary bistro, where Madame Curie is nursing a 7-Up, Galileo a Snapple, and Isaac Newton a Mott's apple juice. (A beverage company was one of the center's major sponsors.)

In addition to a fantastic view of the dish, the center offers dozens of interactive exhibits, from a cloud machine to a model of the radio telescope platform you can move with a joystick. It's all fairly prosaic stuff for audiences jaded on gee-whiz attractions like the Boston Museum of Science or San Francisco's Exploratorium. But this is Puerto Rico's first and only science center, slated to be a magnet for school field trips and teacher enrichment courses, and most of the neatly uniformed masses who'll come here have never seen anything like it. "We're setting an example of what a national research center can and should do in terms of educational outreach," Altschuler says. "If we touch one in a thousand kids, and they decide on a career in science, that's progress."

In fact, one of Altschuler's protégés—Salgado, the University of Michigan graduate student—grew up in San Juan and first saw Arecibo as a twelve-year-old on a school trip. "I was definitely impressed," he remembers. "To learn that this big instrument was on your little island was really amazing." He's been an astronomy fanatic since the third grade, when he got his hands on a gas station giveaway book on the lunar landing. In high school, Salgado worked in various mall stores—bookstore, surf shop—to earn the money for a $900, 100-pound telescope, which he got just in time to watch Halley's Comet. "I would take it up to the roof," he says, "and invite my neighbors and explain the skies."

Salgado started working at Arecibo as a student at the University of Puerto Rico at Rio Piedras, where Altschuler was his advisor. The courtly Salgado has come back periodically ever since, finishing the data-crunching he started as an undergraduate and doing some of his own research. "Although you're only a grad student working on your thesis, they treat you like a researcher," he says of the observatory's resident scientists. "They show concern and interest in what you're doing. You're a researcher just like them, even though you don't have your degree yet." He's also maintained a relationship with Altschuler that's so close, Salgado thinks of him as a second father. Up in Michigan, Salgado likes to go by his formal name, José Francisco. Here, everybody still calls him Paquito. "Basically, they're seeing me grow," he says. "Every time I come back, they make me feel like I really belong."

The observatory itself is an intense, isolated place, an hour and a half away from San Juan. To get there, you first take the *autopista,* which is rather like the Garden State Parkway in its predilection for toll booths every ten or twenty yards. Off the highway, you drive past tiny sherbet-colored houses on a windy mountain road that's two-way mostly due to the dogged determination of local drivers. Outside the Arecibo gate, a ramshackle building offers a taste of faraway Collegetown. It's called the Cornell Bar—and it's the sum total of nearby nightlife. "There's no student union, no cafes," says Salgado. "It's a different atmosphere. It definitely forces you to be focused. At night, you work until you get tired. Then you go to bed and the cycle begins again."

Renting a movie means driving down to the town of Arecibo; getting there and back takes almost as long as the film itself. And this is no place for couch potatoes. The home of the world's largest radio telescope lost its satellite TV dish in a lightning storm, and with all energies focused on the upgrade and the visitor center opening, no one has gotten around to fixing it. "I was expecting a big campus, college-like place," says David Goldbrenner, a former Cornell physics student who transferred to Harvard his sophomore year, earning an engineering degree in December. "Here, it feels very removed, partly because of the climate and the landscape, and partly because it's so remote. It's a good forty minutes just to get to the mall."

Goldbrenner returned to Arecibo in February to finish the work he'd begun as a summer student the previous year, creating a back-up system for the atomic clock that serves as the observatory's official timekeeper. "It was like summer camp, except you had to do work," he grins. "It sort of combined a lot of my interests—engineering, astronomy, Puerto Rico. But I wouldn't like to be here for more than a few weeks, because

I'm used to the city. I'd get bored."

But though Arecibo is no Cambridge, the observatory has an appeal all its own. Like Ithaca, it's *somewhere* that just happens to be located in the middle of nowhere. "Being here and seeing the dish and the work that goes on is very inspiring," Goldbrenner says. "It's very tangible science. You get a sense of what's cutting edge in exploring the universe." The sense of isolation has been particularly acute during construction, when much of the equipment has been off-line and there have been few visitors; that will change once the upgrade is completed. "What's really exciting is all the scientists coming through, getting to talk to them about their research," says Eder. "You're in the middle of all this breaking science. And you can just jump into this marvelous culture of Puerto Rico. Every weekend, there are fiestas somewhere."

In this land of balmy nights and natural vistas, stargazing remains a favorite pastime. Jogging is also popular, with distance measured not in miles but in laps around the dish. And astronomy is hardly a nine-to-five, leave-it-at-the-office job. "I think of it as kind of a royal endeavor," Zimmerman says. "It's a noble endeavor to look at the stars." Zimmo is showing off a newly built ham radio transmitter, gleaming white and nestled in the back of his car like a toddler, that he'll use to bounce messages off the moon. "We reach out and touch the moon," he says, "so we're *lunatics*."

Hobbies aside, though, Arecibo is a tough place to be single. "Sometimes it can get on your nerves," says Xilouri, "but you can feel equally isolated in a big city." Xilouri recently became engaged to an Ithaca-based engineer after a lengthy e-mail courtship; they haven't yet figured out how they'll handle the logistics. Astronomy, it turns out, can be hard on any relationship, since astronomers have to go where the telescopes are. Chris Salter and Tapasi Ghosh—parents of Pia, the young stargazer—met when they were both doing research in India. Eventually, she went to work in Europe, he in the U.S. "When we got married," Salter says, "we had the Atlantic Ocean between us."

Finding jobs in the same place is difficult for any academic couple; for a pair of astronomers, the odds are, well, astronomical. So Salter and Ghosh were thrilled to get positions at Arecibo, where Pia has become the observatory's child as much as their own. Now three, she spends every Wednesday morning in her mother's office, hanging out on a toy-laden blanket. And every night she goes through her bedtime ritual. "We bathe her, put her in her pajamas," her father says, "and she goes out to say good night to the stars."

Beneath the dish, shade and humidity have nurtured one of the world's biggest fern gardens, complete with wild orchids and begonias.

"Eye on the Universe," by Beth Saulnier, *Cornell Magazine*, v99n8 (May/Jun 1997), pp 38-45.

This page was intentionally left blank.

MARCH / APRIL 1998

CORNELL MAGAZINE

VOLUME 100 NUMBER 5

RECEIVED MAR 13 1998 CORNELL VET LIBRARY

2 LETTERS

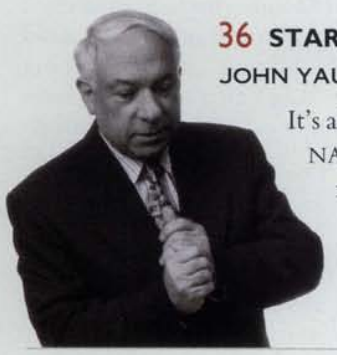
6 CURRENTS
Bilson on Beethoven! *Plus:* survivor of the spiciest, Thelma Filmmaker, the five baby Baers, lipstick vs. Medfly, and advice for the First Pooch.

24 CHASING THE GAME
BRAD HERZOG

For college athletes, weekends mean logging miles to faraway foes. But there are road trips—and then there are road trips. The Golden Bear Classic, 3,000 miles from the Hill, was one of those. Three days in January with the Big Red men's basketball team.

32 VIRTUALLY YOURS
BRUCE ANDERSON

Once upon a time, students used to *write*. Letters scribbled in the back rows of lecture halls kept them in touch with friends and family. Then came e-mail—and instant gratification. In the information age, thoughts on the act of faith of a stamp and envelope.



36 STARS IN THE ASCENDANT
JOHN YAUKEY & BETH SAULNIER

It's almost an embarrassment of riches. In the wake of NASA's downsizing, Cornell's astronomy department has won a mother lode of space agency grants, from studying comets to collecting rocks on Mars. Says chairman Yervant Terzian: "It's a happy, happy place."

20 FROM THE HILL
Go north, young men. *Plus:* Football's Hofher moves on, Lake Source Cooling moves ahead, vets map doggie DNA, and monkeys attack.

45 SPORTS
Following two lacrosse legends

48 AUTHORS
Diane Ackerman's *Book of Love*

49 MARKETPLACE
Classifieds & Cornellians In Business

52 AN INVITATION TO ITHACA
Places to visit, things to do, etc.

56 CLASS NOTES

83 ALMA MATTERS

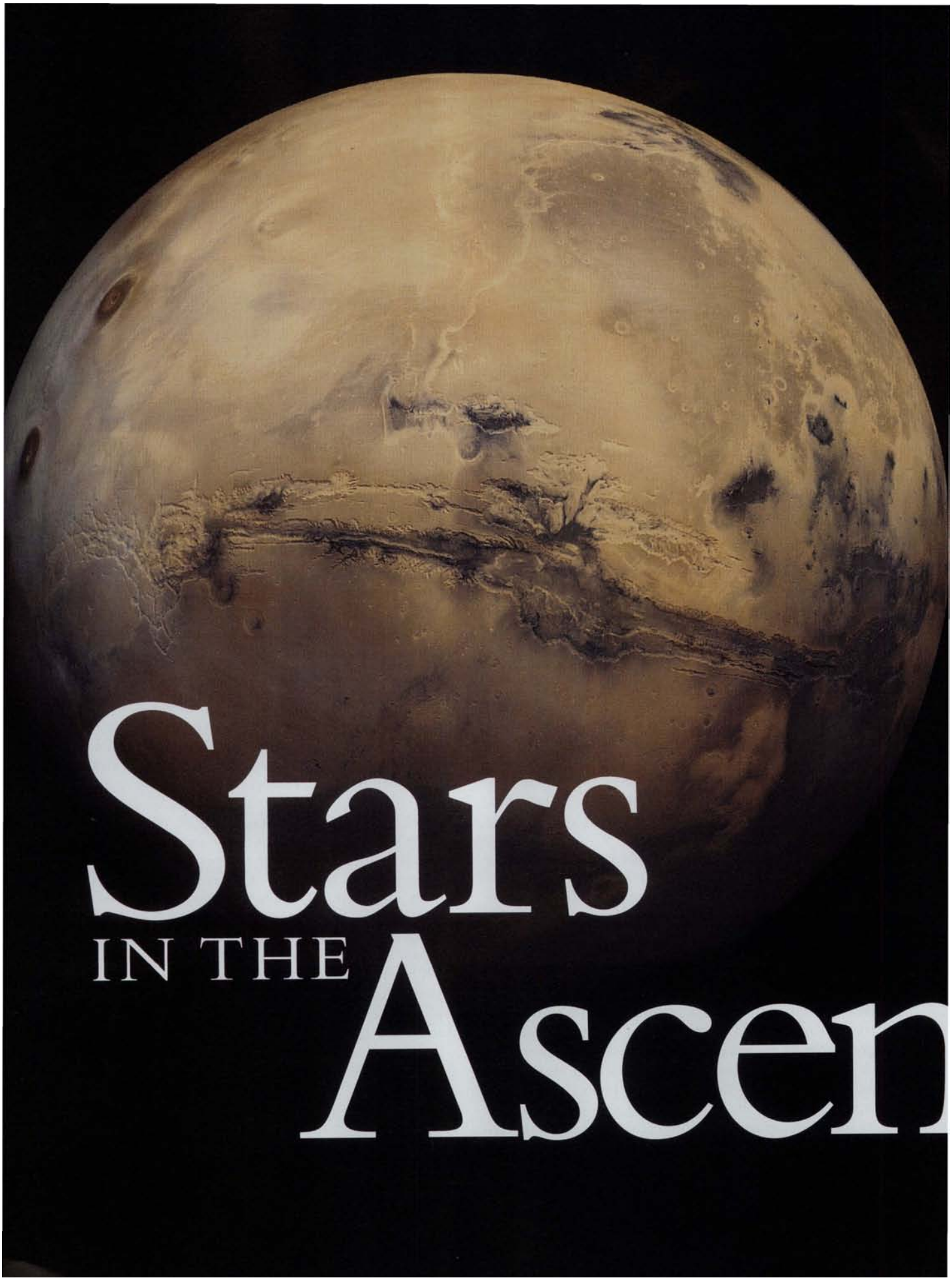
107 ALUMNI DEATHS

112 CORNELLIANA
Freshmen rule!

Cover photo by Frank DiMeo / University Photography

Cornell Magazine (ISSN 1070-2733) is published six times a year, in January, March, May, July, September, and November, by the Cornell Alumni Federation, 55 Brown Road, Ithaca, NY 14850-1247. Subscriptions cost $29 a year. Second-class postage paid at Ithaca, NY, and additional mailing offices. POSTMASTER: Send address changes to Cornell Magazine, c/o Public Affairs Records, 55 Brown Rd., Ithaca, NY 14850-1247.

"Stars in the Ascendant," by John Yaukey & Beth Saulnier, *Cornell Magazine*, v100n5 (Mar/Apr 1998), cover & pp 36-43. It's almost an embarrassment of riches. In the wake of NASA's downsizing, Cornell's astronomy department has won a mother lode of space agency grants, from studying comets to collecting rocks on Mars. Says chairman Yervant Terzian: "It's a happy, happy place."



Stars IN THE Ascen

THE weekly afternoon gatherings in the sixth-floor conference room of the Space Sciences Building were starting to feel like a regular happy hour. The same crowd. The same spread of pizza slabs, snack mix, and the fizz of New York State sparkling wine; the same blazer-clad faculty at the head of the same long conference table; the same grad students lurking at the perimeter, waiting to pounce on another free meal.

In the corner, another professor is beaming. Dressed in a flannel shirt, frayed black jeans, and cowboy boots, he could easily pass for a post-doc. But this department wunderkind—this self-described exploration junkie—will drive the rusty surface of Mars as the designer and operator of NASA's Athena rover, scheduled for launch in 2001.

This announcement celebration, in early November, is astronomer Steve Squyres's moment. The week before, it belonged to colleague Joseph Veverka, chosen to head NASA's $154 million CONTOUR comet-tracking mission. At the same time, two Cornell astronomers and an engineer were named to build and operate an infrared camera aboard a 747 configured to carry an airborne telescope. And a month before, professors Philip Nicholson and Joseph Burns, PhD '66, had announced they'd discovered two new moons around Uranus.

These plums capped a banner year for space sciences at Cornell. In 1997, the massive Arecibo radio telescope fired back to life after a $30 million upgrade; researcher James Bell worked on the front lines of the historic Mars Pathfinder mission; and Professor Edwin Salpeter won the Crafoord Prize, astronomy's Nobel.

It has been almost an embarrassment of riches. The faculty are giddy. The university administration speaks of the astronomy department like a favored child bound for the Ivy League. If there is a downside, it is only the overwhelming paperwork. "This kind of good fortune isn't going to come our way all the time," Squyres says. "We couldn't stand it if it did."

Much of Cornell's boon has come from NASA's bust. Gone are the days the space agency could use its Cold War imperative to leverage a blank check from the government. When the *Challenger* exploded and the billion-dollar Hubble Space Telescope suffered from nearsightedness, NASA went into a tailspin. The public wanted accountability. What's more, with so many problems here on Earth and the Soviet Union crumbling, Congress decided it was time to put NASA on a strict allowance. But the agency still had a trump card—space.

TRACKING COMETS AND COLLECTING THE RED ROCKS OF MARS, CORNELL SPACE SCIENTISTS ARE ON THE (FINAL) FRONTIER OF THE NEW NASA.

BY JOHN YAUKEY & BETH SAULNIER

With limited resources, NASA launched a series of probes into the solar system that beamed back jaw-dropping images of stars exploding, iridescent moons orbiting majestic

dant

STEVE SQUYRES

planets, stars in their death throes, comets exploding into Jupiter's roiling atmosphere, dusty valleys on Mars, galaxies colliding at the edge of the universe.

It was a brilliant public relations campaign, capped in August 1996 when scientists found evidence of what could be microbial fossils in a Martian meteorite. NASA's two-and-a-half hour press conference crystallized theories about how life elsewhere is almost mathematically inevitable. Suddenly everyone wanted more of the final frontier, and NASA was more than happy to supply it.

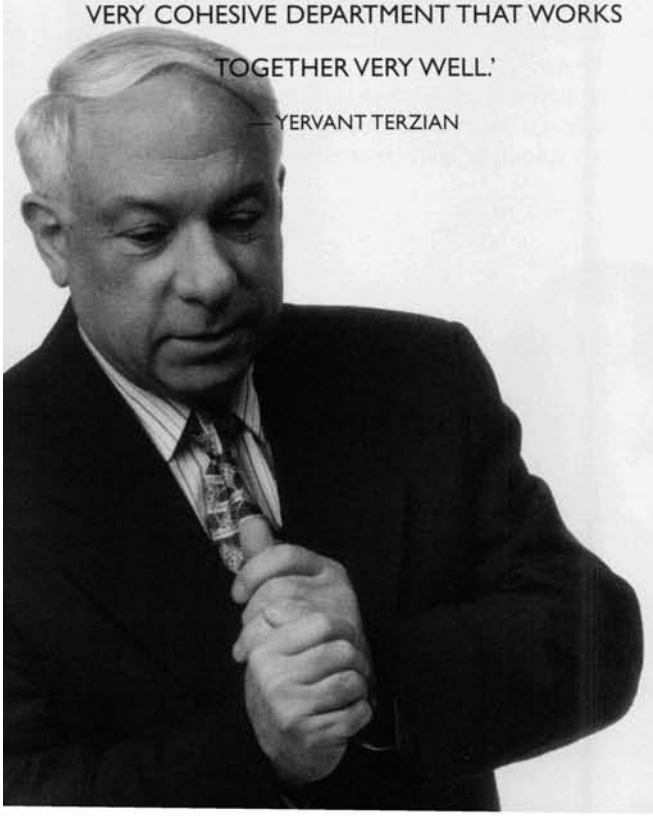
The agency is back on top, but it's not the same old NASA. Once a thinly veiled R&D extension of the military-industrial complex, NASA is now in pursuit of pure science, the stuff of wonder. Its old star players—buzz-cut fighter pilots boasting of Mig kills—have been replaced by bookish astronomers spouting a language of arc seconds, solar masses, and light years. The secrecy that once shrouded much of its research has been supplanted by an educational mission; any research proposal with a hope for success must involve the public. NASA's websites are among the most popular on the Internet.

The new NASA boasts a business acumen that has proved a blessing to research universities. Because, like any sensible corporation looking to cut costs, the space agency is outsourcing—and Cornell astronomers are taking all the work they can handle. During the 1996-97 academic year, the department secured ninety-one grants and contracts from NASA and others, bringing in a total of $10.6 million. "It is, on the average," says astronomy chairman Yervant Terzian, "one successful proposal every few days." Terzian leads a department of just fifteen paid faculty members; the other thirty-five people are research associates whose salaries must be generated through outside sources; as a result, the department has become a well-oiled grant-hunting machine. "This success," Terzian says, "didn't come suddenly upon us."

That Cornell finds itself ideally positioned to take lead roles in NASA missions is no accident. The space sciences department was molded by astronomers and astrophysicists who cut their teeth planning moon missions, building radar, and cracking the complexities of stellar fusion. Squyres, Veverka, and half a dozen others are working on projects from the aging Galileo probe now waltzing among the moons of Jupiter to the plutonium-powered Cassini probe racing toward Saturn. "Every major spacecraft mission has representation here at Cornell," says Bell. "If you're interested in something, you can just wander down the hall and talk to somebody."

'IT'S A HAPPY, HAPPY PLACE . . . WE HAVE A VERY COHESIVE DEPARTMENT THAT WORKS TOGETHER VERY WELL.'

—YERVANT TERZIAN



The department was founded in 1959, when Thomas Gold—a brusque, and some say brilliant, astronomer—was given a mandate to create a world-class space sciences presence at Cornell. In 1968, they recruited a cocky young astronomer from Harvard with a penchant for turtlenecks and a voice that resonated with wonder. The late Carl Sagan's superstardom as a poet laureate of science attracted publicity to the department that only a living extraterrestrial could have eclipsed. Cornell always had respect. But ensconced upstate, it suffered from isolation. Sagan closed the miles, drawing the international media through Ithaca's squat, two-gate airport. "It was a huge loss," Squyres says of his mentor's death in December 1996. "Carl was a unique treasure. You can't replace him. You just go on."

At the department's helm for the past nineteen years is Terzian, an astronomer known for his infectious enthusiasm as well as his natty dark suits. "I've got some fantastic images from the Hubble Space Telescope. Want to see them? Want to see them?" Terzian says one afternoon in December, gleefully calling up colorful images of dying stars. "Look at the symmetry on both sides. Isn't that beautiful looking? NASA decided they look so pretty, we should write a press release."

The son of an Armenian shoe merchant, Terzian was born in Alexandria, Egypt, after his family fled Greece to escape the Nazis. He caught the astronomy bug as a child, borrowing science books from the American embassy. "I remember being seven years old," he says, "giving lectures about astronomy and the stars to my Boy Scout troop." After graduating from the American University in Cairo, he came to grad school in the U.S. with $14 and two suitcases, one filled with books. He's been at Cornell since 1965, working his way up from research associate to department chair. "It's a happy, happy place," says Terzian, who is fluent in Greek, Armenian, Arabic, French, and English. "We have a very cohesive department that works together very well. Every individual faculty member is an international leader in his or her field."

Terzian's department is now a playground for many of astronomy's young Turks, bound for places their academic ancestors could only speculate about: studying the gases swirling around black holes, chasing comets to sniff the most primitive material in the solar system, flying over the Pacific to photograph dying stars in the infrared, and

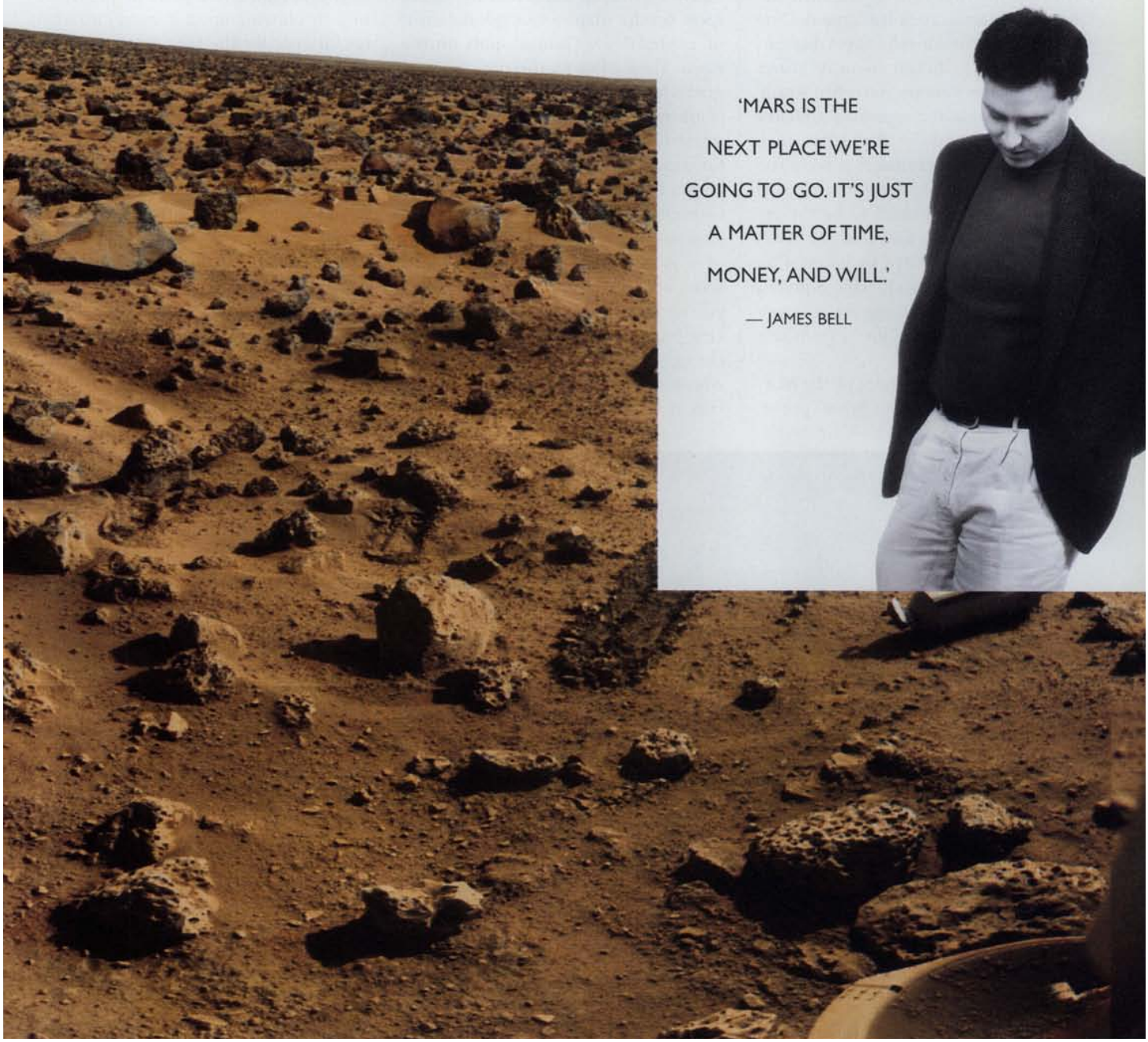
scouring Mars for life—a subject that has ignited some of modern science's most acrimonious debates.

MARS OR BUST

Steve Squyres is at the center of the maelstrom as he designs a rover that will explore a large corridor of the Martian highlands. There, it will collect dozens of rock and sediment samples for return to Earth on a future mission, samples that could contain the first hard evidence of life on the red planet. The six-wheeled Athena rover, which will deploy from a three-legged landing module, is scheduled for launch in April 2001 and arrival on Mars in 2002. In addition to looking for possible life-containing sediments, Athena's rover will gather planet samples that scientists hope will shed new light on the Martian climate billions of years ago, when the now-desolate planet may have been a warm, wet, nurturing environment. Since water is considered necessary for allowing organic molecules to dissolve, interact, and eventually form life, Athena will roam over what scientists suspect are old river and lake beds.

Athena will allow Squyres and his team to select and scrutinize rock and sediment samples that look promising. Thus far, the only samples Mars scientists have been able to examine come from the handful of meteorites that were randomly blasted into space and eventually landed here. "This thing came from who knows where," Squyres says of the controversial meteorite, dubbed ALH84001. "Athena will allow us to select what we think looks interesting. And that's a big difference." NASA will launch another mission in 2005 to retrieve Athena's specimens for arrival back on Earth in 2008.

Athena also boasts an array of highly sensitive on-board instruments capa-



'MARS IS THE NEXT PLACE WE'RE GOING TO GO. IT'S JUST A MATTER OF TIME, MONEY, AND WILL.'

— JAMES BELL

ble of doing on-site chemical analyses of the Martian samples. The front of the probe is equipped with a mosquito stinger-like drill to take samples through rocky surfaces. An imager and infrared spectrometer give Athena the ability to see through dust coatings that normally would obscure spectral analyses of the planet surface, and a microscope imager will reveal surface compositions in minute detail. "We're going to learn a lot from Athena," Squyres says, "whether those samples come back or not."

If Athena's samples turn out to be as tantalizing yet inconclusive as the ALH84001 meteorite, they're likely to rekindle the firestorm of scientific debate the Martian rock has ignited. Over the last fifteen months NASA has endured heavy criticism about its claims the rock may contain microbial fossils. Critics say that the supposedly lifelike chemicals found in the Mars rock formed at temperatures that were too high to support life; that the shapes of the fossils are too small to be the remains of bacteria; and that the Mars rock was contaminated by bacteria on Earth. "I'm equivocal," says Squyres, who is currently working on no fewer than seven NASA missions. "I go where the data take me."

Athena will cover more of the Martian surface than any other probe. Roughly the size of a riding mower with an eye-level antenna, the solar-powered rover marks a giant leap forward in unmanned space technology. Equipped with artificial intelligence, it will be able to navigate around obstacles on its own without time-consuming guidance signals from Earth. That means it can travel a hundred meters a day instead of just a few meters like, the Sojourner rover used in the recent Pathfinder mission to Mars. "If you're an exploration junky like I am," Squyres says, "the satisfaction you get from a mission like this—when it actually works—is fantastic."

A self-described nerd in childhood, Squyres grew up fascinated by "blank spots on the map"—unexplored areas of central New Guinea, spots on the ocean floor. "But by the time I got to grad school," he says, "there weren't any blank spots on the map anymore." His interest in science, married to a passion for mountain climbing, led to an undergraduate degree in geology at Cornell in 1978. He got hooked on astronomy as an undergrad, when, as part of a grad-level course, he spent four hours in the "Mars room" in Clark Hall poring over photos from the 1972 Viking probe. "That was one of those life-changing experiences," says Squyres, who earned an astronomy PhD on the Hill in 1981. "I came out of that room knowing exactly what I wanted to do for the rest of my life. There was this whole world there—this entire, unexplored world."

Squyres's quest to understand conditions on other planets and moons has driven him to study the Antarctic "dry valley," which may resemble Martian lake beds from 4 billion years ago. To explore netherworldly aquatic environments, he has donned insulating SCUBA gear and swum Antarctic lakes. Now he's preparing to come as close to living on Mars as anyone in the foreseeable future will, by surveying the expanses of the planet vicariously through Athena. Once she lands, Squyres will immerse himself in everything Martian, including the longer Martian day. "Each day I'll go to bed thirty-six minutes later," he says with relish. "I'm going to have to live on Mars time."

At the earliest, Squyres' labor will pay off in eleven years—or perhaps not at all. Like policemen and movie actors, astronomers have jobs that require them to hurry up and wait. "This field is not for people who require immediate gratification, and it's not for people who don't like taking risks," says Veverka, recalling the Mars Observer craft that ended five years of preparation by blowing up as it went into orbit. "It's not for the faint-hearted." The iffy nature of astronomy is summed up in a newspaper headline on Veverka's office wall: SHRIMP BOAT DELAYS LAUNCH FOR NASA. But although data can be years in coming, its very elusiveness gives it an extraordinarily long shelf life. "Before Pathfinder, the last landing on Mars was twenty years ago," says Bell, "and there are still new research papers being published on the data."

Bell became something of a local celebrity last summer, when he helped interpret images from the Mars rover; on a trip home to his native Rhode Island, the local press even did a story on what his two small children thought of their dad's job. "I think people are fascinated with going someplace, not just cruising around the Earth," says Bell, who sports a *Star Trek* communicator badge on his fleece jacket. "Mars is the next place we're going to go. It's just a matter of time, money, and will."

COMET TAILS

Bell has a hand in both of the department's high-profile missions: he is a member of Squyres's Athena team and Veverka's CONTOUR crew. The latter, short for Comet Nucleus Tour, culminates a two-decade-long effort by Veverka and others to get a close look at comets, which have fascinated people for millennia. Throughout history, they've

'THIS IS TRUE EXPLORATION,' JOE VEVERKA SAYS OF THE $154-MILLION COMET FORAY, THE BIGGEST SINGLE-MISSION GRANT IN CORNELL HISTORY. 'WE DON'T KNOW WHAT WE'LL FIND.'

been considered divine symbols, even harbingers of doom; witness last year's Heaven's Gate debacle, in which thirty-nine people killed themselves believing that Comet Hale-Bopp was a cue for them to move beyond their earthly existence.

Lately, astronomers have begun to suspect that comets may well have contributed to the formation of life on Earth, possibly supplying some of the planet's primordial organic compounds. CONTOUR, set for launch in 2002, is designed to find out what these nomadic ice balls are made of. About the size of a small car, the solar-powered probe will fly by three comets to take images, do spectral studies, and collect gases for on-board chemical analysis. The mission represents a new level of daring in cosmic voyeurism. The comet imaging will be done from as close as sixty miles, detecting surface features as small as three meters. "This is true exploration," Veverka says of the $154-million foray, the biggest single-mission grant in Cornell history. "We don't know what we'll find."

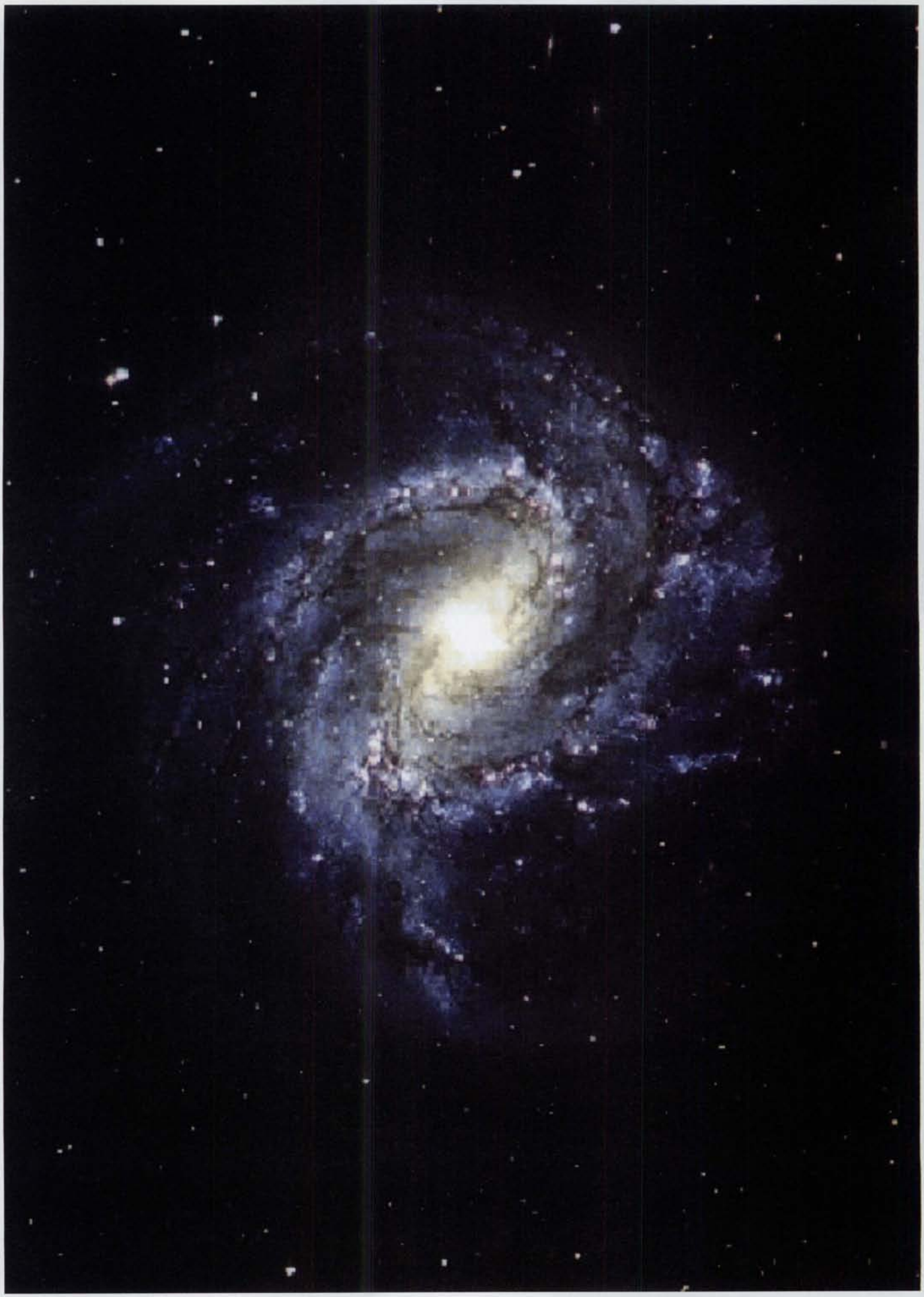
Scientists believe that comets are leftovers from the formation of the solar system, when gases swirled together to form the sun and debris was bound up into the planets. Comets formed in the frigid outer regions of the solar system, where there wasn't enough coalescing debris to accumulate into anything planet-sized and the sun's rays did little to relieve the interstellar chill.

Billions of comets are thought to lurk beyond the planets. Over time, a few have escaped the distant deep freeze and sped to the inner solar system, lighting up Earth's skies. Theories suggest that comets several miles across provided some of the Earth's water when they collided with the planet and melted. Comets may also have brought organic compounds to the planet, possibly playing an important role in the formation of amino acids and, ultimately, simple life forms. "It's all about hope," says Bell. "That's what space exploration is all about. All these *Alien* movies, *Contact*, *Starship Troopers*—there's a real interest in this stuff. It's just a blast to be part of it."

SEEING RED

The subjects of yet another space science project sound like matinee fodder themselves. At the core of the Milky Way, what appears to be a black hole devours streams of gas ripped from space by gravity strong enough to digest light. Nearby in the Orion Nebula, a cocoon of dust envelops infant stars. At the edge of observable space, galaxies waltz together like ballroom dancers.

These are the kinds of tantalizing targets Cornell astronomers are eager to explore from the fringes of the Earth's atmosphere aboard a new airborne observatory they will help build and operate for NASA. Called SOFIA, for Stratospheric Observatory for Infrared Astronomy, the project consists of a 747 fitted with an infrared telescope that will deploy from a garage-door-sized



hole cut in the aft section of the fuselage. "You should have seen the FAA people when we told them what we wanted to do—cut a hole in the side of this airplane and point a telescope out of it," says George Gull '72, a Cornell mechanical engineer who will design and build an infrared camera for the telescope. "Their jaws hit the floor."

Cornell astronomers Terry Herter and Gordon Stacey, PhD '85, will use the camera Gull is building to study a variety of astronomical phenomena when SOFIA begins flying in 2001. "We'll be able to take 'pictures' of regions you can't see with an optical telescope," Herter says. "We hope to look through dust and gas clouds to see stars in their earliest stages of formation, before they've said to the universe, 'Here I am.'"

SOFIA may also help answer nagging questions about what scientists believe is a black hole at the core of the Milky Way. Normally, as black holes draw in surrounding gases they emit tremendous amounts of energy, but the Milky Way's black hole is not emitting anywhere near as much as it should. "Is it episodic?" Stacey asks. "Are we witnessing it in a quiet state? We don't know."

Based at NASA's Ames Research Center near San Jose, SOFIA is expected to give astronomers at least 960 research hours per year in flights over the Pacific and other strategic destinations. The project represents the resurrection of NASA's twenty-five-year-old airborne astronomy program, which rose from the ashes of cancellation two years ago. Herter, Gull, and Stacey had been working aboard SOFIA's predecessor, a military C-141 transport jet known as the Kuiper Airborne Observatory, before it was grounded in 1995 for lack of funds. "At that point we thought we were out of business," Gull says. "Now we're going to be airborne again." Astronomers are excited about the opportunity for two reasons. First, flying at 41,000 feet, the 747 will lift them and their equipment well above the moisture in the atmosphere which absorbs valuable light. Second, it will carry an infrared telescope 100 inches in diameter, ten times more sensitive than the instrument that flew aboard the Kuiper observatory.

Infrared light has longer wavelengths than visible light, occupying the part of the electromagnetic spectrum between visible light and microwave radio. Almost everything in the universe—from warm human bodies to cooling stars—emits radiation in the infrared. This light, however, is too weak to record on photographs and too high-frequency to pick up with radio astronomy. Infrared telescopes can peer through the dust and gas clouds that block optical telescopes like the Hubble, which detects light in wavelengths that the human eye can see. Special infrared sensors capable of detecting this light were first developed by the military for spotting enemy soldiers in the dark and later for cruise missile guidance systems. The gradual release of this technology to the public has spawned great interest in infrared astronomy. Many astronomers believe the field is poised for a renaissance of discovery. "You can't just sit back on your laurels," says Professor Martha Haynes. "The field is way too competitive for that."

Having decided that the university needs to strike out boldly to remain at the forefront of astronomy, the faculty narrowed a field of twelve possible projects to one: an infrared telescope on Chile's Atacama Plateau. The department is in the midst of a feasibility study on the telescope, which may be built with the University of Texas. At 16,000 feet, there is no memory of rain on Atacama. The obscuring vapor that gives stars their false sparkle is absent at this spot, where the Earth reaches up into the cold nothingness of space.

Haynes dreams of the thin air there, where ancient light from the edge of the universe comes out of the darkness high above the fray of civilization. A telescope of the type Cornell is considering would allow astronomers to see light created by events that occurred at around the time galaxies probably started appearing, some 12 billion years ago. What they'll find is anyone's guess. Throughout history, astronomy has posed as many mysteries as it has solved. Recent observations by the Hubble Telescope indicate these early galaxies got out of the starting block fast, with some fully formed by their billionth birthday. These football-shaped galaxies appear as mature as their modern counterparts. This is perplexing, because no current models can explain how the mix of primordial gases created in the Big Bang could have organized itself so quickly.

Astronomy has caught only the faintest glimpses from this distant epoch, and already complications are brewing. But these are the deliciously big questions Cornell space scientists relish. "I'd like to think that maybe 100 years from now we'll have a good idea of how galaxies really work," Haynes says. "I would hope we understand them the way we do the planets now. But you know, there's a lot about the planets we still haven't figured out."

JOHN YAUKEY *is a science writer for Gannett News Service.* BETH SAULNIER *is an associate editor of* Cornell Magazine.

'YOU CAN'T JUST SIT BACK ON YOUR LAURELS. THE FIELD IS WAY TOO COMPETITIVE FOR THAT.'

— MARTHA HAYNES

"Stars in the Ascendant," by John Yaukey & Beth Saulnier, *Cornell Magazine*, v100n5 (Mar/Apr 1998), cover & pp 36-43.

Galaxy Quest

MORE POWER FOR ARECIBO

FRANK DIMEO / AIP

A NEW, $1.2 MILLION INSTRUMENT AT Arecibo Observatory "is going to offer a sea change in the way science is done," says Cornell astronomy professor Martha Haynes. The Arecibo L-band Feed Array, dubbed ALFA, is scheduled to begin operation around 2005. Researchers hope it will allow for the further discovery of pulsars (fast-spinning neutron stars) or even the holy grail of astronomy, a pulsar in orbit around a black hole.

The new array is one of several changes at the facility, located in northwestern Puerto Rico and managed by Cornell. The completion of fiber-optic cables from Arecibo to San Juan, and then to the U.S. mainland, has allowed researchers all over the world to control the radio telescope remotely. Plans are also under way to link the telescope to others in the U.S. and Europe, forming one massive instrument to detect new astronomical sources. "We could watch pulsars move across the sky in a matter of months, or watch supernovas explode," says Haynes. "It hasn't been done before because Arecibo wasn't properly equipped." In January, the facility got a new leader when Robert Brown was named director of the National Astronomy and Ionosphere Center, whose main research site is Arecibo. Brown, formerly deputy director of the National Radio Astronomy Observatory, succeeds Cornell physical sciences professor Paul Goldsmith in the post.

"Galaxy Quest: More Power for Arecibo," *Cornell Alumni News*, v105n5 (Mar/Apr 2003), p 15.

CORNELL
Alumni Magazine

Contents

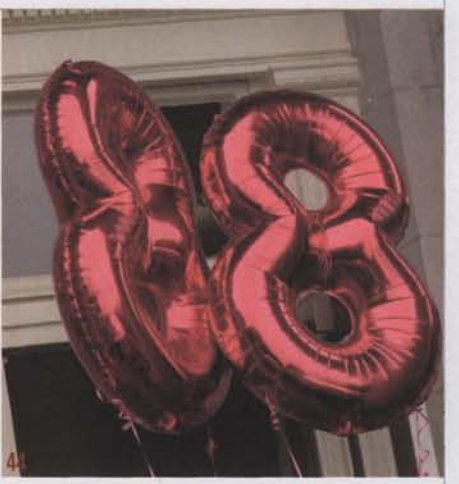
SEPTEMBER / OCTOBER 2003
VOLUME 106 NUMBER 2

44 Reunion 2003
STAFF
They came, they saw, they parked on the grass. A glimpse of the weekend that was: seventy-two hours of receptions, activities, and general campus-wide merrymaking that spanned the generations. Experience it all again, this time without the rain.

52 The Wrong Man
DAVID DUDLEY
Astronomy professor emeritus Thomas Gold has spent his life questioning the scientific orthodoxy about everything from the clockwork of the universe to the origins of life on Earth. Trying to prove the experts wrong, however, has come at a price.

60 Young Guns
SHARON TREGASKIS
In 1892, a teenage boy named Charley Miller was hanged in Wyoming for a double murder. In his story, historian Joan Jacobs Brumberg finds a case study in violence, adolescence, and the media in an earlier America. "For me this was the flip side of the Horatio Alger story," she says. "There's this enormous mythology about success in America. Charley Miller was a dismal failure on all counts."

Cover illustration by Stefanie Green



4 Letter From Ithaca
Counting on diversity

6 Correspondence
Chewing the fat

16 From the Hill
Lehman takes the reins. *Plus*: downtown groundbreaking, a pair of blast-offs, new home for old bones, and CAM blows its own horn.

22 Authors
A novelist's weighty debut

24 Sports
Net loss

26 Currents
Music pirates attack. *Plus*: wee sea turtles, composting cows, mad mice, gnarled roots, and Ann Coulter.

42 Wines of the Finger Lakes
Featured: 2002 Anthony Road Finger Lakes Pinot Gris

68 Classifieds & Cornellians in Business

71 Alma Matters

74 Reunion Notes

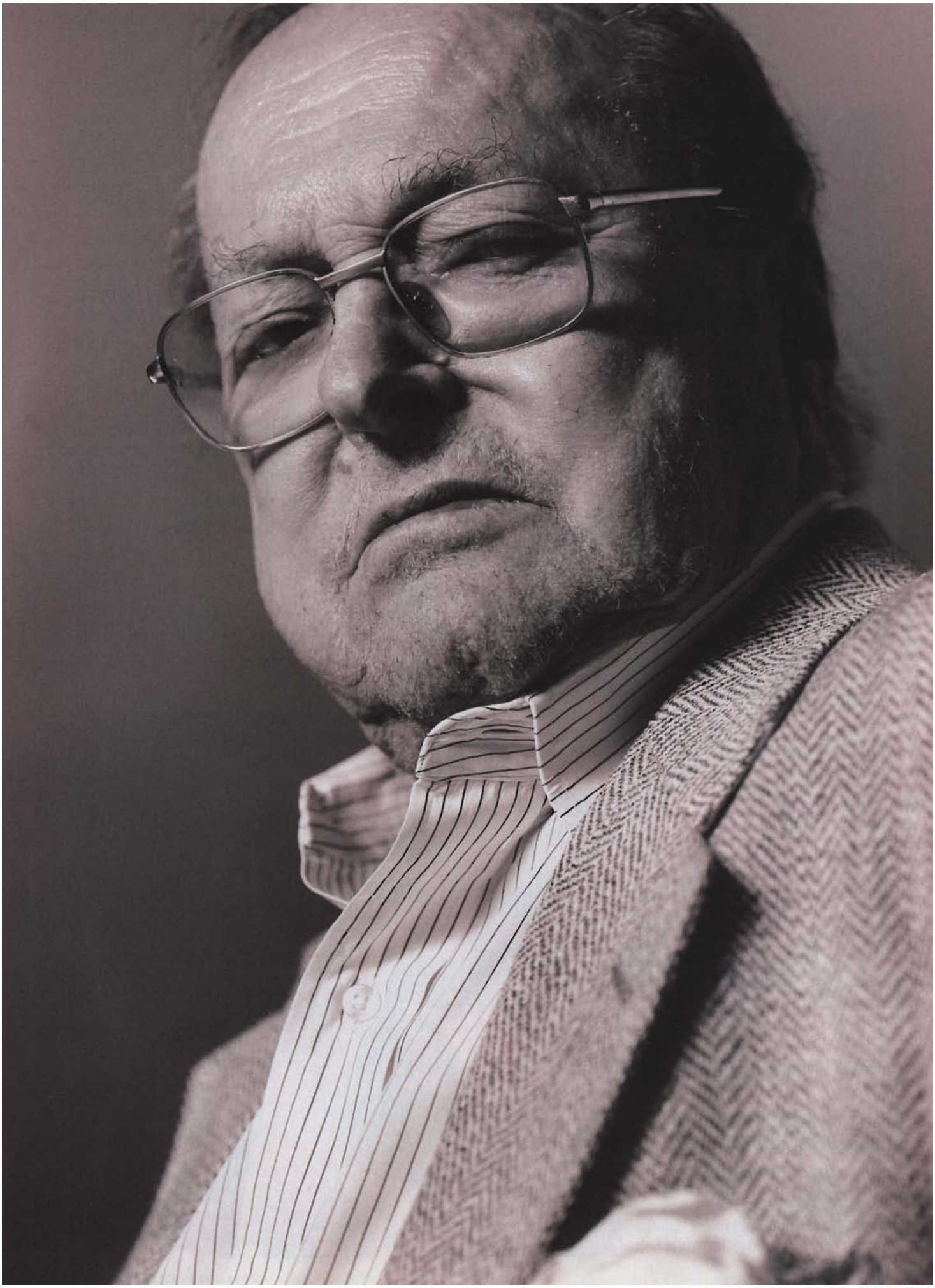
86 Class Notes

124 Alumni Deaths

128 Cornelliana
Glass menagerie

Cornell Alumni Magazine (ISSN 1070-2733) is published six times a year, in January, March, May, July, September, and November, by the Cornell Alumni Federation, 55 Brown Road, Ithaca, NY 14850-1247. Subscriptions cost $29 a year. Second-class postage paid at Ithaca, NY, and additional mailing offices. POSTMASTER: Send address changes to Cornell Alumni Magazine, c/o Public Affairs Records, 55 Brown Road, Ithaca, NY 14850-1247.

"The Wrong Man," by David Dudley, *Cornell Alumni Magazine*, v106n2 (Sep/Oct 2003), pp 52-59. Astronomy professor emeritus Thomas Gold has spent his life questioning the scientific orthodoxy about everything from the clockwork of the universe to the origins of life on Earth. Trying to prove the experts wrong, however, has come at a price.



Friends of retired astrophysicist and full-time contrarian Thomas Gold say he should be quietly tending his legacy as one of the maverick giants of modern astronomy. Instead, he's doing what he does best: making people very angry.

the wrong man

By David Dudley

What would you do if you figured everything out, and no one believed you?

This is Thomas Gold's never-ending story, the distillation of a long career of outrage and insight. The plot goes like this: distinguished but controversial scientist proposes radical idea in some unfamiliar field, something strangely plausible and yet completely heretical about, well, anything—dust on the Moon, or the origin of life, or how the inner ear works. The experts ignore it, or dismiss it, or shake their fists at it. Time passes: years, sometimes decades. And then it turns out the oddball scientist was right after all, or at least half right. But by then no one remembers. Or, perhaps, they prefer not to.

What they do remember is that Tommy Gold, the polymathic Vienna-born astrophysicist and longtime head of Cornell's astronomy department, is one of the premier scientific provocateurs of his time. He has lived and worked in a roiling state of near-perpetual controversy for nearly sixty years, with no end in sight. Gold first found fame of a sort as one of the three architects of the alternative Steady State model of the universe, which dueled with the arch-rival Big Bang for the hearts and minds of the scientific establishment during the 1950s. And they also remember what eventually happened to their theory—tossed, after mighty effort and rancorous debate, into cosmology's bulging dustbin. No one believes in the thing now, and Gold's name is forever associated, along with collaborators Hermann Bondi and Fred Hoyle, with a wrong idea.

If he is even half right, much of what we take for granted about life on Earth will be dramatically changed. But Gold is rarely interested in being half right.

Retired since 1985, Gold has spent much of the last twenty years championing another notion that few mainstream scientists seriously consider—that petroleum is not a "fossil fuel" derived from decomposed plants and animals, but a primordial hydrocarbon that wells up from deep within the planet, providing food and energy for a vast underground bacterial biosphere that thrives miles beneath the crust. What's more, Gold believes that surface-dwellers like us evolved up from this rocky subsurface life, not from the organic soup biology textbooks suggest. The idea formed the basis for his 1999 book, *The Deep Hot Biosphere*, and, if recent discoveries of abiogenic (or non-biologically derived) methane gas and deep-dwelling microbes are to be believed, Gold may yet be proven more correct than many geologists and biologists would prefer. If he's even half right, much of what we take for granted about life on Earth—not to mention the global economy—will be dramatically changed. But Gold is rarely interested in being half right.

"It's completely ridiculous to even debate the issue anymore," he mutters. And then he does just that, patiently restating the geological and chemical evidence he has gathered over the past decades. Gold is eighty-three now, slightly stooped and surprisingly frail for those who remember him as a vigorous ex-athlete, a skier and scuba diver who water-skied Cayuga Lake and entertained cocktail party guests by walking a backyard tightrope, martini in hand. His voice, still bearing the courtly trace of an Austro-English accent, now sometimes barely rises above a whisper. There are only glimpses of the flamboyant scientific streetfighter known and feared for his ability to construct convincing arguments for implausible phenomena. "I don't know if I ever saw him back down from any point of view that he had," says UC Santa Barbara astrophysicist Stan Peale, PhD '65, who was Gold's advisee at Cornell. "It's impossible to reason with him. There's no consideration that he might be wrong."

True to form, Gold refuses to soft-pedal his theory's most controversial claim—that all commercial oil, coal, and natural gas is non-biological in origin and exists in vast and nearly limitless supply. "What people want me to say is that maybe both things exist—non-biological *and* biological petroleum," he says. But compromise seems unlikely. He shakes his head sadly.

"That," he says, "would not be my style."

On a warm June day, the work continues in a stuffy attic over the garage. Gold says he puts in four hours daily here in the office atop his Cayuga Heights home, a room lined with file cabinets straining to contain the paperwork of his far-flung enthusiasms. He's looking for one particular photograph, a close-up of a crater on the asteroid Eros that illustrates his theory of electrostatic dust levitation. But the photo is missing from its proper folder and can't be found. "My wife has tidied up my office, and the result is disastrous," he says, poking into stacks of scientific journals.

Lately, Gold has been doing, in his words, "some novel work on a somewhat esoteric subject"—an issue related to electromagnetic radiation pressure that he believes poses a heretofore unseen conflict between the laws of conservation of momentum and conservation of energy. "You wouldn't think so, but there are so many basic unsolved problems in physics," he says. This is typical for Gold, who has a well-deserved reputation for correcting, gleefully, other people's fundamental errors. As a young lecturer he made a habit of reading popular textbooks in every imaginable field, looking for mistakes—

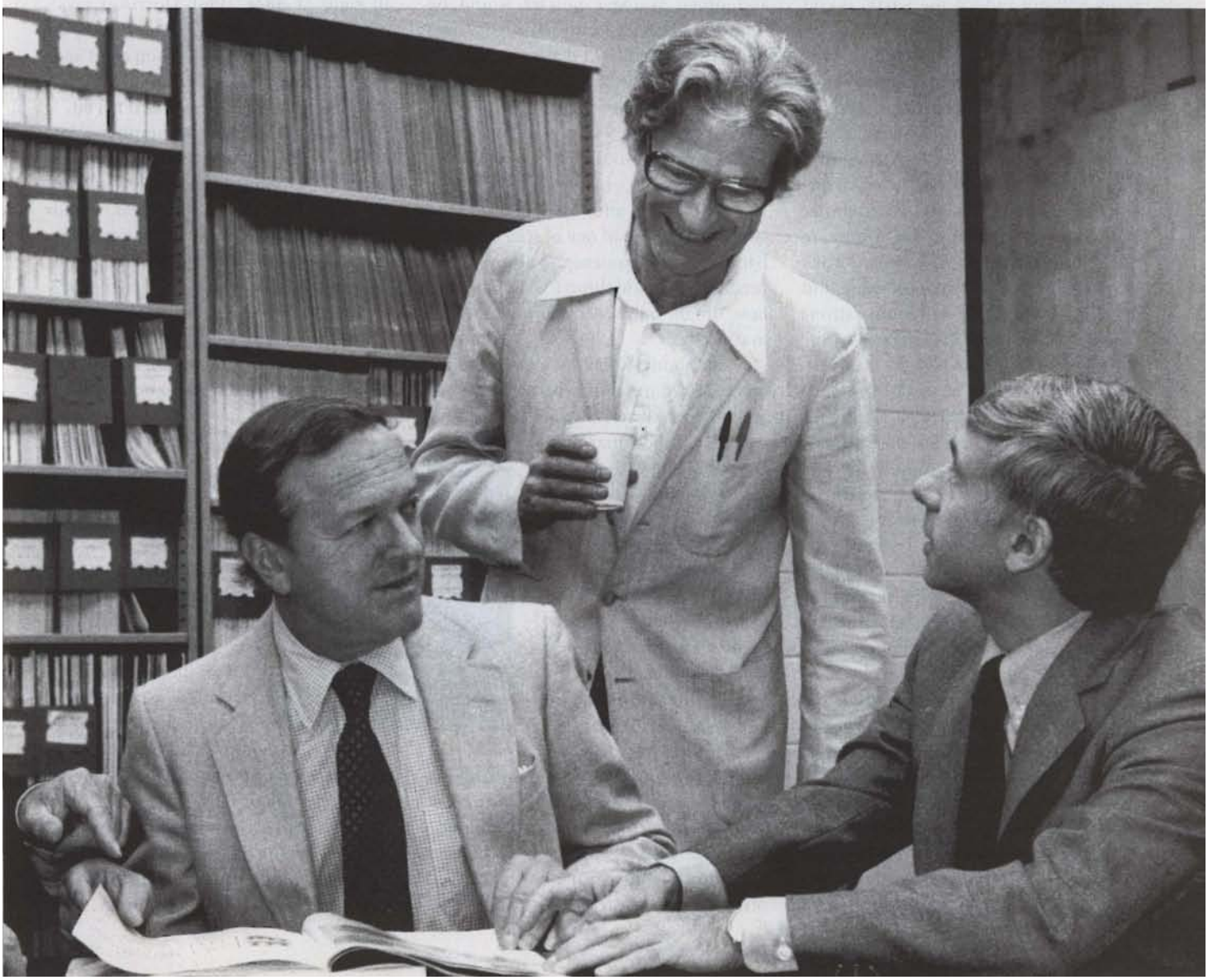
DIVISION OF RARE AND MANUSCRIPT COLLECTIONS / CARL A. KROCH LIBRARY / CORNELL

and alerting the authors when he found one. In this case, he thinks he's poked holes in the assumption behind a popular space travel idea. "Have you heard of the theory of the solar sail, where you use the sun's radiation to propel a spacecraft?" he asks. "Well, it won't work." In September, a private foundation plans to launch the first working solar sail into orbit, and Gold is eager to be on record predicting its impending failure. But he's unable to find a peer-reviewed publication that will take his paper. "To get it into a journal seems out of the question," he says. "I can't find seven people who can understand it."

This, too, is typical for Gold, who has never made a secret of his unhappiness with the hidebound conventions of proper mainstream science. He is a sharp critic of peer review and the resulting blind "herd mentality" that, he believes, stifles the sort of cross-disciplinary work that once bred great innovation. "Gold is no respecter of authority," says friend and former student Steven Soter, PhD '71, now an astronomer at New York's Hayden Planetarium. "One of his credos in school was, 'There is no virtue in timidity and no shame in being wrong.' "

It was a lesson Gold learned early. Educated in a Swiss boarding school, he was studying engineering at Cambridge University when the war intervened; as an Austrian citizen, Gold was temporarily interned in Canada with a fellow Viennese, mathematician Hermann Bondi. After their release, the two were recruited in the British war effort, working on radar research with astronomer and future collaborator Fred Hoyle. It was Gold's engineering background in radar that led him, after the war ended and he had obtained a position as a physics lecturer at Cambridge's Trinity College, to think about how the inner ear worked. Gold thought that, like a radio amplifier, the ear must have some sort of electrical feedback system, and he designed a series of elegant experiments to test the theory, using instruments to listen for the faint sounds of this feedback coming from the ear itself. When he published the results in 1948, the idea was ignored by the auditory experts of the time. "The physiologists didn't understand it," remembers physicist Freeman Dyson, who met Gold at Trinity in 1946 and participated in his experiments. "They thought, well, obviously this guy doesn't know what he's talking about, since he wasn't a member of the club."

Masters of the universe (left to right): Mathematician Hermann Bondi with Gold, Ed Salpeter, and Yervant Terzian at Cornell in the late 1960s.



Thirty years later, British engineer David Kemp detected the sounds Gold had been searching for—"otoacoustic emissions" from the cochlea—and in the 1980s the hypothesis of positive feedback in mammalian hearing was finally validated. The experience left Gold with an enduring lesson: the experts can be very wrong. "I had no doubt that I was giving the right explanation," he says. "And, of course, I was quite disappointed as years and years went by and I couldn't persuade anyone else. I can't help thinking that I was the person who explained the function of the second most important sensory system that we have."

'You can't have a new idea and get it all right at once,' says physicist Phil Morrison. 'Only Einstein could do that. Tommy is 90-percent ironclad.'

Gold learned something else from his brief foray into auditory physiology. "The greater the opposition a theory has, the greater the credit that you get for it when it is finally proved right," he says. "No, the meek will not inherit the Earth, if you know that stupid phrase."

As Gold's early career proved, he lived by that rule. After making scientific waves with the Steady State theory and engaging radio astronomer Martin Ryle in a celebrated disagreement over galactic radio sources in 1951 (Gold won), he was made chief assistant to Britain's Astronomer Royal by 1953. In 1955, Harvard made him a full professor at thirty-two. Cornell lured Gold away in 1958, promising him a free hand to establish a serious astronomy department. Former chairman Yervant Terzian, who arrived in Ithaca in 1965 and ran the department from 1979 until 1999, credits Gold with building it into a space sciences powerhouse, founding the Center for Radiophysics and Space Research in 1959, overseeing the running of the huge Arecibo Observatory throughout the 1960s, and seeding the growing department with similarly adventurous souls like SETI pioneer Frank Drake and the late Carl Sagan. "Modern astronomy," Terzian declares, "started with Tommy at Cornell."

"He was extraordinarily original and thorough," says Phil Morrison of MIT, who was then on the physics faculty at Cornell and, with fellow Manhattan Project veteran Hans Bethe, recruited Gold for the astronomy post. "Always interested in the new and chancy. He didn't accept any words without understanding what they really meant." Physics professor Ed Salpeter marveled at Gold's "immense drive"—and utter fearlessness. "I've not been as courageous as Tommy," he says. "He's gone into totally different fields, just working on his own."

Gold's daredevil approach made headlines and ruffled feathers. When the first pulsars were discovered in 1967, Gold stated that the strange, regular radio signals that galvanized the world were coming not from other civilizations but from a rapidly spinning neutron star, the then-theoretical superdense remnant of a supernova. He further predicted that the pulses would slow as the star decelerated, and other, younger pulsars would be found spinning at a much higher frequency. "I already had that answer in my head," he says. Few believed him. At a conference convened to investigate the mystery, Gold says he was denied floor time: the idea was too outlandish to consider. Within months, his explanation was proven correct, and Gold enjoyed the sweet redemption of one of science's great I-told-you-so moments. "I always make predictions in anything I write," he says now. "It's the only way to get your enemies to concede."

Gold should know. By most accounts, he's collected more than his share of professional adversaries. During the Apollo lunar program, his feud with the late astrogeologist Gene Shoemaker was the stuff of legend. Back in 1955, Gold had theorized that the Moon's maria were covered in a deep layer of dust, while Shoemaker's team of NASA geologists insisted that the surface was hard and volcanic. In 1965 Gold warned that this dust was potentially thick enough to endanger a lunar lander. ("If I were at the controls of an Apollo vehicle tomorrow," he told the *New York Times*, "I would not be willing to set it down—and I am a daring man in other things—for fear that it would sink too much.") NASA geologists thought otherwise, and when Neal Armstrong made his famous first steps in 1969, Gold's "lunar quicksand" was promptly ridiculed. Mention of the topic infuriates him to this day. (Gold now calls the notion that the astronauts would sink out of sight "a pure invention" of Shoemaker, and notes that he wouldn't have designed a stereoscopic camera for Apollo 11 if he'd thought it would disappear in the dust.) Lost in the furor was the fact that Gold's early vision of a fine, powdery surface was otherwise accurate.

"You can't have a new idea and get it all right at once," Phil Morrison says. "Only Einstein could do that. Tommy is 90-percent ironclad." (Morrison says Gold is right about his deep biosphere, too—even if he may have "exaggerated it a bit.") Freeman Dyson puts the number a bit lower. "I think his batting average is around 50 percent, which is pretty good if you have a lot of original ideas." Gold himself stakes out a bolder position.

"I deny that I've made *any* significant mistakes," he says of his published work. "I insist on being right." His eyes are flashing, and for an electric moment he is the swashbuckler of old. "You tell me—what do you think I was wrong about?"

Peter Goldreich '60, PhD '63, was an engineering physics undergrad when he met Gold in 1960. "He sort of adopted me," remembers the Caltech astrophysicist. Gold would serve not only as his graduate advisor, but his landlord: Goldreich and his wife moved into a top floor apartment in the Gold family's home on Cayuga Heights Road. There, between bouts of Ping-Pong, Goldreich had a front-row seat for his mentor's stormy adventures. "He was a scientific explorer," Goldreich says. "He'd sort of stitch together a tapestry of things. And

Fuel On The Fire

Considering its importance to the global economy, one might think that scientists would have figured out where oil comes from by now. But debates about the origins of petroleum have persisted ever since the stuff was discovered. The Russian chemist D.I. Mendeleyev, developer of the periodic table of the elements, proposed that oil was non-biological in 1877, and many of his countrymen concurred—some Russian experts now subcribe to an abiogenic petroleum model. But since the late nineteenth century, the conventional view has been that coal, oil, and natural gas were all created from buried biological debris, cooked by heat and pressure over the millennia. Oil contains the unmistakable molecular fingerprints of biological material, and its predominance near the surface in geologically young sedimentary rock would seem to seal the case.

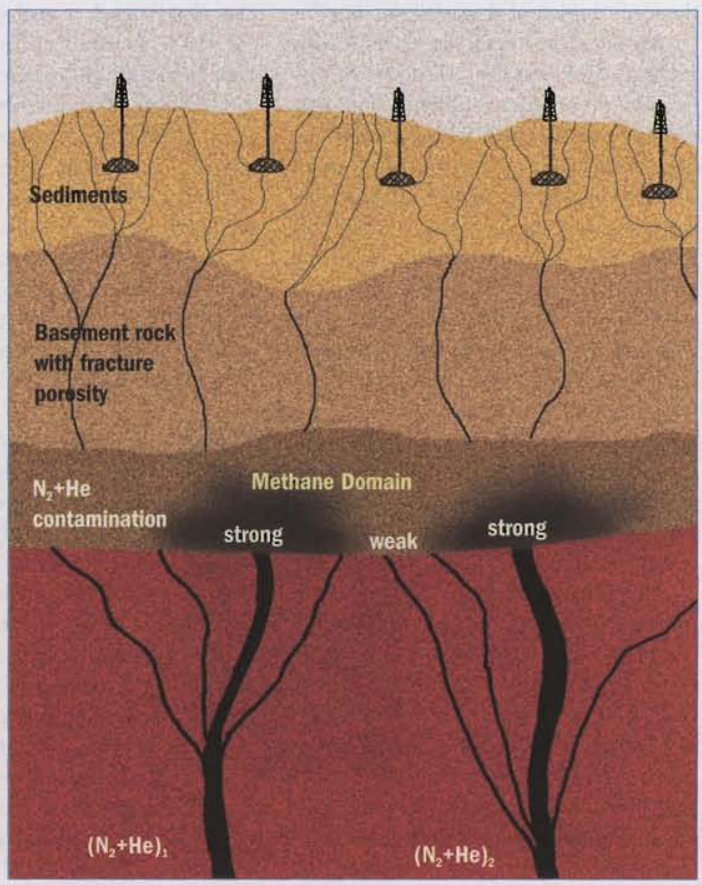
Thomas Gold, however, approached petroleum from a typically cosmic perspective. Hydrocarbon compounds, astronomers know, are abundant throughout the solar system and beyond, from the methane clouds of Saturn's moon Titan to grains of interplanetary dust. Why, then, must our hydrocarbons come from buried prehistoric forests? "The earth is, after all, a planet," Gold writes in *The Deep Hot Biosphere*. His theory turns the formation process upside down: the gas is coming up from below, from primordial hydrocarbon molecules present since the Earth's birth 4.5 billion years ago. As these lighter hydrocarbons seep upwards through the mantle to the crust, they are chemically altered deep underground and turn into the various forms of petroleum that eventually collect in near-surface reservoirs and coal seams. Gold posits that the "biomarkers" in oil are not evidence of biological origin but signs of primitive microbes that feed on hydrocarbons miles beneath the surface.

An abiogenic theory would help explain several petro-oddities: a Gulf of Mexico reservoir that is mysteriously "refilling" itself, coal seams so thick that only eons of dense forests could have compacted to create them, oil fields off the coast of Vietnam producing crude from solid granite basement rock where no dinosaur ever walked. But Gold's favorite evidence involves helium—an inert "noble gas" that is concentrated only in association with natural gas deposits. Gold believes that the helium, which is distributed in minute traces throughout the planet, must be swept up by the migrating hydrocarbons. "You can't pull the helium in sideways," he says. "There's just no way you could make it always flow towards the petroleum—there's no chemical affinity. The only way you can concentrate it is by gathering it up from the greatest depth."

Most petroleum geologists remain unconvinced, but several recent findings support Gold's vision of a massive subsurface microbial realm: bacterial life has been found thriving at depths and temperatures once thought impossible. And in 2002, a University of Toronto geochemist proved that hydrocarbon gases discovered two kilometers deep in an Ontario mine were indeed abiogenic, though their isotopic signature didn't match that of hydrocarbons from commercial fields.

Next summer, the American Association of Petroleum Geologists (AAPG) plans to convene a conference on the petroleum origin debate, bringing supporters of the traditional and the abiogenic models together. "[Gold's] theory is conceivable—it could have happened that way," says geologist and legendary Texas wildcatter Michel Halbouty, who is one of the conference conveners. Fully half of the papers he has received are in the abiogenic school, and Halbouty allows that some of their evidence is compelling. "It makes me believe that there may be something to it."

Gold, however, says he'll sit out this round: he doubts he'll get a fair hearing. "All the AAPG will do is make sure they have enough applicants who support their traditional viewpoint, to overwhelm the rest," he says, shaking his head. "The petroleum geologists will never give in. It's absolutely hopeless."



ADAPTED FROM THE DEEP HOT BIOSPHERE, 1999, P. 76

Volatile issue: Why does helium, an inert element, get concentrated in natural gas fields? In Gold's deep-earth gas theory, the helium hitches a ride with upwelling nitrogen and is mixed with methane.

sometimes he got it completely wrong." Gold's freewheeling style was, Goldreich recalls, of mixed benefit. "For students like me, having a person who spewed forth ideas—some of them half-baked, stuff you wouldn't read in books—this was unusual and very valuable," he remembers. "He was very good at suggesting that there were all these puzzles out there, and if you were a clever guy you could think about all of them."

And Gold did. In his spare time, the former engineer was an inveterate tinkerer, constantly dreaming up unlikely inventions. Some worked better than others: the hydrofoil waterskis were difficult to control, and the no-shovel driveway—with electric heating elements buried in the concrete—proved no match for Ithaca winters. Gold says he tried, and failed, to interest manufacturers in the concept of the ground-fault circuit interrupter years before electrical engineer Charles Dalziel patented the now-familiar household safety device in 1961. "I just thought of it," Gold shrugs, when asked what inspired the idea. "I think of things all the time."

This, students recall, was what life with Professor Gold was like. "He'd play Aristotle, and we graduate students would sit around and listen to him," remembers Stan Peale. "He was really an idea man; he'd have all these ideas, and he'd keep students busy investigating them. He had this incredible intuition and grasp of elementary physics, and he would always look at a problem in a very broad sense, so he would be aware of things that all the specialists who focus on one narrow thing weren't aware of. He was very good at picking these things out—and he was sort of ruthless in showing them how they were wrong, too."

Gold's fondness for flitting from discipline to discipline—and, says Goldreich, the fact that "he was willing to comment on just about anything"—infuriated experts in various fields, who did not always welcome outside input. Gold was also a skillful salesman for his ideas: the more cautious Apollo-era scientists who tangled with Gold during the 1960s were often left in the dust by his Cambridge-honed debating tactics. "Tommy tended to confuse winning arguments with searching for truth," Goldreich says. "He would have been a great lawyer." Peale recalls that Gold "could just devastate people" with verbal attacks. "He was once described to me as 'the most dangerous man in science,' " he says. "Because he was often wrong, but he could argue so persuasively that he could convince you he was right."

'Tommy tended to confuse winning arguments with searching for truth,' Peter Goldreich says. 'He would have been a great lawyer.'

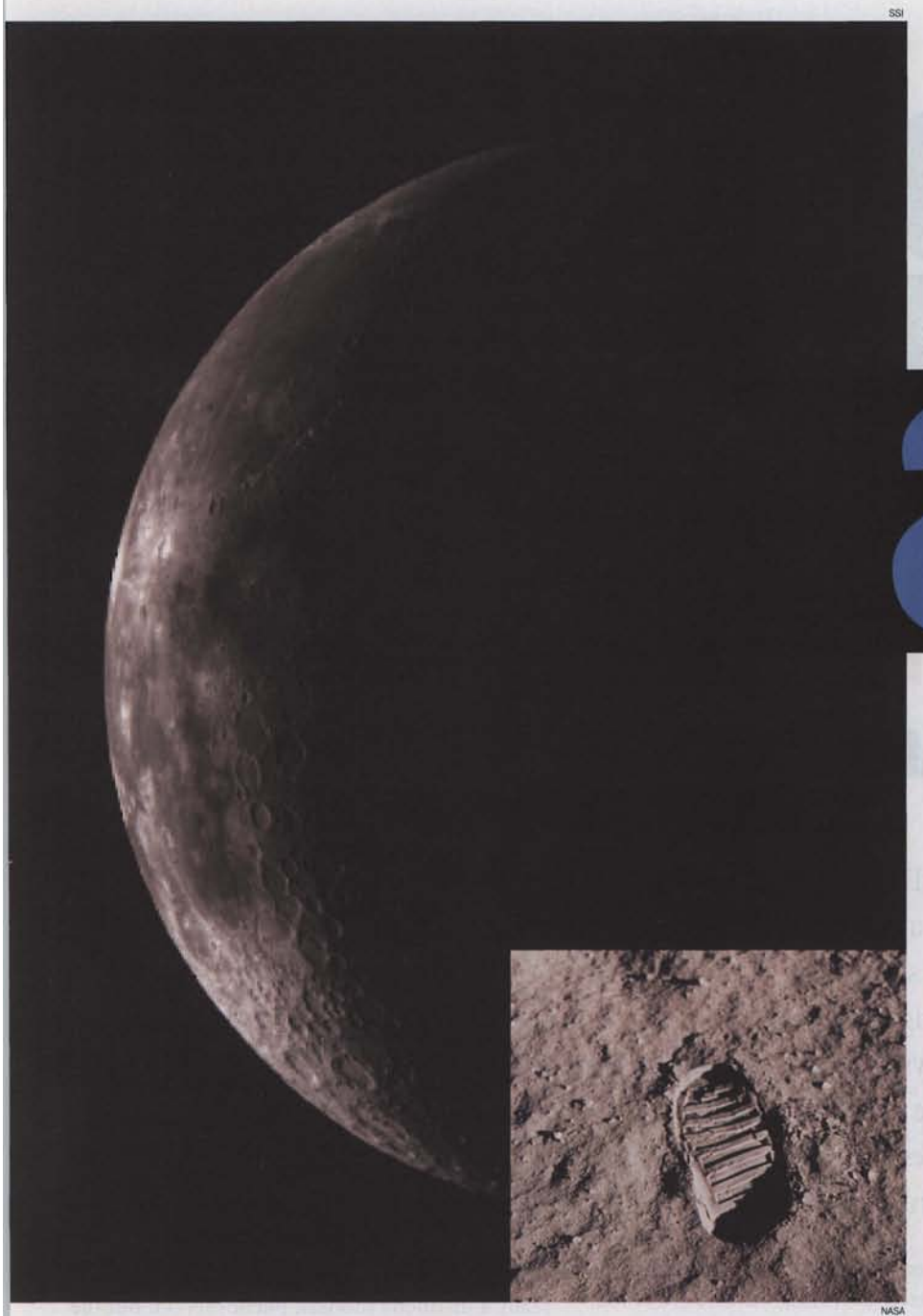
But Steven Soter, who collaborated with Gold on several papers, says that "criticism is the lifeblood of science" and notes that Gold often needed to overcome equally formidable opposition. "There's a resistance to challenges to orthodoxy, particularly when it comes from someone outside the field," he says. "He had to have extremely strong opinions to stand up to the withering criticism." Terzian argues that Gold's track record speaks for itself. "If you're as smart as Tommy," he says, "you have the right to comment on different subjects." Besides, his mistakes were often useful: the discarded Steady State theory, for example, "stimulated a lot of thinking about the nature of the universe." And perhaps science will yet come around to Gold's more recent heresies. "Some ideas take longer to get digested," Terzian says, "and in time, most of Tommy's ideas will be proven to be correct." He pauses, then quickly adds: "I said '*most*'!"

The story—perhaps apocryphal—goes that Bondi, Gold, and Hoyle were at the movies when the Steady State universe was born. In 1946 the three Cambridge colleagues attended a British horror film called *Dead of Night*, an anthology of ghostly tales with an ingenious circular framing story: the protagonist, haunted by nightmares, awakens one morning and then meets the very characters who have inhabited his dreams at a dinner party. At the climax, the hero finds himself at the beginning scene of the film, waking up to repeat the nightmare cycle anew. It was the sort of gimmick Gold loved, and he later wondered aloud if the universe could be constructed like that as well.

Like many scientists of the time, Gold and company were unhappy with prevailing cosmological models. Astronomers knew that the galaxies appeared to be receding from the Milky Way, and that the universe was therefore expanding. Logically, then, there must have been a point of great density in the distant past, a singularity from which all matter somehow burst into being (Hoyle would later coin the derisive term "big bang"). The Big Bang universe had a finite existence, with a definite beginning and end. The alternative Steady State universe that Bondi, Gold, and Hoyle hypothesized was reassuringly eternal: matter was constantly appearing to fill in the gaps between expanding galaxies and maintain a steady density, and the universe as a whole would appear unchanging in space and time, forever creating itself, world without end.

It was an elegant premise, but one that, as radio astronomy improved, tended not to match the newest observational data. The Steady State model slowly lost its devotees in the 1960s. The late Sir Fred Hoyle noisily advocated a variation of it up until the end, however, and many believe that the great British astronomer was professionally isolated and denied a Nobel Prize because of his dogmatic embrace of an unpopular idea. Gold remained a Big Bang skeptic but largely bowed out of the cosmological debate, and he didn't join Hoyle in defending the universe he helped imagine. Lately, however, he thinks maybe the three of them might not have been so wrong after all. "The original, simple-minded Steady State is still the best fitting for all the modern data," he says.

The parallels between the career arcs of Hoyle and Gold are impossible to ignore. "There's some similarity there, yes," Gold agrees. In his case, though, it's been Gold's non-biological petroleum that has made him something of a pariah. Most scientists file the theory alongside cold fusion and perpetual motion machines, and Gold's legacy may have been damaged



SSI

NASA

Lunar dust-up: Gold's concern about the Moon's ability to support weight was ridiculed after Apollo 11. But in other respects, his original 1955 theory of a powdery lunar surface proved remarkably prescient.

by what many see as a quixotic late-career obsession. "I could see the cost on my own campus," says MIT radar astronomer Gordon Pettengill, who made many of the first pioneering observations at Arecibo under Gold during the early 1960s. "I once suggested he come on campus to talk, and the idea just hit the floor," he recalls. "[The geology department] thought he was barking at the moon."

Ed Salpeter says ruefully that controversial figures are often denied credit, and Gold is now paying the toll for a contentious career: "He fights with people and says unorthodox things," he says, "and that probably hurt him." Goldreich muses that "in science, after a while people stop listening," and says Gold's isolation is largely self-inflicted, a blowback from his Ahab-like pursuit of revisionist myth. "He wants it to be on record, when they finally find the deep hydrocarbons, that he was the one," he says. "He wants some kind of immortality."

And what then? The textbooks will be rewritten, the world will turn upside down, and Tommy Gold will pull out one last coup against the timid herd. "He's like an aging heavyweight," Goldreich says. "He's got no legs and no punch, and he's just reeling around the ring. But you can't quite count him out."

Another warm June day, two weeks later, and things are looking up. Frustrated with the inability to find a journal to publish his solar sail theory, Gold posted it on ArXive, a non-refereed Internet clearinghouse for scientific papers—and, for Gold, something of a venue of last resort. As he'd hoped, he has attracted some attention. Within days, a reporter from *New Scientist* magazine called, and Gold looks delighted. He knows, from discussing his theory with dubious physicist friends, that absolutely no one will believe him.

In a week, the *New Scientist* story will appear: "Solar Sailing 'Breaks Laws of Physics.'" And, as predicted, a small uproar will roil the waters of the virtual physics community. On the bulletin boards and news groups haunted by Web science junkies, academics and amateurs alike will engage in long, angry threads of debate over Gold's idea, and exactly why it is wrong. Some of these posters will sound enraged by the very notion, and by Gold himself. He's a crank, a crackpot, an arrogant fool. He's Gold of the Steady State universe, Dr. Moondust, the fellow who thinks the world is made out of oil. He's the most dangerous man in science.

Conspicuously silent in all this, of course, will be Gold himself, who prefers to debate the old-fashioned way, and who now awaits both the outrage and the inevitable redemption with a mischievous grin. "I'm quite happy to have people write in and say, 'This is nonsense,'" he says, eyes alight. "Because then, when that solar sail flies…" And he laughs, savoring the idea of the misbegotten craft, becalmed for eternity in his vast and indifferent universe.

"The Wrong Man," by David Dudley, *Cornell Alumni Magazine*, v106n2 (Sep/Oct 2003), pp 52-59.

Coming & Going

MORE CHANGES TO ADMINISTRATION

DURING THE SPRING SEMESTER, TWO DEANS WERE appointed while two others and the University's chief financial officer announced plans to step down. Lisa Staiano-Coico, PhD '81, the vice provost for medical affairs at Weill Cornell Medical College, was named the new dean of the College of Human Ecology, replacing Patsy Brannon, PhD '79, whose term ended on June 30. Staiano-Coico, a microbiologist, has been on the medical college faculty since 1983. In 2003, she was appointed executive director of the Tri-Institutional Research Program, a cooperative alliance among Cornell, Rockefeller University, and Memorial Sloan-Kettering Cancer Center. Also assuming office on July 1 was Mohsen Mostafavi, the new dean of the College of Architecture, Art, and Planning. Mostafavi came to Cornell after ten years as chairman (equivalent to dean) of London's Architectural Association School of Architecture. He has also served as director of the Master of Architecture 1 Program at Harvard's Graduate School of Design and is the author or co-author of several works on building surfaces, including *On Weathering: The Life of Buildings in Time*, which won the American Institute of Architects' commendation prize. Former AAP dean Porus Olpadwala, PhD '79, has returned to teaching in the Department of City and Regional Planning.

Stepping down at the end of their terms in June 2005 will be Dean Edward Lawler of the School of Industrial and Labor Relations and Dean David Butler of the School of Hotel Administration. Lawler, a sociologist with a doctorate from the University of Wisconsin, Madison, has been a member of the ILR faculty since 1994 and became dean in 1997. He plans to return to research and teaching. Butler, who has been dean since 2000, announced that he will be going into "semi-retirement." He came to Cornell in 1993 after four years as president of Menlo College in Atherton, California.

Also announcing plans to retire was Harold "Hal" Craft '60, PhD '70, the University's CFO and vice president for administration, facilities, and finance. Craft has held a variety of Cornell administrative positions since 1971, including a stint as director of the Arecibo Observatory in Puerto Rico. In the 1990s, he oversaw the implementation of Lake Source Cooling. "Some of these long-range projects that I'm involved in, I'm not going to see them finished," Craft told the *Daily Sun*, "[but] I feel good about a number of facilities projects and about some of the changes in the financial arrangements of the University." Craft said he plans to leave Day Hall by the summer of 2005 and his future plans include "some sailing."

"Coming & Going: More Changes to Administration" (Hal Craft), *Cornell Alumni News*, v107n1 (Jul/Aug 2004), p 11.

Maverick Mind

THOMAS GOLD, 84

ASTROPHYSICIST THOMAS "TOMMY" GOLD, FORMER HEAD of Cornell's astronomy department and influential scientific contrarian, died on June 22 in Ithaca. Famed for his co-authorship—with Fred Hoyle and Hermann Bondi—of the steady-state cosmological theory in the 1950s, the Austrian-born Gold played a leading role in a variety of scientific controversies over the past sixty years. In 1948, he hypothesized about a feedback mechanism used in human hearing, a theory dismissed by audiologists until proven correct in the 1980s. He arrived at Cornell in 1958, and in 1959 founded the Center for Radiophysics and Space Research, which oversaw the new Arecibo Observatory. Gold's 1967 assertion that the recently discovered phenomenon of pulsars was caused by rapidly rotating neutron stars caused a furor in astronomical circles; likewise, his infamous mid-1960s advocacy of a lunar surface model involving a deep layer of fine dust was sharply at odds with NASA geoscientists.

BARKER

Over the last twenty years of his career, Gold championed perhaps his most controversial theory—that primordial hydrocarbons seeping up through the Earth are not only the source of most so-called "fossil fuels" but are the basis for a teeming subsurface biosphere of primitive microbes. Most geologists remain dubious, and debate persists. "He had a fundamental interest in the truth, but he also had a delight in proving the experts wrong," physicist Freeman Dyson told CAM in 2003. "But those two things can go together."

"Maverick Mind: Thomas Gold, 84," *Cornell Alumni News*, v107n2 (Sep/Oct 2004), p 13.

This page was intentionally left blank.

Arecibo Alert

CORNELL BUILT ARECIBO OBSERvatory in the early 1960s and has operated it ever since—but this tenure may be coming to an end. The National Science Foundation's astronomy division commissioned a "Senior Review" of their facilities, with the goal of freeing $30 million (from a facilities budget of roughly $130 million) for the operation of a new millimeter-wave telescope. This review has resulted in cuts to the observatory's budget of 25 percent until 2011, after which Cornell will have to obtain operating funds from new sources or perhaps close the facility. Added to this is the requirement that Cornell strip the lead-based paint from the triangular platform suspended above the dish, which holds the receiving antennas, and repaint the platform; the cost is estimated at $5 million.

Arecibo Observatory is the largest and most sensitive radio telescope in the world; no other facility is expected to exceed even one-tenth of its sensitivity until at least 2020. It is a discovery instrument that has led science in areas such as tests of general relativity, measuring the structure and evolution of the universe, accurate measurements of Earth-bound asteroid trajectories, the understanding of the ionosphere and plasmas, and many others. In addition, Arecibo's Visitor and Education Facility is the most frequented of its type at any NSF-funded location. It serves Puerto Rican education at all levels, from elementary school through graduate school, and is part of the reason so many Puerto Ricans choose Cornell for their university education.

I have been a member of the scientific staff at Arecibo since 1992. More than 150 Cornell employees work for Arecibo, mostly in Puerto Rico but also in Ithaca. The Ithaca and Arecibo staffs have already suffered layoffs, with thirty positions eliminated.

It is in the best interest of Cornell, Puerto Rico, and the world that Arecibo Observatory continue to lead research in astronomical, planetary, and ionospheric sciences, as well as in education and public outreach. I hope that my fellow Cornell alumni will join us in the effort to preserve this unique facility.

Jonathan Friedman '84
Senior Research Associate
Arecibo Observatory
Arecibo, Puerto Rico

(Correspondence) "Arecibo Alert," by Jonathan Friedman '84, *Cornell Alumni Magazine*, v109n4 (Jan/Feb 2007), pp 4&6.

"Sky's the Limit," by Beth Saulnier, *Cornell Alumni Magazine*, v110n2 (Sep/Oct 2007), cover, contents page & pp 40-43.

Cornell
alumni magazine

SEPTEMBER / OCTOBER 2007
VOLUME 110
NUMBER 2

Contents

2 **From David Skorton**
Professorial honors

4 **Correspondence**
Speaking Frankly

12 **Letter from Ithaca**
What you're reading

14 **From the Hill**
Cour de Cornell. *Plus*: Jazz replay, Wyeth redux, new residence named, and AAP dean heads for Harvard.

20 **Sports**
One giant leap

23 **Authors**
Latino L.A.

38 **Wines of the Finger Lakes**
2006 Anthony Road Rosé

56 **Classifieds & Cornellians in Business**

59 **Alma Matters**

62 **Reunion Notes**

73 **Class Notes**

106 **Alumni Deaths**

112 **Cornelliana**
Spanning the centuries

28

112

Features

40

40 Sky's the Limit
BETH SAULNIER

Located in a mountainous region of western Puerto Rico, Cornell's Arecibo Observatory is the world's most sensitive radio telescope and an icon of astronomy. But shifting scientific priorities have prompted the NSF to slash Arecibo's budget, angering researchers and leading many to wonder if the telescope will be forced to shut down.

44 Big Red Roundup
THE CAM STAFF

Reunion '07 brought more than 4,300 alumni back to campus for four days of parties, lectures, scientific demonstrations, athletic outings, and fun under the beer tents. But most important was the chance for Cornellians to catch up with old friends—and see how their alma mater has changed since they were last on the Hill.

50 Plaza Sweet
LIZ SHELDON '09

For decades, the space in front of Bailey Hall was a parking lot—utilitarian, but unsightly. But this fall, Bailey will have a transformed front yard to go with its extensive interior makeover. Award-winning landscape architect Michael Van Valkenburgh '73 has designed a plaza that features a jutting waterfall, benches made of solid wooden slabs, and colorful bluestone that echoes the patterns of pedestrian traffic.

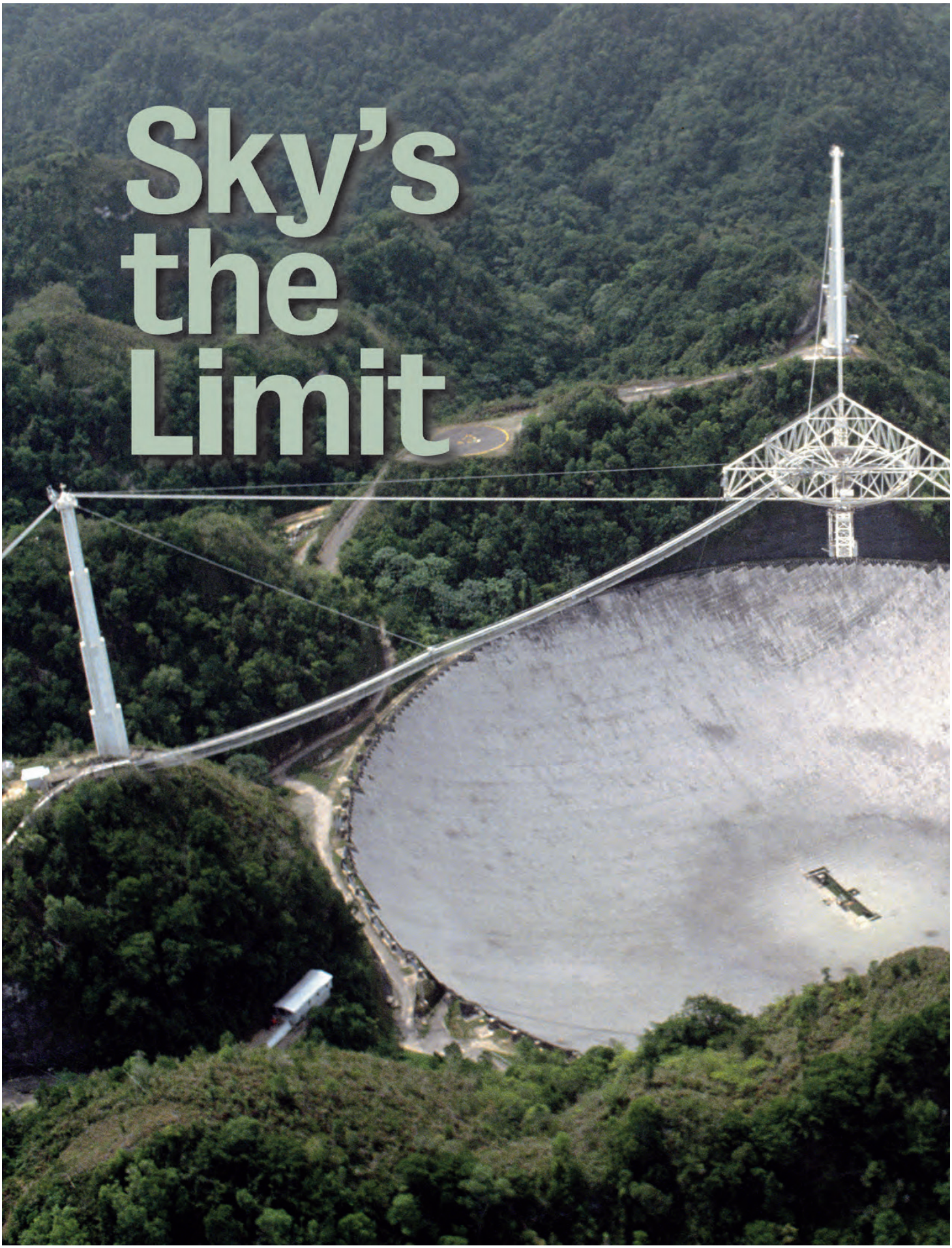
Cover photo from NASA / HubbleSite
Spiral Galaxy NGC 3370

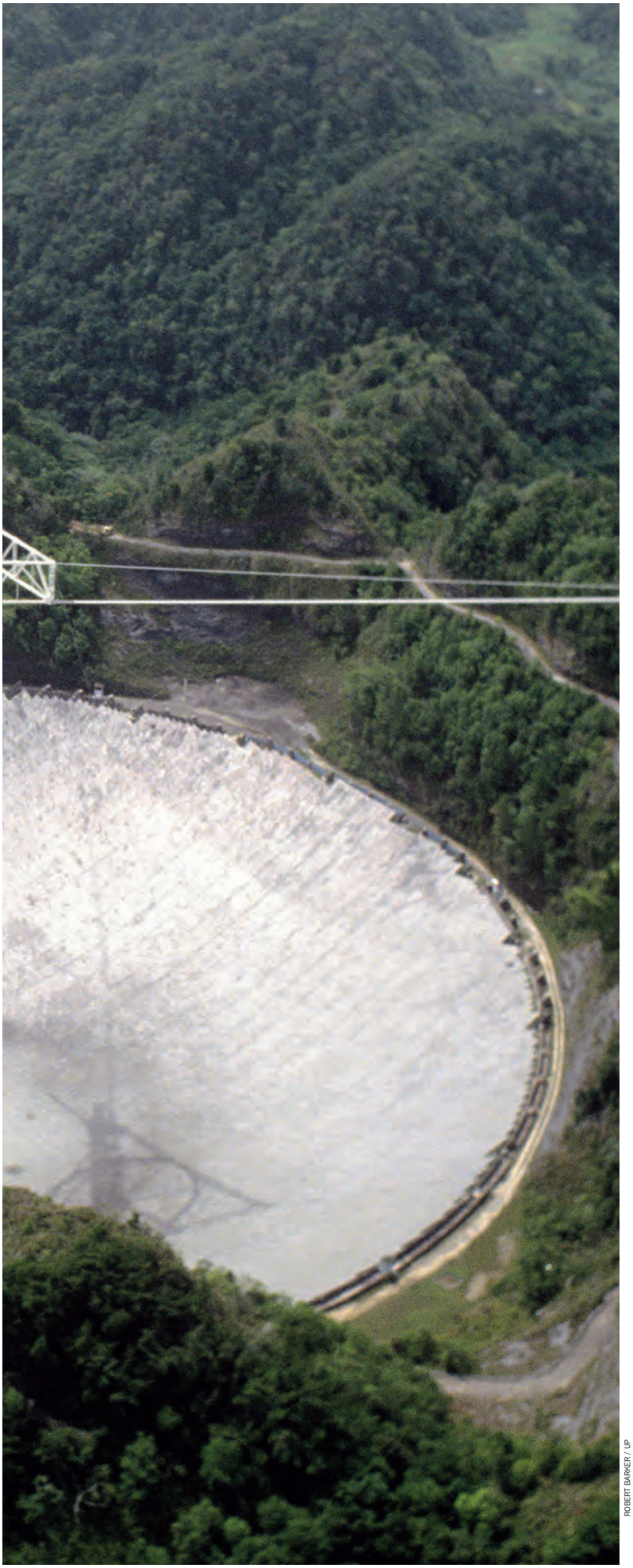
26 Currents

STATE OF THE HIVE | A bee mystery
GOOD BUZZ | Rebecca Barry '90 tells tavern tales
ROAD SCHOLAR | Greg Graffin, punk-rock PhD
BLOG, BLOG, BLOG | Cornell's web diarists
SOMETHING'S BREWING | Those tea-loving Harneys
Plus | Online liars; spooky science

Cornell Alumni Magazine (ISSN 1548-8810; USPS 006-902) is published six times a year, in January, March, May, July, September, and November, by the Cornell Alumni Federation, 401 East State Street, Suite 301, Ithaca, NY 14850. Subscriptions cost $30 a year. Periodical postage paid at Ithaca, NY, and additional mailing offices. POSTMASTER: Send address changes to Cornell Alumni Magazine, c/o Public Affairs Records, 130 East Seneca St., Suite 400, Ithaca, NY 14850-4353.

Sky's the Limit





ROBERT BARKER / UP

Arecibo Observatory is the world's most sensitive radio telescope—but NSF funding cuts may put it out of business

By Beth Saulnier

It has listened for signs of life in outer space, sent a historic greeting to a star cluster 25,000 light years away, served as a setting for "The X-Files" and James Bond. More important for Cornell, it has made significant contributions to astronomy and other scientific fields for nearly a half-century. But does Arecibo Observatory have a future?

The question has been vexing the astronomy community at Cornell and beyond for nearly a year—ever since a senior review committee of the National Science Foundation (NSF) prescribed radical funding cuts that could lead to the facility's closure. In October 2006, the committee—charged with trimming $30 million for redistribution to new initiatives, though it ultimately came up with only $14 million in cuts—recommended reducing the agency's annual contribution toward Arecibo's radio astronomy efforts from its present $10.5 million to $8 million in fiscal 2009 and just $4 million in 2011. (The $2 million a year that another NSF division contributes for atmospheric sciences would be unaffected.) Although the NSF is not condemning Arecibo outright—rather, mandating that it get the bulk of its funding from other sources—the proposed cuts have Cornell astronomers up in arms. "I think the decision is just wrong," says Cornell vice provost for physical sciences and engineering Joseph Burns, PhD '66, a professor of theoret-

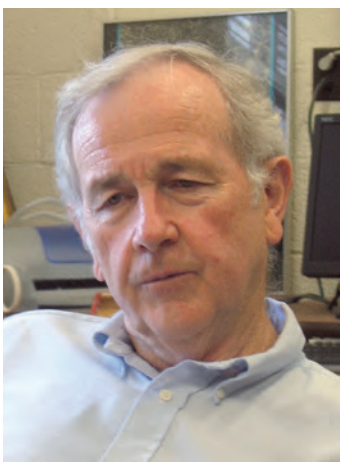
Searching the skies: An aerial view of 305-meter-wide Arecibo Observatory in western Puerto Rico. The dish takes advantage of the region's rugged landscape, distinguished by sharply sloped mountains and deep sinkholes.

BARKER / UP

Wide array: Instruments are suspended 150 meters above the dish by wires connected to three towers. Upgrades include a Gregorian dome, added in 1997, which focuses radio signals.

ical and applied mechanics who specializes in planetary sciences. At such a reduced budget, he adds, "we don't feel that we can do the kind of science Cornell is interested in."

Located in an isolated, mountainous region of Puerto Rico fifty miles west of San Juan, Arecibo is a federal facility; the NSF contracts with Cornell to administer it, and many astronomy faculty use it for research. Built in 1963 to take advantage of the region's sharply sloped karst landscape, it's the world's most sensitive radio telescope, and its 305-meter-wide dish (made up of nearly 39,000 perforated aluminum panels) is the planet's single largest. Although the dish itself can't be moved—it's fixed to the ground, and you can walk under it—the instruments suspended above it from a trio of towers can be reoriented, allowing the telescope to observe some 40 percent of the sky. The receivers have been upgraded several times over the years, including the recent installation of a new detector that increased data collection fourteen-fold. Researchers compete for telescope time via a peer-reviewed process, with some 300 scientists from 150 universities worldwide using the facility each year. "The fact that it's the largest collecting-area telescope, it has more users than it has ever had, and it's doing forefront science that no other facility on Earth can do—to think that it would close seems to me outrageous," says Martha Haynes, the Goldwin Smith Professor of Astronomy. "If you close this facility, you shut down areas of science, and I don't think that was the committee's intention. In some senses, it boggles the mind."



STEFANIE GREEN

Joseph Burns

For Cornell, Arecibo is more than just another research facility; like the medical college's branch in Qatar, it's a symbol of the University's international scope and global mission. When visitors arrive at the observatory after a drive up a winding mountain road, they're greeted by three flags: those of the U.S., the Commonwealth of Puerto Rico, and Cornell University. "It's an icon for astronomy, and to be associated with such an icon is important to Cornell," Burns says. "It speaks to Cornell's expansiveness—to be able to go to a distant place and use the special geography there to look out at the universe."

The telescope has been a longtime contributor to the Search for Extraterrestrial Intelligence (SETI), which scans the skies for evidence of alien life. On November 16, 1974, the dish was used to broadcast a message of interstellar greeting designed by Carl Sagan and famed astronomer Frank Drake '51, among others; it included ordinal numbers, a graphic of our solar system, and the structure of DNA. The facility has a three-part mission: radio astronomy, planetary radar (used to examine nearby celestial bodies), and atmospheric sciences, which study Earth's own gaseous layers. (The observatory was originally built to use radar to study Earth's ionosphere, or upper atmosphere; Arecibo's planetary radar, the world's most powerful, is considered the best early-warning system for tracking asteroids that could collide with Earth.) And Hollywood has come calling more than once: portions of the film version of Sagan's novel *Contact* were shot there, and the dish doubled as the villain's lair in the James Bond adventure *GoldenEye*, with special effects allowing it to emerge from under a lake.

Recently, the telescope has made possible a number of discoveries in astronomy and planetary sciences, including Mercury's molten core, highly sensitive detections of pulsars, and what appears to be a "dark galaxy"—one with a great deal of mass but no stars. "We are doing the best science we've ever done," Burns says. "We've been on the cover of *Science* and *Nature* three times in the last year. We've been ranked by the NSF, as far as atmospheric sciences, as the best facility they've got. In terms of planetary radar, we're twenty times more sensitive than anything else in the world. And we're doing the best educational and public outreach effort in the NSF—we have more than 100,000 visitors annually, more than all the other observatories combined."

C. Wayne Van Citters, director of the NSF's Division of Astronomical Sciences, says Arecibo's scientific merit was never in question. In fact, he says, the agency doesn't want to see Arecibo closed. "The senior review itself said that none of the facilities for which they were recommending reduced funding—or even possibly closure—should be regarded as redundant to the scientific enterprise," he says. "They're all exceedingly productive facilities that could keep

doing good science for the next couple of decades. It's just a question of scientific priorities and having to withdraw funding from some things to do new things that are extremely exciting too."

Once a decade, NASA and the NSF charter a study to look at the needs and priorities of astronomy as a whole; the most recent one, in 2000, sketched an ambitious program requiring the construction of several cutting-edge facilities—with big price tags. They include the Atacama Large Millimeter Array, now being built in a remote area of Chile, and the Advanced Technology Solar Telescope, which may begin construction on a mountaintop in Maui, Hawaii, as early as 2009. According to Van Citters, the 2006 senior review committee "looked at the science program that the astronomy community wanted to do—looked at capabilities, output, number of users, and so forth, and ranked things that way. So in large measure it's a scientific judgment call, but that's why we convene committees to do that sort of thing."

UP

Martha Haynes

Some at Cornell are more skeptical; they say that the decision was made without full consideration of Arecibo's capabilities. Burns and Haynes point out that the senior review committee didn't include representatives from radar astronomy or atmospheric sciences, which make up 30 percent of the work done at Arecibo. "In some sense, we went in with our maximum grade being 70 percent," Burns says, "so at the end of the day we're told that we are the one place that can take a big hit." Burns and Haynes both charge that the funding cuts are more political than scientific: Burns points out that two facilities that emerged unscathed have powerful friends in Congress. Robert Byrd, chairman of the Senate Appropriations Committee, is from West Virginia, home to the National Radio Astronomy Observatory in Green Bank; Pete Domenici, another veteran senator, represents New Mexico, where the Very Large Array is located. "Also, from a political standpoint," Burns says, "it's probably not insignificant that Puerto Rico has no representatives in Congress."

Van Citters, though, flatly denies any political motives or back-room deals. "The best I can do is to assure folks that it was a scientific—not a political—decision," he says. "Actually, one of the first questions the committee asked us was, 'Do we have to take political considerations into account?' And I said, 'Absolutely not—if you did try to second-guess political interests, we'd get so tied up in knots you couldn't make any decisions.' We were very careful to keep Congress briefed on the process while it was being carried out, and I've had no 'protection moves,' so to speak."

Will there be an Arecibo Observatory a decade from now? The question remains open—though Cornell's astronomy community doubts the worst will happen. "I am 100 percent confident that it will still be there and still be operating," says Robert Brown, director of the National Astronomy and Ionosphere Center (NAIC), the entity Cornell created to oversee Arecibo. Says Haynes: "People keep talking about how the telescope is going to shut down, but I don't believe it. I don't believe that the United States or the NSF would ignore the benefits, the scientific capabilities, that Arecibo has." Supporters point out that the NSF just funded a $5.3 million project to repaint the facility's detector, basic maintenance necessary to prevent corrosion and protect workers. Haynes compares it to repainting your house even though you're planning to demolish it. "We're getting an incredibly mixed message," she says. "I like to think of that as a positive sign, that they're going to let this report play out but they're going to ignore it."

Cornell and the NAIC have begun seeking alternative funding sources to keep Arecibo open; one possibility includes a partnership with the government of Puerto Rico, which relies on the observatory not only for employment and tourism but as a symbol of pride and scientific possibility. "Half of the students on the island have visited the observatory," Burns says. "Puerto Rico is very poor, and to have this iconic technology sitting in its backyard is important." Another potential funding source, Brown says, could come from projects such as the Very Long Baseline Interferometry program, in which a dozen or more telescopes around the world look at the same object at the same frequency and combine their data to get a highly detailed image. "We will go through a phase where we actively seek sponsors for the observatory, and those new programs will necessarily be implemented at the expense of some of the research that is going on right now," Brown says. "Eventually, it will be clear whether the observatory is headed in a favorable direction. So I think we're engaged in something close to an experiment."

The NSF cuts have already prompted the observatory to tighten its belt: a quarter of its 150 positions have been eliminated through layoffs or attrition. Observations have been limited to night-time hours and the scope of investigation redirected to favor sky-wide surveys rather than examinations of individual objects. "In forty-two years the observatory had never had a cutback, ever, and so people who take jobs there do not expect to see the staff trimmed," Brown says. "It had a pronounced effect on morale." Still, he and his colleagues are hoping for a reprieve. Perhaps, they say, through political support or a twist in the labyrinthine budget process—as funding recommendations make their way through the NSF hierarchy to the National Science Board to the Office of Management and Budget to Congress—something will give. "To a different audience with a different perspective, Arecibo can do very well," says Haynes. "I think there's a lot of sympathy out there beyond this one committee."

Burns points out that closing the facility is much more complicated than it sounds. The University can't just padlock the gates and walk away—the dish would have to be dismantled, buildings demolished or repurposed, and the site returned to something resembling its natural state. Van Citters says the NSF is in the process of assessing the cost of decommissioning, which Burns estimates at upwards of $100 million. "If it turns out that we can't possibly afford to close it, then we want to know that now," Van Citters says, "so we can make a plan that removes uncertainty about what's going to happen."

"Sky's the Limit," by Beth Saulnier, *Cornell Alumni Magazine*, v110n2 (Sep/Oct 2007), cover, contents page & pp 40-43.

Star Trek

ASTRONOMERS AIM TO SAVE ARECIBO

CORNELL'S ARECIBO OBSERVATORY, SET FOR SEVERE FEDeral budget cuts that could lead to its closure, may get a reprieve. The world's most sensitive radio telescope was the subject of a two-day scientific meeting held in Washington, D.C., in September. More than seventy astronomers discussed the observatory's future, making a scientific case for its continued existence. A few weeks later, two U.S. Representatives introduced a bill seeking to guarantee Arecibo's funding. Said Congressman Luis Fortuño of Puerto Rico: "Maintaining this facility is an investment in our nation's future. The cost is small compared to the benefits for America and mankind." Congressional hearings on the importance of detecting potentially dangerous near-Earth asteroids—a field in which Arecibo is a leader—are scheduled for November.

"Star Trek: Astronomers Aim to Save Arecibo," *Cornell Alumni Magazine*, v110n3 (Nov/Dec 2007), p 13.