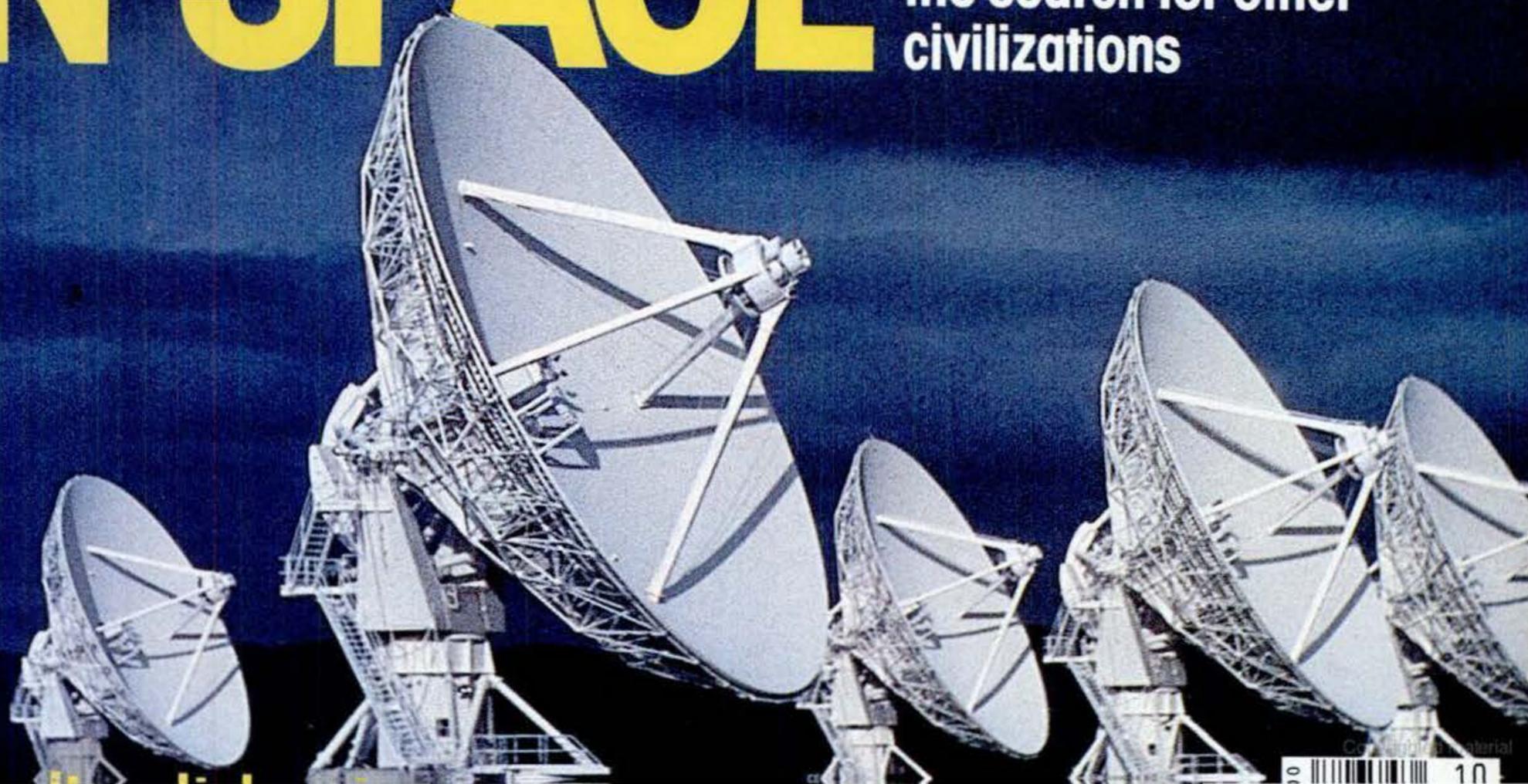# Popular Science

NEW SEARCH FOR LIFE IN SPACE

Soon, scientists using the world's most complex computerized radio telescopes will begin the search for other civilizations

New search for life in space

Are we alone? Is anyone else out there? The questions have been asked for millennia. And for a few decades, astronomers have made sporadic and unsuccessful efforts to answer them by eavesdropping on the torrent of radio frequencies spewed out by the galaxy. Now the National Aeronautics and Space Administration has begun a 15-year program, using the most sophisticated signal processors ever built, to answer the questions once and for all.

By ARTHUR FISHER

Sometime this fall a truck loaded with bulky wooden crates will rumble some 500 miles south and east from NASA's Ames Research Center in Mountain View, Calif., to the Jet Propulsion Laboratory's Goldstone Observatory deep in California's Mojave Desert. Nesting inside one of the padded crates will be a chest-high VAX main-frame computer. In another, a standard gray equipment rack will bear vertical circuit boards wrap-wired with miles of copper strands and interconnected by yards of flat cable. A third crate will house a shiny copper box within a vacuum bottle that will be filled with liquid helium.

Together with specially created computer software, these components will constitute arguably the most sophisticated apparatus for receiving, analyzing, and processing radio signals ever built. This brainchild of teams of engineers, physicists, and astronomers working at Ames, the Jet Propulsion Laboratory, and Stanford University will be yoked to Goldstone's 26-meter (85-foot) radio telescope, part of NASA's Deep Space Tracking Network. As the great scope scans the heavens, the equipment will split the galaxy's chaotic outpouring of radio signals into 74,000 narrow frequency channels and then sift patiently through the data, seeking the one unambiguous pattern

that would signify something totally extraordinary. It will be the first stage of a newly organized, long-term, highly complex search—there have been earlier, more-primitive attempts—for intelligent life in space.

Even as the new search begins, an old quarrel continues. One group of scientists, including astronomers and biologists, has emerged with the conviction that extraterrestrial intelligent life—ETI, for short—is overwhelmingly probable and that a well-planned search should be able to detect it. Yet to others the search for extraterrestrial intelligence (SETI) is a chimera; they consider the quest itself antiscientific and a waste of time, intellectual resources, and money.

Question with a history

The belief that intelligent life might exist elsewhere in the universe—for some a near-mystical article of faith and for others a logical outcome of rational thinking—was not subjected to a truly scientific inquiry until recently. Yet it undoubtedly antedates recorded history and was stated as early as the fourth century B.C. It was then that Metrodorus of Chios wrote in his book *On Nature* that "to suppose that Earth is the only populated world in infinite space is as absurd as to believe that in an entire field sown with millet, only one grain will grow."

The first actual suggestion that the human race try to communicate with

other intelligent races was made by the brilliant German mathematician Carl Friedrich Gauss in the middle of the 19th century. He wanted to plant a gigantic forest in the shape of a right triangle. Astronomers on other planets who saw this symbol would then immediately realize that Earth is peopled with creatures cultivated and intelligent enough to be familiar with the Pythagorean theorem.

The man who first moved from speculation to experiment, the man who put the S in SETI, was Frank Drake. Now a silver-haired professor of astronomy at Cornell University, Drake in 1960 was a young radio astronomer at the National Radio Astronomy Observatory in Green Bank, W.Va. By 1960 radio astronomers had discovered that the heavens were full of radio emanations from every direction—a cosmic cacophony. Following a 1959 recommendation of two Cornell University physicists, Philip Morrison and Guiseppe Cocconi, Drake decided to canvass two nearby stars, Tau Ceti and Epsilon Eridani, to see whether he could detect the kind of pulsed or coded radio signal that another intelligent race might use to send a message. So Drake wheedled some time on the observatory's huge-for-the-time 85-foot antenna, and thus began Project Ozma (named for the princess in the Oz books), the first serious attempt to find other races. It failed to do so.

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Life in space

In the years following Project Ozma some three dozen different radio searches for ETI have been aimed at more than 1,000 stars and a few galaxies—conducted primarily in the U.S., the Soviet Union, and Canada. (Some have had rather wistful names, including "Qui appelle?" "Serendip," and even "Mania.") In the 1970s Project Ozma II, headed by Ben Zuckerman and Patrick Palmer at the National Radio Astronomy Observatory, tuned in on more than 600 stars within 80 light-years of the sun.

Neither these nor any other searches were rewarded with a true "encounter," although there have been a number of false positives. For example, in 1967 Cambridge astronomers Jocelyn Bell and Anthony Hewish were trying to measure the scintillations of quasars. Suddenly they began to receive from a point in the sky a series of radio pulses that had a precise, unvarying rhythm. Said Cambridge astronomer Sir Martin Ryle, "Our first thought was this was another intelligent race trying to reach us." But in fact they had discovered a pulsar—a kind of rotating neutron star that mimics a radio beacon. This first pulsar was dubbed "LGM," for little green men.

What dictates the frequencies at which such searches are conducted? They result, Drake explains, from the limits imposed by certain cosmic phenomena: "You don't use the state of your technology to select a frequency. You select optimum frequencies as set by the laws of physics in the universe. One of these laws says that the energy required to communicate a bit of information rises directly with the frequency—in other words, the signal-to-noise ratio gets worse as the frequency increases. There's no overcoming that with any technology. If that were all, you could say that you should use the lowest frequencies. That would be horrible because they don't penetrate the ionosphere and wouldn't propagate in the galaxy at all.

"Moreover, there is a second phenomenon: galactic radio noise. That increases as you lower the frequency, so going too low, in essence, jams the radio telescope.

"So on the lowest frequencies you are jammed by the galaxy, and on the highest you have a bad signal-to-noise. And there is yet a third phenomenon that gets into the act: the three-degree black-body radiation left over from the primordial fireball. That imposes its own noise level. If you take these three sources of noise and sum them at every frequency, you find the range of frequencies in which the total noise is at a minimum.

"It turns out that the best signal-to-noise ratio is at about a 10-centimeter wavelength. But the minimum is broad because there isn't much more noise at 21 centimeters or at three centimeters."

Interstellar oasis

Most of the past radio searches have been in this band or at something aptly called "the water hole," a designation apparently first used by Bernard Oliver, a vice-president of Hewlett-Packard and a SETI pioneer. In the summer of 1972 he and John Billingham of the Ames Research Center conducted a summer study session named Project Cyclops, in essence a SETI think tank. Describing the results of the study some years later, Oliver wrote: "The Cyclops team felt that it found an appealing reason to favor a rather narrow region at the optimum part of the spectrum. At 1.42 GHz there is a strong spectral line caused by interstellar hydrogen. Just a little bit higher in frequency, at 1.66 GHz, is another spectral line caused by hydroxyl ions in space. We think that this may be the interstellar communication band, defined for all of us by nature itself.

> ❝ *Detecting just one signal would answer many fundamental questions about life in the universe* ❞

"Water separates into hydrogen and hydroxyl ions, both of which are important in all life processes. So is water. Thus the band lying between the two spectral lines of the two dissociation products of water is a poetically symbolic place for water-based life to search for its kind. Where shall we find intelligent species? Why, at the age-old meeting place of all species —the water hole."

Despite all the sporadic attempts to find extraterrestrial life, and the lively debate over the quest, today's serious attempt got under way only recently. In 1982 the Astronomy Survey Committee of the National Research Council, under the chairmanship of Harvard-Smithsonian Institution's George Field, issued a highly influential report titled "Astronomy and Astrophysics for the 1980s." It recommended that SETI be one of our national goals.

In August 1982 the august International Astronomical Union, with members from more than 70 countries, established a new commission: Commission 51, Search for Extraterrestrial Life, under the chairmanship of Boston University's Michael D. Papagiannis. Drake was vice-chairman.

Two months later the correspondence pages of *Science* (October 29) carried a long letter in the form of a petition, written by Carl Sagan and co-signed by 72 other prominent scientists from 14 countries, including seven Nobelists. The petition began: "The human species is now able to

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The mathematics of searching for intelligent life

When Frank Drake launched Project Ozma in 1960 he sought a way to calculate the probability of finding other intelligent races. Within a few years he had formulated the equation that remains a kind of tablet from the mount for SETI researchers—an expression in mathematical terms of the likelihood of the number of extraterrestrial civilizations willing and able to communicate across the galaxy. The equation goes like this:

$$N = R^* \; F_p \; N_p \; F_l \; F_i \; F_c \; L$$

Though somewhat formidable looking, this is simply the number (N) of technological civilizations in our galaxy, as the product of a string of probabilities:

R^* = the average rate in stars per year of star formation in the galaxy.

F_p = the fraction of stars having planets.

N_p = the number of suitable planets per planetary system.

F_l = the fraction of planets on which life starts.

F_i = the fraction of life that evolves to intelligence.

F_c = the fraction of intelligent species to develop the means of communication.

L = the longevity (in years) of the technological phase of such a society.

Drake and other early extraterrestrial-life enthusiasts, including Carl Sagan, arrived at a value for N between 100,000 and one million—still only about one technological civilization per million stars in the galaxy, which astronomers reckon contains approximately some 200 billion stars.

When asked whether his own assessment of N has changed over the intervening years, Drake replies:

"The terms in the equation still seem to me to be right. The precise numbers or estimates or guesses that are put in the equation have changed over the years—some have gone up and some have gone down. But the product N has stayed about the same. Sometimes I ask myself whether it's just that I want to come out with the same answer as 20 years ago, and I finally decide no . . . it's just coming out that way."—A. F.

communicate with other civilizations in space, if such exist. Using current radio-astronomical technology it is possible for us to receive signals from civilizations no more advanced than we are over a distance of at least many thousands of light-years. The cost of a systematic international research effort, using existing radio telescopes, is as low as a few million dollars per year for one or two decades. The program would be more than a million times more thorough than all previous searches, by all nations, put together. The results—whether positive or negative—would have profound implications for our view of our universe and ourselves."

The letter concluded: "We urge the organization of a coordinated, worldwide, and systematic search for extraterrestrial intelligence."

In November 1982 Congress approved a modest $1.5 million in the NASA budget to begin the development of a long-term SETI project.

Technical challenges

The new work under way grows out of an unfortunate fact: The equipment typically used by radio astronomers is not good for SETI projects. The reason, explains Jill Tarter, a research astronomer at the University of California at Berkeley, is that SETI requires extremely high-frequency resolution.

Tarter, a svelte young woman with a penchant for ice-cream lunches, spends much of her time working at Ames, one of NASA's SETI Project Offices. In a trailer at Ames festooned with computer printouts and star maps, she explained the technical challenges of the program:

"Signals generated by natural phenomena in the cosmos have a bandwidth of kilohertz or megahertz. The kind of signal we want to look for is very narrow, only a few hertz wide, because if we did detect such a narrow-bandwidth coherent signal, we'd be pretty sure it was generated by another technologically advanced civilization. Why? It's the one type of signal we don't know nature to produce. Of course, if we happened to discover a previously unknown class of physical phenomenon—that would certainly be interesting in itself.

"The narrowest kind of phenomena in the universe are hydroxyl maser sources, with bandwidths of about ½ kHz. The channels we are now looking at are just five kHz wide. That's the kind of signal we ourselves create for communications—carrier waves that are one kHz or narrower [there is some amount of spreading of any radio signal due to multipath scattering as the signal travels through ionized gases in the interstellar medium].

"The reason one would use as narrow a channel as possible—so long as the bandwidth doesn't get narrower than the broadcast frequency—is to get the best possible signal-to-noise ratio. On the one hand, we want to scan very narrow channels; on the other, we don't know—within a fairly broad range—which particular frequency another civilization's signal might arrive on. So we want to listen to very many frequencies on very narrow channels."

Until now, Tarter and her associates have been using special high-speed tape recorders, developed for the very-long-baseline-interferometry astronomy program, to generate 65,000 channels of spectral data—recorded directly at the 305-meter (1,000-ft.) dish at Arecibo Observatory in Puerto Rico —each channel only five Hz wide. That observing program looked at 200 to 300 stars.

The long-term program approved for NASA is far more ambitious. It calls first for the development of a prototype instrument called a Multichannel

Spectrum Analyzer. That is the phase just completed at Ames, Stanford, and the Jet Propulsion Lab. Its purpose is to filter a wide-band signal into many narrower bands and to do it in real time. "The prototype now built," says Tarter, "has 74,000 channels, each one Hz wide. Eventually it will grow to eight million channels—maybe more, depending on how fast the electronics program progresses in the next five or six years."

Later in the program the signal analyzers will be yoked to the Deep Space Tracking Network's 64-meter (210-ft.) radio telescopes at Goldstone; Tidbinbilla, Australia; and Madrid,. Spain, as well as to the Arecibo antenna. In a sense it will be the most powerful dedicated computer ever made. Generating a billion bits of information a second, the analyzer will examine more interstellar data in minutes than the total of all SETI projects heretofore, from a broad region of the radio spectrum in which background noise is low.

John Billingham is chief of NASA's Extraterrestrial Research Division at Ames, under which the SETI program falls. "The way it is structured now," he says, "we have a five-year R&D program in which to check out exhaustively the design of the SETI systems,

including the analyzer. By that time we will have tested the prototype extensively. Then we will have roughly a 10-year period during which we will build the search machine proper, which will cover a much wider spectrum than the prototype; we will distribute search machines to various large radio telescopes and then begin the search according to a very specific pattern that we have developed over the years.

"We would not expect to detect anything during the R&D phase because

Extraterrestrial life could establish a colony somewhere in the asteroid belt

we're not going to make that many observations—it's going to be mostly checking out the instruments. I would say there is a chance of making a detection during the following 10-year period. Beyond that it's difficult to say, because our technology will have improved enormously 15 years from now.

"Just the detection of one signal would answer many fundamental questions. They have to do with the

nature and distribution of life in the universe. What are we doing here? Where are we going? Are there others, and if so, what are they like?"

The hope that some of those questions just might eventually be answered lures even some who had turned skeptical into supporting the SETI program. Take Ben Zuckerman, for example, who talked to me during a lunch break at the University of California at Los Angeles:

"The searches that Pat Palmer and I carried out ended about 1976. I guess I was an agnostic in the matter of intelligent life in the universe when we first started those searches. But in the late '70s my view started to shift. I felt more and more that they weren't out there, and that there might be very few or no civilizations in the Milky Way more advanced than ours.

"That was partly because the searches didn't find anything, but even more because of an argument Michael Hart [professor of physics at Trinity University in San Antonio, Texas] presented in a paper in 1975. Essentially he said that if advanced civilizations existed in such great numbers—100,000 or more according to people like Drake and Sagan—then at least one of them ought to have
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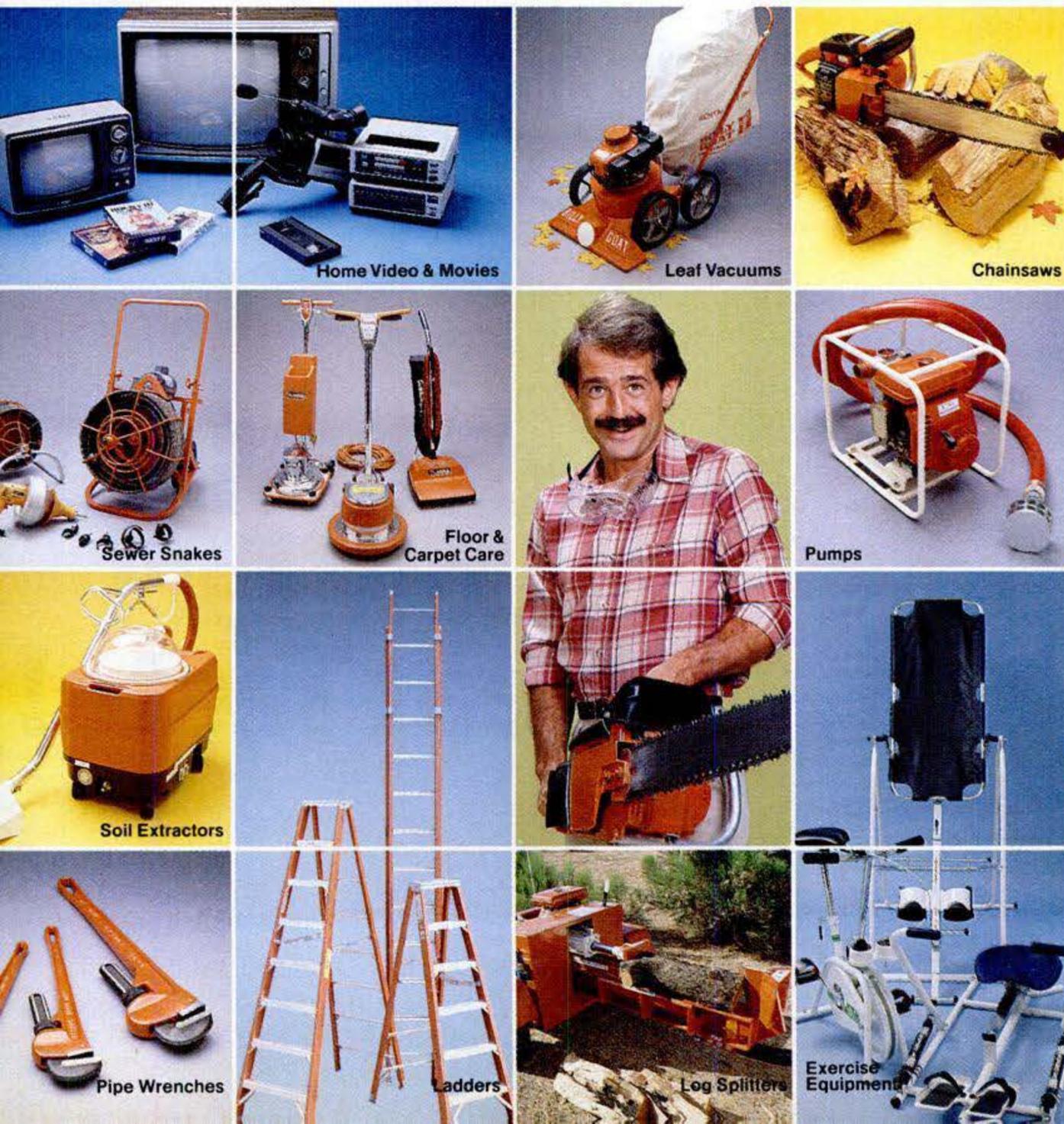
been here already; they should have colonized not only us but the whole galaxy. Because they are clearly not in our solar system, and there is no evidence for them elsewhere, maybe there just aren't any anywhere.

"But even so, I signed the petition in *Science* that Sagan drew up because although the negative arguments are strong, I don't think they are airtight. I think we are extrapolating so far from our own civilization to possibly super-advanced creatures that we still have to do more searching. The searches up to now have not been sensitive or comprehensive enough that we can give them a great deal of weight. It would be nice to get that extra radio data."

The basic argument against the existence of any other advanced civilization in the galaxy—or the universe —was formulated years ago by that very enquiring mind, Enrico Fermi, and has become known as the Fermi Paradox. If there are so many of them and they are so advanced—certainly possessing the secrets of nuclear power, for example—then, Fermi asked: "Where are they?"

An elaboration of this viewpoint is given by Michael Papagiannis, whose speech—and perhaps the intricacy of his reasoning—suggests his native Greece. "Radio searches," he says, "are based on the assumption that an evolving civilization stays within its own solar system. Implicit in Drake's equation [see box] is the notion that it was impossible to travel from star to star to initiate a colonization process. The reasons were based on our thinking of 25 years ago that no race would be willing to make the trip if it took longer than a lifetime.

"But our thinking on this score has changed. Perhaps a very large self-sustaining colony, with many individuals willing to spend generations on spacecraft, could travel at a fraction of the speed of light—perhaps only a few percent. That is feasible with forms of energy we have now. Four years ago at an International Astronomical Union meeting, someone said that would exhaust the total stockpile of nuclear weapons on Earth. Then everybody laughed when they realized what a terrific idea that would be!

"Thus arose the idea of 'star-hopping,' of civilizations expanding—like a gas filling empty space—and going from star to star until a colonization wave would fill the whole galaxy."
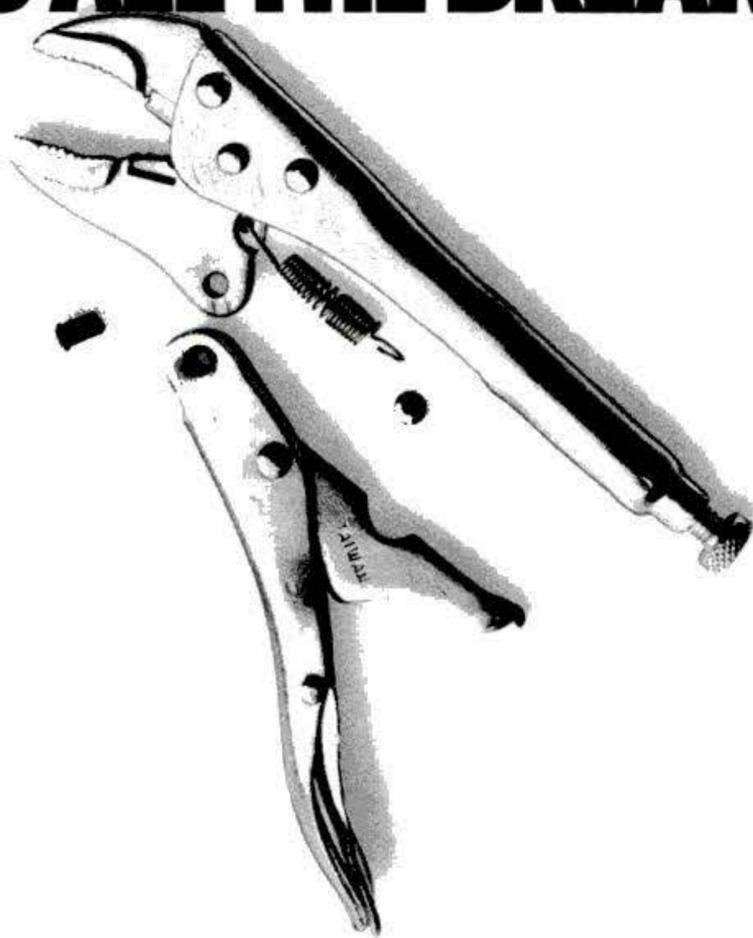
The calculations that attend this speculation are fascinating. "Has colonization started?" asks Papagiannis. "If so, they must be everywhere in the galaxy. If travel took place at the speed of one percent of the speed of light, it would take about 10 million years to colonize the whole galaxy. Now 10 million years is a very small fraction of the lifetime of the galaxy—10 billion years. In this context the conversion of a vast desert to a galaxy teeming with life would be almost instantaneous."

Drake resists the idea of the inevitability of an advanced civilization colonizing away from its own star system: "My argument is that any civilization that takes a look at the time, risks, and energy requirements of such a trip will stop and say, 'This is crazy —we'll colonize our own system.' For example, the kinetic energy of something just the size of a 747 going at one-tenth the speed of light is equal to the total energy generation of the United States."

Probability dictates that because colonization could have started any time within the last five billion years (leaving a few-billion-year developmental period for an advanced civilization), the chance that it started only yesterday is very small. "After all," says Papagiannis, "if you visit a family
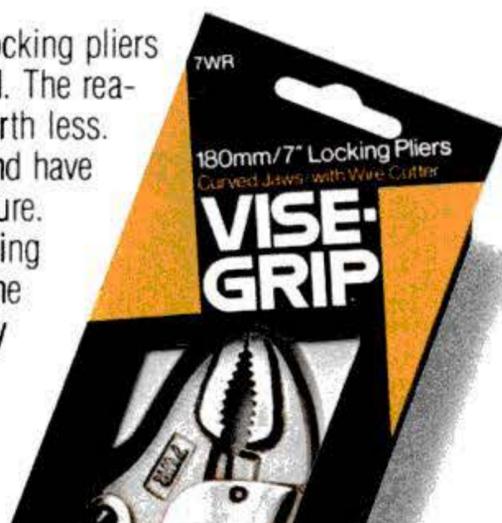
Life in space

with children in Boston, the chance that a baby was born last night is very, very slim. So if we grant these assumptions, we have to conclude that the galaxy is colonized now. The next question is one that has been making the rounds for a long time—the one attributed to Fermi: 'Where are they?'

"Some people have answered by saying they're going around in flying saucers or they built the pyramids, but there has been no scientific evidence for these notions. For the time being it does appear that we are indeed alone. There are several hypotheses to account for this observation:

"1. They are in fact around but they don't want to interfere with us, regarding Earth as a kind of zoo or preserve.

"2. Perhaps they are not communicating with us because they don't know whether we are some kind of cosmic disease that should be eradicated or promising youngsters that should be helped to join the galactic club. Maybe the ethic of cosmic civilization is to leave us alone to demonstrate which we are. I have myself suggested this possibility.

"3. Most likely," Papagiannis continues, "they are not around to contact us, although we can't completely exclude hypotheses 1 and 2. The next question is, what is so special about Earth that made us develop a technology here but nowhere else?"

There are two possible answers, both somewhat chilling. They are, according to Papagiannis:

"1. Intelligence leads to technology, but civilizations with advanced technology simply don't last very long—they end up destroying themselves. Then it would not be surprising that there were no colonizing civilizations—they self-destruct before they start. Such civilizations could have appeared and disappeared many times in the history of the galaxy—like shooting stars, just a flicker and then out.

"2. Another possibility is that because of the very long time that it takes life to evolve—four billion years on Earth from the first appearance of life until technology appeared, a substantial fraction of the age of the universe—conditions on a planet may change to become unfavorable to life rather than hospitable. It's possible that on many planets life appears and begins evolving, but then conditions change for the worse. For example, water freezes or boils, and evolution is interrupted."

Hide and seek

What if extraterrestrial beings exist but have chosen not to show themselves? "Then it won't be long before they have to, or we will find them," Papagiannis explains.

Papagiannis has suggested that it would be worthwhile to search the asteroid belt for possible extraterrestrial colonies: "This is based on the assumption that if they have colonized the solar system, they would probably have parked their space habitats somewhere in the asteroid belt to be close to the least expensive and most plentiful source of raw materials. They could establish a perfectly self-sustaining colony there.

"Out of all the confusing arguments put forward," adds Papagiannis, "no one has come up with a statement that has convinced everyone. I think that in the next 10 or 20 years we will either have detected some sort of signal from SETI, or we will begin to accept the fact that we are alone in our galaxy. If the latter happens, it shouldn't be considered a failure of the process. To know that you are the only technologically advanced civilization in the galaxy is important. It would also have some effect on our own future behavior. Knowing we are the only ones might make us realize that we are too valuable to destroy." **PS**