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COVER: In this photograph, taken in the direction of the center of our Milky Way Galaxy, there are, very roughly, a million stars. Optimistic estimates on the abundance of galactic civilizations suggest that a million stars must be examined before we have a fair chance of detecting an alien signal. This is one reason that serious SETI programs require substantial commitments of time.

PHOTO: David L. Talent. © 1978
The Association of Universities for Research in Astronomy. The Cerro Tololo Inter-American Observatory.

From time to time, Planetary Society members are urged to write to their local newspapers in support of the exploration of the planets and the search for extraterrestrial life. There are a large number of thoughtful people throughout the world who support such activities, and their opinions should be known. Also, newspaper editorialists can change their minds. As an example, we first reprint an editorial from the Sunday *New York Times* expressing great concern about SETI; next, a letter published in a subsequent issue of the *Times* from Planetary Society president Carl Sagan, reassuring the *Times*; and, lastly, a follow-up Sunday *Times* editorial re-evaluating their stand, concluding "SETI is an important and worthwhile endeavor." Dr. Sagan adds that "because we are probably the youngest civilization in the Milky Way Galaxy that has radio astronomy, it is perfectly proper for us to listen and let other more advanced civilizations with greater technological and energetic resources broadcast."

Beware the Cow in E.T.'s Barn —*December 28, 1982*

In the days when saber-toothed tigers prowled the night, humans acquired a healthy instinct: fear of the dark. Astronomers, boyishly defiant of this inherited wisdom, have renewed their search of the universe's dark spaces for signs of alien civilizations. What if they should find them?

The implicit assumption is that other life will be more civilized than ours, and command higher technology. But what if these high-tech aliens are unpleasant, mean or even cannibalistic? Contact with an extraterrestrial civilization could have its hazards.

If, by good fortune, the astronomers turn up a friendly crew, the peril is hardly less. How demoralized we would be to learn that our science, by comparison, is medieval, our art prehistoric or our mores Paleozoic. Should the other-worlders be less advanced, we may learn little—yet be tempted to send mercenaries and missionaries to enchain their bodies and liberate their souls.

It is, of course, otiose to speculate on the nature of alien civilizations. Assume we were the aliens. Who would lightly venture, single and unarmed, to stumble among us on a dark night in the universe? History records how ruthlessly our stronger civilizations have preyed on weaker neighbors. Do our stargazers realize the dangers?

Under the auspices of the National Academy of Sciences, astronomers recently reported on their plans for exploring the universe. With one exception, all have great merit. But their report remarks that reception of signals from space "could have a dramatic effect on human affairs, as did contact between the native peoples of the New World and the technologically more advanced peoples of Europe."

Precisely because it recalls the fate of American Indians, you might think the report would go on to counsel caution. To the contrary: "The effects would be beneficial, if the information could be deciphered and should prove generally useful; on the other hand, they could be harmful if humanity is not ready to use the information wisely."

The caveat about deciphering does not reach the more fundamental problem of comprehension. As Wittgenstein warned, "If a lion could talk, we would not be able to understand him." The laws of physics and chemistry may be the same on other worlds; those of semantics surely differ.

As for the effects of contact with another civilization, less naiveté can be found in the words of the cockroach whose mode of signaling was to thud on the lower-case keys of Don Marquis's typewriter:

"i once heard the survivors/of a colony of ants/that had been partially/obliterated by a cow's foot/seriously debating/the intentions of the gods/towards their civilization"

The new search is merely to listen for signals, but if any are detected, the case for contact will doubtless be pressed. As they rummage through the dark crannies of the universe, astronomers should take care not to stir up extragalactic tigers or oblivious cows.

If Extraterrestrials Do Exist: Not to Worry —*January 30, 1983*

TO THE EDITOR: At a time when a serious radio search for extraterrestrial intelligence (SETI) is being advocated by a distinguished group of 70 scientists from 13 nations, including seven Nobel laureates (news story Oct. 22) and when a small amount of money has finally been authorized for the United States component of such a search (news story Dec. 21), it is surprising to find the *Times* advocating "fear of the dark" of space ("Beware the Cow in E.T.'s Barn," editorial Dec. 28). It happens that we live in this dark.

We do not know the motives of extraterrestrial civilizations, should they exist. But some of the anxieties expressed in your editorial are unwarranted:

Extraterrestrial "cannibalism."

It is implicit in the evolutionary process that extraterrestrial carnivores are unlikely to find the sequences of amino acids in human proteins especially tasty. Even if human beings were a famous interstellar delicacy, the

(continued on page 22)

The Search for Extraterrestrial Intelligence (SETI)

by Thomas R. McDonough

We are delighted to devote this issue of *The Planetary Report* to the Search for Extraterrestrial Intelligence, known among scientists as SETI (rhymes with "jetty"). This issue has been in the planning for about a year, and presents one facet of The Planetary Society's program to inform the public about scientists' recent efforts to find signs of advanced civilizations in space.

The modern SETI program is almost as old as the space age itself. On October 4, 1957, with the launching of *Sputnik 1* by the Soviet Union, the human species took its first tentative step into the Galaxy. Just two years later, Giuseppe Cocconi and future Society advisor Philip Morrison (interviewed on pages 12–14), published in *Nature* their classic paper on strategies in the search for extraterrestrial civilizations. They concluded that the search for radio signals was the most likely to be fruitful. At about the same time another scientist, also destined to become a Society advisor, Frank Drake, was conducting the first modern search for extraterrestrial radio signals of intelligent origin.

It is probably no coincidence that both theoretical and experimental SETI studies began so soon after *Sputnik*. *Sputnik* drew the attention of humanity skyward and dramatically made us aware that we are inhabiting just one speck in a vast universe of possible worlds. Overnight, planets that had since antiquity been unthinkably distant became neighbors we might one day visit, and the seeds of SETI were planted.

The Planetary Society is concerned with educating the public about SETI and with supporting this research. In the short two years since the Society began, we have enabled American scientists to attend a SETI conference in the Soviet Union, we have helped to get NASA's SETI program reinstated by Congress, we have supported George Gatewood's search for planets around other stars, and we have enabled Paul Horowitz to build "Suitcase SETI," which has already looked at two hundred and fifty nearby stars. [The latter two projects are described in this issue.] As this is written, scientists from NASA's Jet Propulsion Laboratory are preparing, with our support, to go to Australia to perform a SETI program in parts of the sky that are not visible from the northern hemisphere.

The 1980s may well become known in history as the decade of SETI. From the enormous public enthusiasm for motion pictures such as *E.T.: The Extra-Terrestrial*, to the SETI programs of several countries, the world is dealing in both fiction and fact with the possibility of other life. In a petition initiated by Carl Sagan and published in *Science* last October, seventy-three scientists around the world (including seven Nobel laureates) affirmed their support for SETI (see page 11). Japan is building a radio telescope to be used, in part, for this type of research. The Soviet Union is engaged in SETI. NASA Ames, JPL and Stanford University are building a major computer-controlled SETI receiver.

Today's SETI programs are taking advantage of the relatively inexpensive computers now widely available. Soon these will enable us to search through hundreds of thousands of possible radio channels at once, where previously those channels would have had to be searched individually. Modern electronic technology is, in part, the result of the need for compact, light, reliable equipment to fly in space. Thus it is fitting that this same technology is now being harnessed for SETI.

Because of the improved technology and the international activity, we can be sure that the 1980s will see a more thorough search of the sky for artificial signals than has ever been done before. This means that the likelihood of success is greater than it has ever been, although no one can tell how long the search must run.

Since the universe is 10 to 20 billion years old, and the Earth is only 4.5 billion years old, a civilization out there may now be millions or even billions of years older than ours. They may have discovered cures for the social, economic and ecological ills that afflict younger civilizations. It may be that if we just point our antenna at the right piece of sky, and tune to the right channel, we will discover signals giving us knowledge that other beings have been storing for eons. Even if we could not decipher them, just knowing of one other civilization advanced enough to broadcast radio signals could be vital. The differences between Americans and Russians, Arabs and Israelis might come to seem as insignificant as the differences between two dolphins.

Some past experiences give us a glimpse at what the first successful SETI detection may be like. Frank Drake's original SETI program actually did discover artificial signals, but they turned out to be from a secret military experiment. Then, in England in 1968, strange, regular signals from outer space were found by radio astronomers. Sounding like the ticking of a clock, the signals were totally unlike any that had ever before been detected in astronomy. So artificial did the signals seem to be, that the discoverers, Jocelyn Bell and Antony Hewish, at first called the source LGM-1, for Little Green Men. For a while scientists debated the possibility that they might be from alien civilizations. Gradually, the evidence mounted that they were in reality rapidly rotating neutron stars—now called pulsars—broadcasting without artificial aid.

Imagine for a moment that you are seated at the controls of a radio telescope somewhere on the Earth when the first signals ever detected from another civilization are received. The first sign is the beep of a computer. It heralds an unnatural pattern from a part of the sky heretofore thought to hold nothing of interest. Then the computer printout shows a signal unlike anything known to astronomy. Your blood quickens, and you start the lengthy tests to eliminate the possibility that the signal is from some neighbor's faulty car ignition, or from one of the thousand artificial satellites orbiting our planet. Only after many tests and further observations can you rule out the possibility of artificial Earthly or natural astronomical sources. But each test that the signals pass gives you a growing confidence that you are the first human to hear the sounds of a being from another world.

This decade may be the first time in history to provide clear evidence of intelligent life elsewhere. The Planetary Society is dedicated to helping that happen. So turn the page and read some signs of terrestrial intelligence.

Thomas McDonough is SETI Coordinator for The Planetary Society and a lecturer in engineering at the California Institute of Technology.

Searching for Signals from Extraterrestrial Civilizations

by Paul Horowitz

The last few decades have seen a resurgence in the belief that other intelligent civilizations almost certainly inhabit our galaxy. This has been spurred by several developments, in particular the findings that 1) in star formation, planetary systems and multiple stars are probably the rule rather than the exception, 2) organic molecules are common in interstellar matter, and 3) complex organic building blocks necessary for life form in abundance when ultraviolet light and electric discharges are passed through a flask containing the simple constituents believed to have comprised the early atmosphere on Earth. This means that a suitable habitat for life and a mechanism for its origin may exist near many of the 200 billion stars of our galaxy. Our Sun and planet are ordinary; thus, the galaxy may be teeming with life and technology.

Even without relying upon detailed speculations as to the probabilities of planetary formation, chemical and biological evolution, the rise of intelligence, technology, and the like, it is useful to observe that, in all of nature's variety, we never see a phenomenon that has happened only once. With apparently billions of opportunities for life to arise in our galaxy alone, it would be astounding (to say the least) if we turned out to be the sole example of intelligent life.

Fortunately, grand rocket ships of the "Star Wars" variety are not required to establish contact with another technological civilization in our galaxy. Elementary calculations based upon fundamental constraints of physics demonstrate dramatically that relativistic space travel is extremely costly in energy terms: A round trip to the nearest star at 70 percent of the speed of light would use energy equal to

An alien radio telescope searches the sky for signals from another technical civilization.
Painting: David Hardy

the total electric power consumption of the United States for a half million years, and this only if we postulate an ideally efficient rocket powered by a pure matter-antimatter engine. On the other hand, communication over interstellar distances via radio transmissions turns out to be not only feasible, but cheap: Using current technology, we could communicate with another civilization like ourselves situated on any of the several million nearest stars; an interstellar telegram to one of the farthest of these stars (at a distance of 1000 light-years) would cost about $1 per word!

If another technological civilization (by which I mean a civilization capable of such radio frequency communication) does exist, is it likely to be at or near our level of advancement? Probably not, as a moment's thought will convince you: We have been capable of interstellar communication for a mere 20 years or so; in other words, on the grand time scale of civilizations, we have just entered the communicative era. Others who can communicate over interstellar distances are likely to be far more advanced. We have not seen the end of the stunning advances made in electronic technology over the past few decades; thus, communication over galactic distances is surely even easier than we estimated above. (The same optimistic conclusion does not apply to our hypothetical rocket flight, which already went to the fundamental limitations imposed by laws of physics.)

It is no exaggeration to say that communication with an extraterrestrial intelligent species would be the greatest single discovery in human history. How, then, should we go about the job of detecting and deciphering alien communications? For a starter, we should listen, not talk: We're the newcomers in this galactic club, if such exists. And where do we listen—to which astronomical objects, on what wavelengths? Current thinking on this subject suggests some interesting "magic frequencies." The basic idea is that the best frequency for communication is the one where communication is most efficient. It turns out that, because of noise and other irreducible background—cosmic "static" —the best frequencies appear to fall in the microwave region of the radio spectrum, roughly 1 to 10 billion cycles per second, or gigahertz in the lingo of science.

But that's still an enormous range of frequencies; what's needed is some universal frequency marker that would be recognized by civilizations that had not previously communicated. As it turns out, there is just such a "magic frequency" in that region of the spectrum. The classic paper on this subject is Cocconi and Morrison's, published in *Nature* in 1959, suggesting microwave communication near the 1.4 gigahertz frequency emitted naturally by neutral hydrogen atoms, 1420405751.768 vibrations per second. This particular frequency is emitted by the simplest and most abundant atom in the universe; its radiation must be well-known to radio astronomers everywhere. It seems reasonable that this, or some other compelling magic frequency chosen from the limited set that has been suggested, would make sense as a meeting place in the vast radio frequency spectrum, thus simplifying our search for signals of intelligent origin.

Thanks to a grant from The Planetary Society in October, 1981, we were able to construct an advanced receiving system that can be easily used on existing radio telescopes to search for signals at any special frequency—for example that emitted by neutral hydrogen. The apparatus, nicknamed "Suitcase SETI" because of its transportability, allows us to listen to a quarter of a million separate radio channels simultaneously, and was first used in May, 1982 at the giant 1000-foot antenna at Arecibo, Puerto Rico. That experiment, in which we spent 75 telescope hours looking at 250 nearby stars similar to our Sun, constituted the world's most sensitive (though not the most comprehensive) search for extraterrestrial signals thus far. That system can easily detect an Arecibo-like system transmitting from any of the nearest million stars, and accomplishes more searching in one minute than would have been done in 100,000 years with the first receiver constructed specifically for SETI—the pioneering Ozma project of 1960. Suitcase SETI reports any suspected detections to the observer immediately, so a possible signal can be eliminated or verified on the spot; it also archives all data from each star we search. For reasons difficult to explain in detail in this short article, it additionally provides a high degree of discrimination against the interfering radio signals of our own terrestrial intelligence.

Paul Horowitz' six-year-old son, Jacob, reaches up toward the 84-foot dish of the radio telescope at Harvard's Oak Ridge Observatory. This facility has been refurbished and sensitive signal acquisition equipment assembled with funds provided by The Planetary Society. The Planetary Society/Harvard SETI program is the most comprehensive and sensitive such effort ever attempted.
Photo: Paul Horowitz

During our search at Arecibo, we did not find any extraterrestrial signals. This should not be cause for discouragement, since most scientists in this field believe that to have a reasonable chance of finding another technological civilization, we might have to examine a million candidate stars. Unfortunately, occasional searches conducted at busy telescopes like Arecibo can never examine enough stars: to do a million stars would take 20 years of continuous telescope time. Brief searches serve mainly to eliminate the possibility that the galaxy is teeming with life and radio signals.

What is needed is a highly sensitive search, patiently carried out over many years, using a radio telescope dedicated 100 percent to that task. Once again The Planetary Society has come through with support, this time for our proposal to devote Harvard University's 84-foot radio telescope full-time to SETI. We are now using the Suitcase SETI apparatus to conduct a meridian transit search of all stars between 30° south and 60° north of the celestial equator, beginning at the neutral hydrogen frequency of 1.420 gigahertz, then successively examining other magic frequencies. The result will be overlapping coverage of every potential source of extraterrestrial signals in more than two-thirds of the northern sky, switching to a new magic frequency each year. Of course, our ultimate sensitivity cannot match Arecibo's powerful antenna (it is the world's largest); but we hope to compensate with vastly greater sky coverage. After all, there may be a very small number of very powerful signals up there, in which case the problem isn't sensitivity, it's persistence!

We are particularly pleased that The Planetary Society has chosen to fund these exciting projects, and we would like to express our thanks for its enlightened support. It seems to us an ideal partnership, since SETI is an important adventure for humanity as a whole, one whose significance can be easily understood and appreciated without any special training in science.

Paul Horowitz is Professor of Physics at Harvard University and the designer of Suitcase SETI.

The NASA SETI Program

by Samuel Gulkis and John H. Wolfe

People have wondered whether or not humankind is alone in the universe throughout recorded history, and probably before then as well. Originally discussed in the contexts of theology, science fiction and out-and-out speculation, the subject acquired scientific respectability more than two decades ago through the pioneering paper by Cocconi and Morrison, "Searching for Interstellar Communications," in which they discussed electromagnetic waves as a technically feasible means of communicating across space. They suggested that, since interstellar travel is impractical (so far as we know), a technically feasible means of communicating across space is electromagnetic radiation. The electromagnetic spectrum encompasses everything from radio to visible light to gamma rays (**Figure 1**).

Atoms emit and absorb radiation at specific frequencies, called spectral lines. Cocconi and Morrison proposed that transmissions in the neighborhood of the 1420 megahertz spectral line of neutral hydrogen, the most common element in the universe, might be one means by which civilizations communicate with each other over interstellar distances. They also realized, as have subsequent investigators, that the challenge lies not in the detection of the signal, but in the search itself—and in the ability to sort rapidly through the myriad possible signal types and locations. The situation is somewhat like trying to find a friend in a large city where the friend may be visiting. It is easy to recognize the friend once you spot him or her, but it's difficult, without some prior arrangement, to know where to look.

The circumstances are considerably more complicated for SETI since we not only have to worry about where to look, but also at what frequencies. To do a comprehensive search, we must examine many different directions over a wide range of frequencies and signal characteristics. To investigate all possible combinations is out of the question. As an example, consider the problem of searching for a signal only one hertz (cycle per second) wide, out of the total radio band of 100 billion hertz. If we took one second to tune our radio to each frequency, it would take 100 billion seconds, or over 3000 years! But this is only for one direction in space. If we wanted to investigate the 10 million Sun-like stars out to several thousand light years, the time required would increase to a billion billion seconds, more than the age of the universe. Clearly some means of searching quickly must be an integral part of any SETI program. Fortunately, we now have the technology to search the radio spectrum rapidly and need not be discouraged yet.

Although scientific interest in extraterrestrial life has remained high for the last several decades, and projects that could search quickly for its signs have been advocated for nearly a decade, there have as yet been no comprehensive American searches. Many individuals in the U.S. have carried out searches, beginning in 1959 with Frank Drake's Project Ozma. Drake's observational program explored approximately 400 kilohertz of bandwidth from each of the two stars Tau Ceti and Epsilon Eridani. To date, 36 different searches have been carried out. (See table, page 18.) While these efforts have not detected any evidence of extraterrestrial life, only a tiny fraction of the possible frequencies and directions has been covered. These pioneering efforts emphasize the magnitude of the search effort.

Now, for the first time in the United States, public funding is available to begin research and development leading up to a program that will cover 10 million times the search space examined to date. Managed by NASA's Life Sciences Office, the program is being carried out jointly by Ames Research Center and the Jet Propulsion Laboratory. The NASA SETI program is the first major U.S. government program designed specifically to search for evidence of extraterrestrial intelligence. Its approval by the U.S. Congress was due, in part, to arguments presented by The Planetary Society.

The NASA program focuses on a microwave search using radio telescopes and advanced spectral analysis techniques. The background noise of the sky has a pronounced minimum in the microwave spectral region (**Figure 2**). Receiving instruments operating in this spectral range can have increased sensitivity, and this is our primary reason for undertaking the search in this region. Any extraterrestrial technical civilization should draw the same conclusion from a similar analysis. During our planned five years of R & D we will design, develop and thoroughly test a prototype instrument at NASA's Deep Space Network site at Goldstone, California and at the Arecibo Observatory in Puerto Rico.

Then we will begin observations, using two distinct strategies. In the first, we will search selected nearby stars and other regions of interest for weak signals. In the second, we will scan the entire sky for strong signals. With this observation system we will have the ability to process millions of separate frequency channels each second and to identify candidate ETI signals in real time. The use of ultra-low-noise receivers with wide bandwidth and tunability will make these instruments highly sensitive.

One objective of the NASA program is to survey the entire sky over a wide range of frequencies. This all-sky survey increases the probability that all potential sites for intelligent life will be observed, albeit often with low sensitivity. Using a relatively small radio telescope (typically 34 meters in diameter) and observing each direction in space for only a few seconds, this survey will have limited sensitivity. But this sky survey will cover the entire celestial sphere over the frequency band 1.2 gigahertz to 10 gigahertz spanning the flat minimum on the terrestrial microwave window (**Figure 1**), and a few spot bands between 10 gigahertz and 25 gigahertz.

A second goal is to examine directions in the sky that seem especially promising. Here we will search a smaller frequency range than in the all-sky survey, but with considerably greater sensitivity. We will observe 773 specially-chosen stars within 80 light years of the Sun as well as regions of special interest, such as the center of the Milky Way and some external galaxies. We will cover a frequency range of 1.2 gigahertz to 3 gigahertz, as well as a few spot bands between 3 gigahertz and 25 gigahertz. This spectral band includes the "water hole," 1.4 gigahertz to 1.7 gigahertz (**Figure 2**).

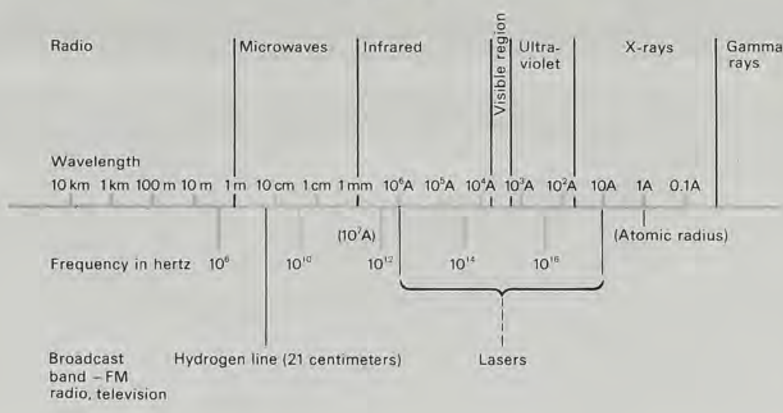
Our greatest technological challenge is to develop instruments that can process the gargantuan data rates needed for the search. A. M. Peterson and K. S. Chen of Stanford University have already designed a special-purpose digital signal processor that can filter a wide-band signal into many narrower (and easier to search) bands. The design provides simultaneous output bandwidths of approximately 1 hertz, 32 hertz, 1024 hertz and 74 kilohertz over a spectrum that is about 8 MHz wide, thus permitting simultaneous search for signals in any of these bandwidths. In its operational configuration for SETI the processor will have over 8 million channels and data rates more than a billion bits per second, where a "bit" is a datum recorded as a zero or a one. A prototype instrument with only 74,000 channels is under construction at Stanford and will be tested this year. (The Suitcase SETI of Paul Horowitz, supported by The Planetary Society, already has 128,000 channels.) Other instruments to handle the data from the NASA SETI project have yet to be designed. These instruments will sort through the data and decide which signals require further analysis. In the R & D phase, the data handling will be done using a small, general purpose computer. Later, specialized digital hardware will be designed, built and incorporated into the system.

With this new equipment we will not only be able to search for extraterrestrial signals, we will also gather valuable astronomical data. The all-sky survey will provide a combination of relatively high sensitivity, delicate fine-tuning ability, and full-sky coverage, uniquely enabling systematic cataloging of emissions from both inside and out of our Galaxy. Conventional radio astronomy telescopes, which are neither instrumented as the SETI equipment nor dedicated to an all-sky survey, are unlikely to collect these data. NASA also plans to make the SETI equipment available to individual investigators for their own observations independent of the SETI program.

Will the NASA SETI program detect evidence of extraterrestrials? No one can answer with certainty. However, a substantial delay in the search will decrease the prospects for the success of a ground-based program. Loud signals from Earth unavoidably enter our instruments, causing confusion and wasted effort. Each day the radio signals of our own civilization take another leap in intensity. We must search now if we are to do it economically, without having to observe from deep space to shield ourselves from our own noise.

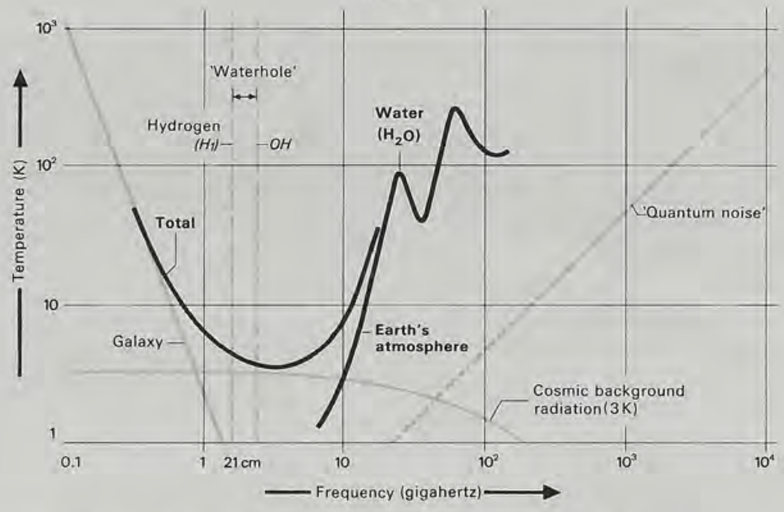
Samuel Gulkis is a Senior Research Scientist at the Jet Propulsion Laboratory and the Deputy SETI Program Scientist. John H. Wolfe is a planetary scientist at the NASA Ames Research Center and the SETI Program Scientist.

Figure 1



The frequencies of the electromagnetic spectrum are shown on this chart in both wavelengths (given in meters and atomic Ångstrom units) and hertz (cycles per second) SETI researchers regard the 21 centimeter or 1420405751 hertz (or 1420 megahertz or 1.420 gigahertz) line of neutral hydrogen to be a good frequency for interstellar communication.

Figure 2



This chart illustrates the radio-quiet region in which an advanced civilization might choose to send and receive signals. The units shown are those used by radio astronomers. The background noise level is measured in degrees Kelvin, the temperature above absolute zero. (We want it as low as possible.) Frequency is measured in gigahertz (GHz), a unit equal to a billion crests or troughs of a radio wave passing a fixed point every second. Between the radio noise of our galaxy and the radio absorption of our atmosphere there is a low-noise region ideally suited for communication. The radio noise of our own galaxy (galactic radio background), largely due to fast-moving charged particles in interstellar space, dominates at lower frequencies. Cosmic radio background noise at three degrees Kelvin, left over from the Big Bang, falls on all radio telescopes. At about 50 gigahertz, this noise decreases, and the "quantum noise" inherent in any radio receiver (rightmost line) becomes dominant. At the upper right are shown peaks in radio absorption, due to molecules in the Earth's atmosphere. These absorption peaks limit the sensitivity of ground-based searches in that frequency region. The frequency range of relative radio quiet is between 1 and 10 gigahertz. Almost in the center of this quiet region are the natural frequencies of two prominent natural radio emitters: the interstellar hydrogen atom (H), and the interstellar hydroxyl radical (OH), oxygen chemically bound to hydrogen. Here are the words of the Cyclops Report, the first complete engineering study of a SETI system, on the possible significance of these two natural frequencies:

> *"Nature has provided us with a rather narrow quiet band in this best part of the spectrum that seems especially marked for interstellar contact. It lies between the spectral lines of hydrogen (1420 megahertz) and the hydroxyl radical (1662 megahertz). Standing like the Om and the Um on either side of a gate, these two emissions of the disassociation products of water beckon all water-based life to search for its kind at the age-old meeting place of all species: the water hole."*

In Search of Other Worlds

by George D. Gatewood, Nancy Nowakowski Robinson and Frank D. Drake

Scientists have often posed the question: "Can extra-solar planetary systems be detected?" The answer is: "Yes—with the right instrumentation." Within the last few years the measurement precision in the classical field of observational astronomy has advanced several-fold and we now have a device which may let us actually detect a planet orbiting within the nearly overwhelming glare of its star.

Several currently proposed detection techniques are refinements of those used to observe double stars. The least practical, but still technically feasible, method is simply monitoring the brightness of thousands of stars. From time to time a planet might move between us and its star, slightly dimming the starlight. But because of our angle of view, it is very unlikely that the dimming could be seen from here. Out of several thousand stars, chances are that only one would show such dimming, and then only for a day or so every several years.

A more obvious and promising approach is to image the star and the field around it onto a highly sensitive detector. This is more difficult, however, because a star would outshine its planet by more than a billion times. To overcome this problem, at least partly, scientists from Stanford University and the Hewlett-Packard Corporation are working on a detector which uses light interference to darken a star's image while producing identical images of a possible planet on either side of the star. The spaceborne system would scan the remaining scattered light around the star, noting bright points duplicated on each side of the star. These could be monitored for a number of years. If a pair of points seems to orbit the star, a detection has been made.

Though very complex, the system has a good chance to detect well-placed planets orbiting nearby stars. If a trial system succeeds, larger, more elaborate systems with greatly enhanced capability may follow.

Yet of all the techniques for the discovery of distant planetary systems, the most promising is the first ever tried—astrometry. For years, astrometrists have been looking for small wavy motions that stars should make as they orbit the barycenter, the center of gravity of the star-planet system. However, their lack of success does not indicate that extra-solar planets are not there. Until 1980 we did not have instruments precise enough to detect any but the most unlikely planetary systems—those in which planets many times larger than Jupiter might orbit tiny stars much smaller than our Sun.

In early 1980, a group of University of Pittsburgh astronomers at the Allegheny Observatory successfully tested a system many times more accurate than any previously available. With it they will be able to see the small wobble caused by a Jupiter-sized planet orbiting any of 100 nearby stars. Careful examination of this small motion could tell the astronomer the mass of the planet, the length of its year, and its distance from its star. We may find stars with complicated motions indicating the presence of several planets. If the wobbles are large enough, the motion could be analyzed to reveal entire planetary systems.

To give astronomers a better look at these small motions and to allow them to detect large planets that may orbit nearby stars, two new telescopes have been proposed. They would be located at excellent astronomical sites, one in the northern and one in the southern hemisphere. By carefully examining the motions of the 1000 closest stars, these telescopes would prepare for the careful charting of planetary systems near our Sun.

But the wobbles induced by Earth-sized planets would be too small to be detected from the ground. The Allegheny group, working with scientists at NASA's Ames Research Center, has proposed a spaceborne system for this effort. The precision possible from space depends only on the size of the instrument and can theoretically be used to search for the planet-induced motions of any star that can be seen. The Allegheny-Ames group is considering a system that could be launched by the Space Shuttle. This special purpose device would be large enough to detect any Earth-sized planet within 40 light years of Earth. It is a smaller and less complex telescopic system than the Space Telescope.

By combining the various devices now under development by astronomers across the United States, we can now begin to chart the way ahead. We will need at least 15 years to complete a study of the first 50 to 200 stars, and decades to do the entire solar neighborhood. To help astronomers begin this work, a group of astronomers and laypersons have joined to form the Extrasolar Planetary Foundation. The group hopes to act as a focal point through which public support can be funneled to where it can do the most. Last year The Planetary Society provided a $2,500 grant to help the Foundation in its work.

We no longer need to stare wistfully at the stars. Now is the time to begin to search for other planetary systems. Soon we may know of other worlds and in that knowledge, understand ourselves better.

George Gatewood is Director of the Allegheny Observatory and Associate Professor of Physics and Astronomy at the University of Pittsburgh. Nancy Robinson is Business and Operations Manager of the Allegheny Observatory. Frank Drake, formerly Director of the National Astronomy and Ionosphere Center, is Professor of Astronomy at Cornell University and a member of the Board of Advisors of The Planetary Society. All are Board Members of the Extrasolar Planetary Foundation.

IRAS and SETI

The mission of IRAS, the NASA infrared astronomical satellite launched on January 25, 1983, is relevant to the search for extraterrestrial civilizations; not because we expect to find them transmitting in the infrared (although that is by no means out of the question) but because a main class of objects to be viewed by IRAS comprises stars at a very early moment in their life histories. Scientists believe that when a dense interstellar cloud collapses to form a star, the system goes through a stage where most of its energy escapes in the infrared, other wavelengths of radiation being absorbed by a cocoon of gas and dust (the likely birthplace of planets) around the forming star. IRAS is already detecting many infrared sources; perhaps a number of these will eventually turn out to be stars caught in the act of gathering planetary systems. While IRAS is not expected to observe extrasolar planets directly, it may tell us much about the fundamental processes that lead to their formation. *Painting: Ken Hodges, JPL/NASA*

Detecting Extrasolar Planetary Systems

by David C. Black

The lunar station first acquired the signal at 9:13 in the evening on the tenth of January, 2083. When the system alert appeared on the operation console, the operator assumed that the signal was from Titan Orbiter 9, although the data relay from that spacecraft was not expected until just after midnight local time. Mildly puzzled and eager to break the monotony of his job, the operator requested spacecraft identification from the station's computer. The response "Beta Hydri Probe I," both surprised and confounded the operator. After a quick check he confirmed the identification, activated the intercom to the station chief's office, and requested display of all available data concerning Beta Hydri Probe I that were stored in the station's central computer. Before the station chief arrived in the operations room, the mystery of Beta Hydri Probe I was solved. The spacecraft was a self-contained intelligent probe that had been launched in the year 2018 toward the G2 type main sequence star Beta Hydri in the constellation Hydrus, the water snake. Even though the probe was accelerated at 1 g for roughly a year to a speed greater than half the speed of light, it had taken 42 years to reach this star in the southern sky. The reason for this mission was simple. A concentrated effort to detect and study other planetary systems, begun late in the 20th century, had revealed that this Sun-like star only 22 light years away had a complex planetary system like our own. Beta Hydri Probe I, sent to explore this system, was beginning its report to its creators about their future in the cosmos.

The events described above are fictional, but are they likely to happen someday? The answer depends on two things. First, whether or not planetary systems, such as our solar system, are common in nature and second, whether or not humankind develops the instruments needed to detect other planetary systems. At the present time there is *no* unequivocal observational evidence for another planetary system. But, why is a systematic search for other planetary systems scientifically important? How might we detect other planetary systems? What are the prospects for mounting a comprehensive search?

There are three scientific studies which would be directly affected by a comprehensive search for other planetary systems. First, if life is to evolve to an advanced (intelligent?) state, it must have suitable conditions. If planetary systems can be shown to be abundant in nature we can have more confidence that life, in some form, exists elsewhere. Second, our present understanding of how stars are formed predicts that most stars should have planetary companions. Confirmation or denial of this prediction would have a major impact on our understanding of star formation.

Finally, and perhaps most important, data from a search for other planetary systems are essential to understanding the origin of our solar system. Without these data, we will be confined to conjecture as to how the solar system formed, unable either to check our current hypotheses or to formulate others should our present views prove to be incorrect.

It is this tremendous potential of broad, interdisciplinary impact, ranging from astrophysics to life science, that makes a comprehensive search for other planetary systems so important.

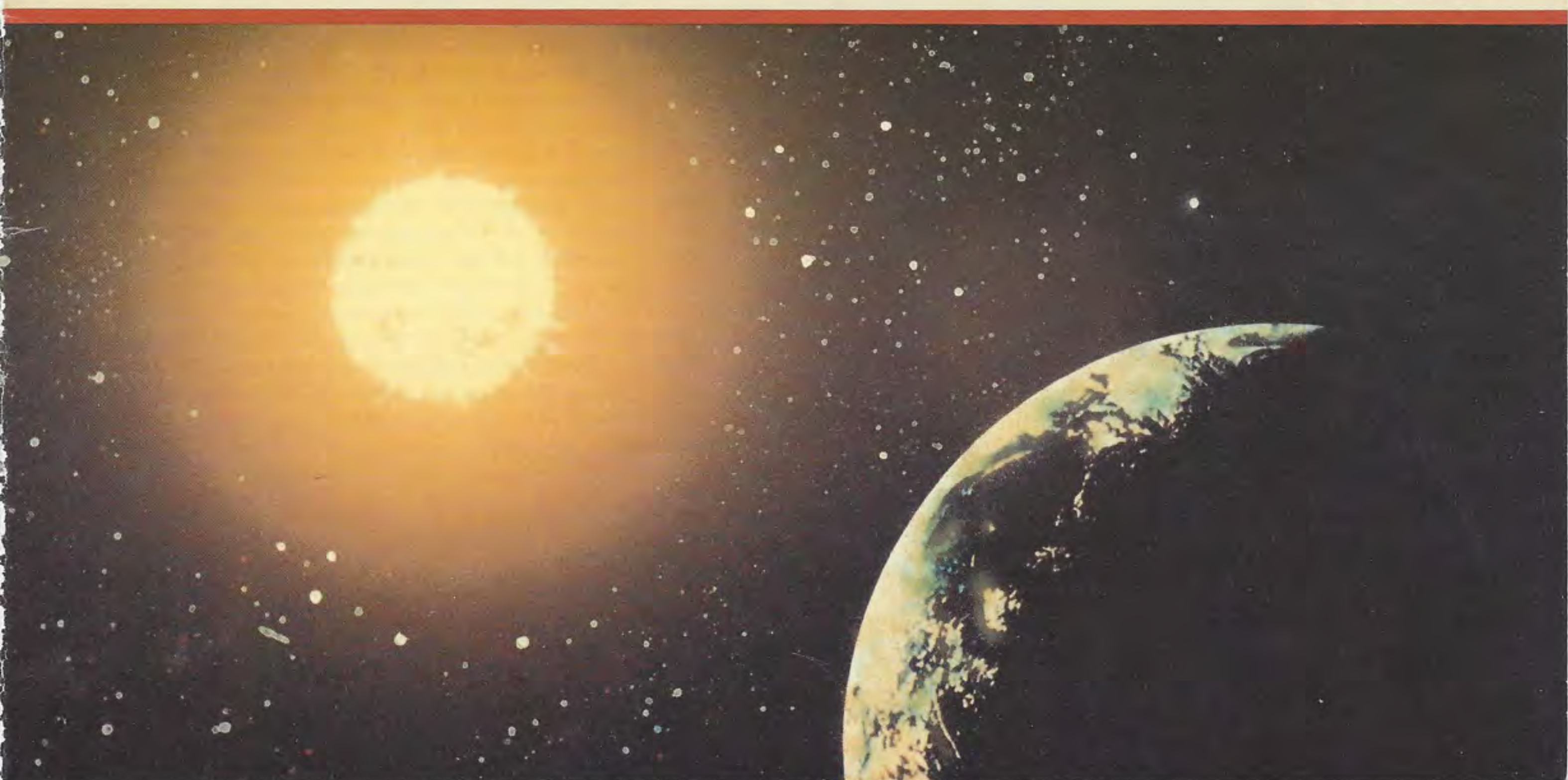
How to Find Them?

We can detect other planets by the radiation they emit, as well as, in principle, some observable effect that they might have on their central star.

Because planets are both small and cold, it is extremely difficult to detect them even around the nearest star. (The nearest star, Proxima Centauri, is part of a triple star system,

(continued on next page)

An Earth-like planet orbits a star somewhere in the Milky Way Galaxy. From what we have learned from our own solar system, we would expect to find numerous planets orbiting other stars.
Painting: Jon Lomberg



A star-planet system does not move about the center of the star but orbits a point at the center of their combined gravities, the barycenter. When an observer in another star-planet system tracks the motion of the distant star, it appears to "wobble" as it moves across the sky. Detection of these wobbles in a star's apparent motion could indicate that the star has one or more planets.

(continued from preceding page)

Alpha Centauri, about 4.3 light years from the Sun.) We see our solar system planetary neighbors because they reflect visible sunlight. Detecting this reflected light from the planetary companions of other stars is very difficult, for two reasons. First, at the great distances involved, planets are very dim objects. Second, those dim objects are right next to a relatively bright object—their central star. For example, Jupiter is roughly a billion times dimmer than the Sun; detecting Jupiter from another star system would be like seeing light from a penlight that is attached to the edge of an extremely powerful searchlight.

Planets also emit infrared radiation. The situation is more favorable in the infrared because, at that wavelength, many stars are not as bright as they are in visible light. In the infrared (at a wavelength of 30 microns or 60 times the wavelength of visible light) Jupiter is about 10,000 times dimmer than the Sun.

A major limitation of efforts to detect planetary radiation, be it infrared or visible, arises from turbulence in the Earth's atmosphere. (This turbulence is what makes stars twinkle.) The limitation is so severe that searches for radiation from planetary companions of other stars will have to be conducted with space-based telescopes.

NASA's Space Telescope, scheduled for launch in 1985, will be the first telescope capable, in principle, of detecting reflected visible light from distant planets. However, the Space Telescope was not designed for this extremely difficult task; the best we can hope for is a chance discovery of a planetary companion to one or more of the very nearest stars. While positive results would give us confidence that planetary systems are common in nature, negative results would tell us nothing. Furthermore, the Space Telescope would not be able to conduct a comprehensive search of many hundreds of stars.

There are no current plans to launch an infrared telescope that would be capable of detecting planetary systems. Scientists at NASA's Ames Research Center and the Jet Propulsion Laboratory are currently studying a Large Deployable Reflector (LDR) which would have approximately the same capability in the infrared that the Space Telescope has in the visible part of the spectrum. It is unlikely, however, that the LDR would be launched any earlier than the mid-1990's.

A Shift in Mass

The most likely observable effect that a planet would have on its central star is to shift the center of mass of the planetary system away from the center of the star. The star would actually orbit an imaginary point, called the barycenter, the center of gravity for the star-planet system. The bigger the planet and the farther away from the star, the larger the wobbles in the motion of the star. These wobbles can be detected by two techniques: spectroscopy and astrometry.

We can use spectroscopy to measure Doppler shifts in the star's light caused by this orbital motion. When the star is coming toward us, features in its visible spectrum shift up in frequency, toward the blue. When it is receding they shift down, toward the red. This technique is used to observe binary (double) stars that are too close to each other to be seen as separate points of light; they are called "spectroscopic binaries." The shifts due to a planet, however, would be very much smaller than those due to a companion star, so our spectroscopy for detecting planets must be much more precise.

Recent developments by groups at the Lunar and Planetary Laboratory at the University of Arizona and at the Canada-France-Hawaii Telescope Corporation will soon make it possible to measure stellar velocities with an accuracy of 10 meters per second or better. We should then be able to detect the effects of planets similar in mass to Jupiter on several nearby stars, but not planets with smaller masses such as Saturn, Uranus and Neptune. Fortunately, this search method can be used with ground-based telescopes, and search programs are expected to begin within the next two years.

Another technique, astrometry, can be used to measure the wobble in the star's apparent motion as it moves across the sky, much like the motion of a reflector on a bicycle wheel. The apparent size of the wobble in a star's motion depends on how far the star is from us. If we were observing the Sun's motion from 33 light years away, we would see a wobble of about 0.0005 seconds of arc—comparable to viewing Lincoln's head on a U.S. penny from 5000 miles.

The promise of astrometry as a detection technique justifies the efforts of the pioneers in this field, notably Peter van de Kamp of Sproul Observatory. While researchers at Sproul and other astrometric observatories did not clearly detect another planetary system, they did provide a sound foundation for future researchers. Recent studies have shown that the photographic plates used as detectors in astrometric work are themselves a major source of error. Groups at the Lick and Allegheny Observatories (see the preceding article) are developing photoelectric detectors which are more accurate than photographic plates. Use of these new detectors with new telescopes may lead to nearly 10 times better accuracy with ground-based studies. But this is still not sufficient for a comprehensive search using Earth-based telescopes.

A recent study conducted by Lockheed for the California Space Institute and NASA examined the feasibility of a highly-accurate space-based astrometric telescope. The study revealed that a system with an accuracy of 0.000001 second of arc—equivalent to Mr. Lincoln's head on a penny viewed from 2.5 million miles—could be built and launched at a tolerable cost. With this accuracy we could detect Earth-sized companions to perhaps a dozen nearby stars, and Jovian-mass companions to thousands of stars. More important, if a system this sensitive did not detect a wobble, we could conclude with some confidence that a star had no planetary companions of any consequence.

We now possess the technological capability to mount a comprehensive search for other planetary systems. If we choose to employ that capability, we will obtain the answer to one of the most scientifically valuable and philosophically compelling questions posed by humankind. The search for planets around other stars would require time and money, but it would signify an implicit faith and investment in humanity's future. If we proceed, and if we do find planetary companions to nearby stars, the fiction of the Beta Hydri Probe I could well become the fact of tomorrow.

David C. Black is a theoretical astrophysicist at Ames Research Center. His primary interests are the formation of stars and planetary systems. He is presently writing a book for CRC Press on the search for other planetary systems.

The International SETI Petition

The International SETI petition is printed here with an up-to-date list of signatories. The petition was prepared by Carl Sagan, with Planetary Society logistical support, and organized by Mary Maki.

THE HUMAN SPECIES is now able to communicate with other civilizations in space, if such exist. Using current radioastronomical 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 radiotelescopes, 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.

WE BELIEVE such a coordinated search program is well-justified on its scientific merits. It will also have important subsidiary benefits for radioastronomy in general. It is a scientific activity that seems likely to garner substantial public support. In addition, because of the growing problem of radiofrequency interference by civilian and military transmitters, the search program will become more difficult the longer we wait. This is the time to begin.

IT HAS BEEN SUGGESTED that the apparent absence of a major reworking of the Galaxy by very advanced beings, or the apparent absence of extraterrestrial colonists in the solar system demonstrates that there are no extraterrestrial intelligent beings anywhere. At the very least, this argument depends on a major extrapolation from the circumstances on Earth, here and now. The radio search, on the other hand, assumes nothing about other civilizations that has not transpired in ours.

THE UNDERSIGNED are scientists from a variety of disciplines and nations who have considered the problem of extraterrestrial intelligence — some of us for more than 20 years. We represent a wide variety of opinion on the abundance of extraterrestrials, on the ease of establishing contact, and on the validity of arguments of the sort summarized in the first sentence of the previous paragraph. But we are unanimous in our conviction that the only significant test of the existence of extraterrestrial intelligence is an experimental one. No *a priori* arguments on this subject can be compelling or should be used as a substitute for an observational program. We urge the organization of a coordinated, worldwide and systematic search for extraterrestrial intelligence.

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(Affiliations are for identification purposes only)

A Talk with Philip Morrison

Philip Morrison, Institute Professor at the Massachusetts Institute of Technology, is one of the SETI pioneers. Since his seminal paper with Giuseppe Cocconi, published in 1959, which stressed the importance of the radio channel for interstellar communication, Professor Morrison has chaired numerous NASA panels and study groups on SETI. His distinguished scientific career ranges from the Manhattan Project to the physics of cosmic rays and quasars to his influential popularizations of science. He has also been a member of our Board of Advisors since the inception of The Planetary Society. We are pleased to publish this interview with him, conducted by Charlene Anderson and Louis Friedman of The Planetary Society staff.

Charlene Anderson: How did you get interested in the possibility of communicating with extraterrestrial intelligence?

Philip Morrison: Giuseppe Cocconi and I were thinking about possible new channels in astronomy as a whole. We first thought that cosmic gamma rays would be interesting to look at, then we realized that we knew how to make gamma rays. We were making them downstairs at Cornell in the synchrotron. So Cocconi said, "Maybe they would be useful to communicate through space." It seemed that they could work, but they weren't very strong. I then said, "We should study the whole spectrum to see which is the best wavelength." We knew very little about radio astronomy. But after we made the study, we realized that radio is much better than anything else. We decided to write the paper because it was so clear that it was a real possibility.

CA: What started you thinking about the possible existence of extraterrestrial intelligence?

PM: That wasn't really the issue. It comes about in a backwards way. It's the typical approach of a scientist. We don't know if they are there or not, but using a communications band is a way to find out. See, you were thinking that in order to call up somebody, you have to have somebody to call. I'm saying that before you call, you have to have a telephone system. We got our initial idea from the telephone system, not from thinking that anyone is there. We don't know how to estimate the probability of extraterrestrial intelligence, and it may not be very high. But we said that if we never try, we'll never find it. We went about it from an instrumental point of view.

One of the hardest things that scientists have to communicate to people who are not doing scientific things is that, in science, you can't do what you can't do. It doesn't often help you to talk about something that is not at least indirectly measurable. At least the consequences (of a radio search) were measurable. So what we asked was not, "Who's out there sending?" but, "Suppose there are thousands of civilizations sending, how would we find that out?" There is a way, with radio. Then we could ask, "How many cultures could be sending radio and where would they be?" But the first thing was to establish the fact that there is a telephone system.

Louis Friedman: Why did you narrow the communications band down to the radio frequencies?

PM: The idea of gamma rays was just an inspiration of the moment because we were making gamma rays that week! So I said, "Let's look at it systematically so that we don't jump to any conclusions. Let's find out what's in the rest of the spectrum." So then we looked in the library, talked to people, made calculations, and a few weeks later we simply had gone through every domain. It was clear that microwave radio is much the best and that the 21 centimeter line distinguishes itself.

LF: Why is microwave better than visible light?

PM: The essential reason is, God knows how to make light but he does not know how to make microwaves. Consider the animals on the surface of Earth. It is very hard to find any animal, or any plant for that matter, which does not respond to the light of the Sun. The light of the Sun is a powerful, dominant thing. But no animals or plants respond to microwave radio; that's an invention of human beings—that's generally true. The stars put out huge amounts of light, but they do not put out much microwaves. The transmitter of the Arecibo dish is 1000 times a stronger source of microwaves because you can concentrate direction and frequency in microwaves and you cannot do as well as that with light. Even if we put all the physicists in the world to work on it, we could not make a white light that could be distinguished from the Sun as seen from a distant star. If you set off 1000 hydrogen bombs, and if I were looking at it from 100 light years, I would not notice the explosion. The Sun's light and its natural flaring variations are too great. But the Sun's radio is nothing compared to even little Arecibo in a narrow beam and band.

Radio technology requires large things which are not biological and at the same time not as large as stars. It's a human scale thing, requiring stationary objects, pieces of antenna. That's not very common in the universe; the universe is made of drifting gases.

CA: What do you think of the

searches that have been done so far?

PM: Excellent. I have always called them pioneering searches. This is the age of pioneers and they are sort of taking a covered wagon out into the territory, establishing a homestead, but I am looking for some real occupation with cities and railroads.

CA: What about the search for extrasolar planets?

PM: I think they are sure to succeed or find out that there are no extrasolar planets around the hundred nearest stars. I think it will be done in the next five to ten years, both with ground-based observatories and with the Space Telescope. Both plans are moving forward and look promising to me. Of course, that is a long way from SETI, but it is a related question and very interesting.

CA: The Soviet astrophysicist N. S. Kardashev has speculated about three possible levels of extraterrestrial civilization. A Type I civilization could harness the total energy of a civilization for communications, Type II could harness the power output of a star, and Type III could control the entire energy output of a galaxy. What do you think of this type of speculation?

PM: I don't think the important thing is to speculate on how these societies behave, because we won't be able to get the answer to that problem. It's expecting too much from philosophical speculations. I'm excited by his three levels; it makes a good story. But I don't believe it is true, I don't believe it is false. There is no way to tell.

CA: If you had your choice as to the type of search to be done, would you prefer something like Project Cyclops, which would have been massive in size and expense?

PM: That is going about it too strongly. I don't think people want to spend all that money with no reliable experience. The search being proposed by NASA is the very best kind, a big strategy which combines some guessing at magic frequencies, some searching through frequencies, looking mostly in the galactic plane, but not neglecting high galactic latitudes or other galaxies. I have always said to put your bet on many horses; the biggest bet on the best horse, the next biggest on the second horse. But you don't overlook any horse that makes any kind of sense, because you do not know enough to be sure.

LF: What about interstellar travel? Might that be the easiest way to communicate?

PM: I doubt it very much. The costs in energy alone are so prodigiously different. If people won't invest a modest sum, say $1 million a year to do a radio search, it's hard for me to see that they would do a $100 billion search that would take much more than 100 years.

LF: The argument against interstellar travel in the scientific literature is always that if you wait twenty years the technology is so much better that the interstellar probe that you send out now will catch up with the interstellar probe that you would have sent out earlier, and that is always going to be true.

PM: The speed of light is the speed of light. We can never get news faster than the speed of light. And this is the speed that we are using with radio. Of course, we are expecting that the signal is already present so that we are not even waiting for the round trip—half the trip is made. We could find that out tomorrow; we can't find it out tomorrow by any probe. You could send a space probe out and wait for them to send a message back: "Your probe arrived in good shape and here is the telegram that says so." Long before the probe returned you would have a message from the beings who had seen it. Communication is much better than transportation. In fact, I think transportation will probably never occur except maybe in a ceremonial manner. Transportation is used when you have some good to gain. You send people out to live there or you bring back gold or whatever. There is nothing that will bear the cost and time of setting out through the domain of space as long as radio communication is the cheapest and fastest thing. The only valuable resource is information; everything else is negligible in comparison. I would try not to be negative if someone wants to do it, but I see no signs of preparation to voyage to the stars.

CA: Frank Tipler and some other scientists have argued that if intelligent extraterrestrials existed they would have visited us already, therefore they do not exist and SETI is a waste of time and money. What do you think of their arguments?

PM: I first read Tipler's papers some three years ago. I say that there are three ancient philosophical guides to this issue and they categorize the approaches. I name the first one after Aristotle, and that is: What good is SETI? We are the center of the universe, Earth is God's footstool and we have to clear up the Earth before we find out anything about other worlds. The second philosophy is the Malthusian view of Tipler, Gerard O'Neill and others. It says that life and human beings have a built-in exponential function that is never going to be stopped, swoosh, right up to any power that you like. Therefore, they can easily turn the galaxy into Central Park, and since this does not look like Central Park, we must be the very first. That is based on the very unlikely assumption that we are going to be infinitely powerful in some modest time and I think that is a very over-optimistic assumption. Like all other beings in the world, we are limited in our powers; limited in our energy sources, limited in what we want to do and what we can do. That limitation is perpetual. It will not be a tight, firm limitation but it means that we will go slowly, rising in a curve, plateauing off, then slowly rising in bumps over a long time. I imagine that that has been true of all the others. Of course, those bumps will not be exactly the same, and so we expect some differences. But I don't imagine the beings that we are going to meet would be so different that they would dominate a whole galaxy, as Kardashev says. That is an overly optimistic view based on the fact that we have been through a long, exponential rise in population and technical power. What every physicist knows is that there is no exponential curve that doesn't reach a turn-over point.

I don't think we can say, "Well, look, we've gone to the Moon in only 20 years." Actually, our speed in space is very small; the farthest that we've gone is not very far.

The third view is the one we are taking; that's the Copernican view that we are typical in the universe. We are not the central thing. What's going on here can be expected to go on elsewhere. Growth is limited and power is short here, and probably it's somewhat short and limited elsewhere, too. On the other hand, we're not especially singled out; why should we be the only place where there's life? There should be many worlds broadly like ours, but not exactly like it. That is the modest view of Copernicus.

CA: What about the arguments against SETI from the supposed improbability of life, the claim that the sequence of events leading up to life is so improbable that it wouldn't have happened anywhere else?

PM: Well, again, it's a speculative argument, and I think that it's going to be disproved. I imagine that we will make life here on Earth within the next generation or two. And that will answer that. All these things are based on premises and calculations which are very tenuous. I don't want to sit here and speculate on how likely it is; we have to look.

PAINTING BY JON LOMBERG

Speculations go on; there's nothing new. Much the same arguments now used by Francis Crick, Fred Hoyle and Michael Hart were published in a 1938 book by Le Comte de Nuöy, who did not invent them, but took them, as he says, from a Swiss philosopher of 20 years before (whose name I forgot). These conjectures rise in the popular literature every generation or so. I doubt that they are right.

CA: How do you respond to people who think that SETI can be postponed indefinitely, that in the current economic climate we should not be spending money on it?

PM: I think that's a plausible position. But on the other hand, it's not plausible to postpone every exploration and every novelty. If you do that, you will never get out of your state. The most depressing and negative stance that you can hold is to say that we can try nothing new and innovative because we're in trouble. New and innovative approaches and attitudes are what we need to solve our problems. I'm not arguing that SETI is more important than any particular problem. We're asking for a very small part of the resources which are disposed of daily by the government, even in the same scientific domain. It makes sense to try it on a small basis. It would be inappropriate to try it on a gigantic, gigadollar-a-year basis, which nobody wants to do anyhow.

CA: What about Bruce Murray's argument that we've got about a 20-year window before Earth-based radio noise becomes so great that we won't be able to hear anything from space?

PM: That is an argument that is somewhat supported by the work that they're doing here at JPL. The Deep Space Network is quite sensitive to that. I'm a little less apprehensive. I suspect that the techniques for discriminating the interference will get better. You'll lose five or ten percent of the sky, but the next year you'll regain ten percent. It's a shifting kind of barrier. It's like the appearance of clouds in a telescope. No astronomer desires it, but they can all cope with it. And I think it's much the same thing.

CA: Why do you think it's important that we do SETI?

PM: Well, I don't know. I take a very permissive attitude towards this. I don't think that it can be done enthusiastically until people decide it's worthwhile to do. When they decide to do it, once they decide to do it, they'll do it. If you're not persuaded by thinking of the consequences and the challenge, then I don't think you should do it. After you are persuaded, you cannot be stopped from doing it.

CA: How would you persuade people that it is important?

PM: You just ask them, "Do you want to know if human beings are alone as intelligent beings in the universe?" If that question doesn't move them, I wouldn't go any further.

LF: Do you think that the consequence of receiving an extraterrestrial signal will only be finding out about "existence"? Might we not see more in it than existence?

PM: I don't believe that it will be like that. Nobody will send out only an acquisition signal. It's extremely easy to attach the acquisition signal to an information channel. As soon as you get this, within five years you'll have a giant wide-band signal pouring in its message, which, to begin with, you won't understand at all. But you'll have all the deciphering people and all the philologists in the world working on it, studying it like cuneiform. It's the same kind of problem, except it's exciting because it's a voice not from the past, but from the future. Archaeology of the future is what it should be called. Archaeology of the past is very interesting because it tells us what we once were. But archaeology of the future is the study of what we're going to become, what we have a chance to become.

CA: So you take the approach that it's like finding our place in the universe?

PM: Yes, it's a missing element in our understanding of the universe which tells us what our future is like, and what our place in the universe is. If there's nobody else out there, that's also quite important to know.

CA: With the wide variety of life forms that you think possible, how would we find our future in their example?

PM: Our future has detached itself from the life forms of Earth. These beings are much closer to our future than are any other animals on Earth, even if they're made of a completely different chemistry, because they're using radio communication unique on Earth to humankind.

CA: So it's the technology....

PM: It's the culture. Technology is culture. It isn't something that is evolved by genetics, it was developed by culture. If these beings have got enough culture so that living near a star somewhere they have built radio transmitters, then they are something like our future. It doesn't matter if they have six arms and are blue and made of silicon, they would still have problems of how to deal with their own technical transformation of the universe. Of course, if they've never made radios and they're just sitting contemplating the world from a mystical point of view, we'll never find out about them. So SETI is a biased affair; it looks for people who have the biases of the Jet Propulsion Laboratory. I admit that. But can you think of any other way to go? And maybe they have found something useful to Earth.

CA: I've heard SETI scientists argue that we're going to blow ourselves up if we don't find somebody who's got an answer to prevent us from doing it.

PM: Yes, this is the gospel reason, the good news. I'm neither so pessimistic nor optimistic as that. I don't think we're likely to blow ourselves up. And I don't think that, if we were, getting radio signals would help us. But it might. That's what Fred Hoyle thought. He built a fascinating scenario that says civilizations grew, developed, and declined, then finally they made contact. That stopped them from blowing themselves up. And gradually this spread over the whole universe.

But who knows, it's all science fiction. I say, and say again, it's one thing to sit here and think of possibilities and write good science fiction; it's another thing to look into the real world.

CA: On that note, do you have anything to add?

PM: It's good that this is a receiving and not a transmitting program. It's much easier and much less expensive to receive than to transmit. And it contains the answer to many reasonable people who say (with, I think, an overly pessimistic view) that if you transmit, you might give away your location to some predatory menace in the galaxy. To which I answer, as Fred Hoyle has already said in his novel, *The Black Cloud*, maybe the best thing that you can do to prevent being preyed upon is make yourself so interesting that they won't eat you. But I don't really believe that. All I'm saying is that to avoid all these difficulties it's much better to receive than to send. This is a program which is designed to listen for a long, long time, and which makes no mark on the universe at all. I don't favor sending or establishing a program to send until, after lots of experience, we decide as a society that's the right thing to do. □

News & Reviews

by Clark R. Chapman

A few months ago, the November issue of a very obscure publication arrived in my mail. At first I quite overlooked its astounding news. Months later journalists picked up the story; by now, many of you may already know that a meteorite found in Antarctica is probably a piece of the Moon. I don't recommend that Planetary Society members enter subscriptions to the *Antarctic Meteorite Newsletter*, but it was in that publication that Brian Mason first reported that meteorite 81005 from the Allan Hills region of Antarctica "appears to be a very rare bird" and that it has "striking similarity" to certain rocks recovered from the lunar highlands by *Apollo* astronauts.

Speculations on Moonrocks in Antarctica...

The *Newsletter* suggested that the sample "may be lunar in origin," a remarkable speculation, indeed, based on very preliminary evidence. What would Brian Mason have thought of this meteorite if it had been found in the 1960s, before anyone had been to the Moon? Nowadays, we know a lot about rocks from the Moon—their trace element chemistry, their ages, their isotopes, their exposure to particle radiation from space, and so on. Mason's speculation, therefore, has led scientists in many laboratories to search for proof that this meteorite is a moonrock in every respect. All the data are not yet in, but so far the measurements seem to confirm that the meteorite is, indeed, from the Moon. (See "A Stone's Throw from the Planets," in the February, 1983 *Sky and Telescope*.) Thus, a few observations lead to a speculation, which leads to more research, and finally the scientific process yields a new established fact.

Europan Habitability...

Speculation is a valid part of science, but it is well to remember that it is not all there is to science, despite its tendency to dominate the news media. Scientific speculation is often publicized long before a definitive article appears in a reputable scientific journal. The flimsiest publication can be sufficient excuse for a science journalist to "go public." A recent example is the wide public exposure given to some speculations by three NASA scientists on "the habitability of Europa." Their initial article, just two inches long on page 1022 of the November 9, 1982 issue of another obscure publication (*Eos*), was one of hundreds upon hundreds of reports presented at the winter meeting of the American Geophysical Union; yet, it dominated media reports of the meeting. Steven Squyres and his colleagues have considered why the surface is so smooth on Jupiter's second Galilean moon, Europa, and modeled the processes that might maintain an ocean beneath Europa's icy surface. (Squyres will write on this subject in a forthcoming *Planetary Report*.)

It is a jump of speculative imagination, to say the least, to worry about photosynthesis and biological evolution in such an ocean. I am glad that creative scientists are trying to think about what Europa is really like as a world and about the profound question of the potential habitability of planets. But I believe the media give undue emphasis to preliminary speculations while largely ignoring the other kinds of scientific research.

Starving Dinosaurs...

A few years ago, iridium enrichments measured in sediments deposited about the Earth 65 million years ago led to the hypothesis that an asteroid impact was responsible for the mass extinctions that marked the end of the Cretaceous Period. There has been much speculation—widely reported in the media—as to how such an event could have erased entire species as diverse as dinosaurs on land and oceanic plankton. Now some planetary physicists have taken the first tentative step beyond speculation and have used computer programs designed to model atmospheric physics to see what might happen if a huge asteroid struck the Earth. They calculated how long it would take for the resulting dust cloud to spread over the whole Earth (a few weeks), how long it would last (a few months), how much it might block out the Sun (totally), and how it might affect the climate (continental temperatures would drop by 70° Fahrenheit within a few months). The calculations by James Pollack and his colleagues appear sound. But there will be much debate about the speculations on biology with which the article concludes; for example, that the dinosaurs died because they could not *see* their food in the utter blackness produced by the dust cloud (see *Science*, Jan. 21, 1983).

Tides on Titan...

Another weekly science journal specializes in speculation: *Nature*, published in London. Because of its rapid publication policy and preference for short articles on new hypotheses, *Nature* is often the first journal to publish new ideas, whether half-baked or of lasting value. Readers of *Nature* should be alert that such articles often report on just the first phase of scientific research—hypothesis development—and that much further research will be necessary before the ideas can enter the realm of "knowledge."

A recent *Nature* article that demonstrates the role of sober speculation ("The tide in the seas of Titan") was written by Planetary Society President Carl Sagan and his Cornell colleague, Stanley Dermott (December 23–30, 1982 issue). Sagan and Dermott are up-front about their speculative approach, and well they should be because there is no direct evidence that the subject of their article—the seas of Titan—even exist. We do have some facts about Saturn's largest moon, however, which provide grist for the intellectual mill: We know how big Titan is and also its mass. We know the size of its orbit and also that the orbit is elongated by several percent; furthermore, *Voyager* measured the composition of Titan's atmosphere and also its temperature-density profile. Evidently there is methane in Titan's atmosphere, and the surface temperature is near the liquidus of methane—where this "marsh gas" can exist simultaneously as gas and liquid, just as water does on Earth. Using physics based on experience with tides on our own planet, Sagan and Dermott calculate that Titan's orbital eccentricity could not be as large as it is unless Titan's putative methane oceans are at least half a kilometer deep and have eroded and inundated virtually all the "land" on Titan. It is difficult to be sure about geological and oceanographic processes on a world whose surface we have never even seen. But eventually a spacecraft may be sent to study Titan; if that hasn't happened by the mid-1990s, Sagan and Dermott believe it may be possible to use the Arecibo radar to detect methane oceans beneath the Titanian haze.

Clark R. Chapman, a member of the Imaging Science Team on Project Galileo, *is planning studies of Jupiter's clouds.*

THE SEARCH FROM ARECIBO

by Jill Tarter

If you are very fond of magnetic tapes and large computers, and if you have a lot of processing time and only a little bit of observing time available to you, then you too can conduct a SETI investigation of 210 nearby stars over 8 megahertz of bandwidth, in two polarizations, 5.5 hertz at a time—examining a huge haystack, straw by straw per channel. However, if you wish to keep your sanity, you will probably do so only once! I can say this because I've just done it at the Arecibo Observatory in Puerto Rico, along with Tom Clark from Goddard Space Flight Center, Bob Duquet from the Very Large Array and Larry Lesyna from Stanford University. We wanted to conduct a SETI for narrow-band signals *and* cover a broad range of possible frequencies, so we persevered with this program even though Tom and I knew how frustrating it could be: We had previously undertaken a smaller search with David Black and Jeff Cuzzi of the NASA Ames Research Center, using the 300-foot dish at the National Radio Astronomy Observatory. Until equipment being built at Stanford University and the Jet Propulsion Laboratory specifically for SETI becomes available in prototype form later this year, magnetic tapes and laborious computer processing are the only game in town!

It is true that Paul Horowitz' Suitcase SETI and his new Planetary Society-supported sky survey using Harvard University's Oak Ridge Observatory can produce very, very, high-resolution spectra in "real time" to search optimally for narrow-band signals, but Paul has to know or guess the exact frequency of the ETI signal. At present, a systematic search, with extreme resolution over a range of possible frequencies, just isn't possible in real time. NASA is trying to develop just this capability, but as Planetary Society members are aware, there have been a few stumbling blocks along the way. My collaborators and I didn't want to wait! We realized that our efforts to detect ETI signals, even if unsuccessful, would provide a unique picture of the universe and would be a useful training ground for the signal detection and recognition processing which must be done once all those frequency channels become accessible in real time. Here's what we did.

We proposed to the National Astronomy and Ionospheric Center, which operates the Arecibo Observatory, that we look at the 243 stars, similar in spectral type to our Sun, which lie within 80 light years and can be seen by the Arecibo telescope (we actually observed 210). We wished to look specifically for narrow-band signals (one good candidate signal type for intentional transmissions from another technology) over a large number of possible frequencies surrounding both the 21 centimeter (1420 megahertz) line of neutral hydrogen and the 18 centimeter (1667 megahertz) line of the radical, OH—the "water hole" region of the spectrum. We asked the observatory to construct a special piece of equipment for us: a rapid one-bit sampler. Miguel Feyjoo of the Arecibo Electronics Department built a device capable of sampling the signal voltage as rapidly as 10 million times per second. Bob Duquet wrote the software that allows the observatory's normal data acquisition and tracking computer to accept this new data stream, reformat it on-the-fly and then write it directly on magnetic tape.

We used this apparatus in conjunction with the station's tracking computer to point the telescope in the direction of a particular star; quickly record a mass of signal data; then point off the star and repeat, so as to get a background measurement for comparison.

After about four minutes of observing, we would have filled up one-half of a 2400-foot magnetic tape and would be ready to slew the telescope to our next candidate star. It is not surprising that we needed a few trial runs to get everything working!

During two one-week sessions in November of 1980 and 1981, we recorded hundreds of magnetic tapes at Arecibo. At the NASA Ames Research Center we mathematically converted the data on the tapes to show us how the signal strength varied from channel to channel for 65,536 channels, each one only 5.5 hertz wide (about one-millionth the size of TV channels). We then searched for significant occurrences of excess power in any channel, above what was predicted from noise alone. We detected 291 "birdies." We then checked to see if the detected spectral feature persisted in time, and if the signal was due to some local form of interference. We also examined the data for clues to the nature of the signal. After analyzing some 10,426 spectra, we detected the anticipated number of false alarms due to random radio noise, nine interstellar hydrogen clouds between us and some of the stars, a disconcerting number of human-made signals, and a handful of residual signals to be reobserved. These residual signals are the typical end-result of such a search. We do not claim that they are the ETI signals we are seeking, but only that we cannot unambiguously recognize their origin: In some cases, the tape drive failed, or a suspected hydrogen cloud wasn't where we thought it would be, etc. We need to reobserve them.

All of this will become easier as we develop the capability for real-time systematic exploration, but it will never become trivial. Our observations may not have produced a signal from an extraterrestrial civilization, but we certainly discovered a jungle of complex terrestrial signals which should keep even the most intelligent signal-processing hardware and software and their creators busy in the years to come. If we didn't know before, we certainly know now—SETI must be done soon if it is to be done at all from the surface of this increasingly noisy planet!

Jill Tarter is a research astronomer at the University of California, Berkeley and NASA's Ames Research Center.

The Arecibo radio telescope, 305 meters in diameter, is the largest radio telescope in the world. It lies in a natural karst valley in Puerto Rico.
Photo: National Atmospheric and Ionospheric Center

Southern SETI

by Thomas B. H. Kuiper and S. Gulkis

American and Australian investigators, with financial support from The Planetary Society, are collaborating in a search for extraterrestrial intelligence in the southern skies. Southern-hemisphere observations offer unique views of our own Milky Way Galaxy and the Magellanic Clouds, the nearest external galaxies.

The search will use the NASA 64-meter deep space tracking antenna, 20 miles southwest of Canberra at Tidbinbilla, Australia. This is one of three similar antennas (the other two in Spain and in California) which communicate with distant spacecraft such as *Voyager*. The search strategy is to allow the Earth's rotation to carry the antenna beam from west to east across the sky, taking 24 hours to complete a single scan. This strategy takes advantage of a four-month period when the 64-meter antenna will not be tracking spacecraft, but will be held stationary for bearing maintenance.

A receiver will monitor a narrow radio frequency range often used by radio astronomers to detect water vapor in the interstellar medium. A spectrum analyzer and computer will break the signal into 256 discrete bands and record the strongest signals for later analysis.

Water is vital to life on Earth and may also be important for extraterrestrial life. Changes in the rotation of water vapor molecules cause them to emit radiation in certain narrow frequency intervals, called spectral lines. One of these occurs near a frequency of 22.2 gigahertz. Advanced civilizations biologically similar to ours and wanting to attract the attention of others might choose to transmit near this spectral line of water because it occurs in a part of the spectrum where the natural galactic noise background is quite low (see chart on page 7).

Using the Earth's rotation, the system will obtain approximately four seconds of data at each antenna beam position in the sky. By repeating the scan on several different days, the investigators will be able to separate genuine signals from random noise emissions and absorption by water vapor in our own atmosphere, and radio frequency interference. Although normal antenna tracking movement is not allowed because of the bearing maintenance, small adjustments in elevation of the telescope can be made, so as to move the daily west-to-east sweeps slightly north and south, so in four months it will be possible to survey about half a percent of the sky.

The Large Magellanic Cloud, below, and its close companion, the Small Magellanic Cloud, are the Milky Way's nearest galactic neighbors, only 16,000 light years away. These small, irregular galaxies, which appear as faint nebulosities to the naked eye, move about the south celestial pole and were used by early navigators to mark the south celestial pole as they used Polaris to mark the north pole. Among many other possible sources, the southern SETI researchers will listen for radio signals that might be emanating from these nearby galaxies.
Photo: Dr. Hans Vehrenberg

The investigators include Drs. S. Gulkis, T. Kuiper and E. Olsen of JPL, Dr. D. Jauncey of Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Radiophysics, and Dr. W. Peters of the Australian National Observatory. After the investigators install the instruments on the telescope, station personnel under Director T. Reid will carry out the daily survey activities. Data tapes will be returned regularly to JPL for analysis. Dr. Gulkis coordinates the project.

Independent of SETI, the survey may be of general astronomical interest. Given what we now know about natural water line sources, the survey may detect one or two additional ones. However, if astronomers have by chance overlooked a class of sources, the detection rate may be higher. Discovering a new class of water line sources would be important even if they were not produced by extraterrestrials.

The survey will also evaluate this mode of data acquisition for future SETI programs. Next summer, the 64-meter antenna at Goldstone, California is scheduled to undergo major maintenance. A similar survey could be carried out there with a 65,000-channel receiver, greatly increasing the effective sensitivity and coverage of the search. □ *Thomas Kuiper is a Research Scientist at the Jet Propulsion Laboratory specializing in radio astronomy. Samuel Gulkis is a Senior Research Scientist at JPL.*

SUMMARY OF ALL KNOWN SETI OBSERVING PROGRAMS (AS OF FEBRUARY, 1983)

DATE	OBSERVER	SITE	OBJECTS	TOTAL HOURS
1960	Drake, "Ozma"	U.S.A.	2 stars	400
1963	Kardashev & Sholomitskii	U.S.S.R.	quasar	---
1966	Kellermann	Australia	1 galaxy	---
1968 & 1969	Troitskii, Gershtein, Starodubtsev, Rakhlin	U.S.S.R.	12 stars	11
1970 & on	Troitskii, Bondar, Starodubtsev	U.S.S.R.	all sky search for sporadic pulses	700 and continuing
1970 to 1972	Slysh	France	10 nearest stars	---
1971 & 1972	Verschuur, "Ozpa"	U.S.A.	9 stars	13
1972	Kardashev & Steinberg	U.S.S.R.	omni-directional	---
1972 to 1976	Palmer, Zuckerman "Ozma II"	U.S.A.	674 stars	500
1972 & on	Kardashev, Gindilis	U.S.S.R.	all sky search for sporadic pulses	---
1973 & on	Dixon, Ehman, Raub, Kraus	U.S.A.	all sky search	continuing
1974 to 1976	Bridle, Feldman, "Qui Appelle?"	Canada	70 stars	140
1974	Wishnia	"Copernicus" satellite*	3 stars	---
1974 & on	Shvartsman, "Mania"	U.S.S.R.	21 peculiar objects	---
1975 & 1976	Drake, Sagan	U.S.A.	4 galaxies	100
1975 to 1979	Israel, de Ruiter	Netherlands	50 star fields	400
1976 & on	Bowyer et al. U.C. Berkeley, "Serendip"	U.S.A.	all sky survey	---
1976	Clark, Black, Cuzzi, Tarter	U.S.A.	4 stars	7
1977	Black, Clark, Cuzzi, Tarter	U.S.A.	200 stars	100
1977	Drake, Stull	U.S.A.	6 stars	10
1977 & on	Wielebinski, Seiradakis	German Federal Republic	3 stars	2
1978	Horowitz	U.S.A.	185 stars	80
1978	Cohen, Malkan, Dickey	U.S.A. and Australia	25 globular clusters	80
1978	Knowles, Sullivan	U.S.A.	2 stars	5
1979	Cole, Ekers	Australia	nearby F, G and K stars	50
1979	Freitas, Valdes	U.S.A.	stable "halo orbits" about L4 and L5 libration points in earth-moon system	30
1979 & on	JPL, UCB, "Serendip II"	U.S.A.	apparent positions of NASA spacecraft	400 to date
1979 to 1981	Tarter, Clark, Duquet, Lesyna	U.S.A.	200 stars	100
1980	Witteborn	U.S.A.	20 stars	50
1981	Lord, O'Dea	U.S.A.	north galactic rotation axis	50
1981	Israel, Tarter	Netherlands	85 star fields	600
1981 & on	Biraud, Tarter	France	300 stars	80 to date
1981	Shostak, Tarter	Netherlands	galactic center	4
1982	Horowitz, Teague, Linscott, Chen, Backus	U.S.A., "Suitcase SETI"	250 stars	75
1982	Vallee, Simard-Normandin	Canada	galactic center meridian	72
1983 & on	Horowitz	U.S.A.	sky survey	---

*This search in the ultraviolet is the only program listed that was not performed in the radio spectrum.

WORLD WATCH

by Louis Friedman

The Planetary Society is now serving people around the world, so it is natural that we expand our "watch" beyond Washington. We will continue to focus much of our effort on the United States Space program with datelines from Washington, as well as Houston, Pasadena, Cape Canaveral and other places where the business of planetary science is conducted. Now we have expanded our horizons to other spacefaring nations and countries where people are interested in planetary science, such as Canada, where several thousand members joined us in the last few months. And so, with this issue, we initiate the new column, "World Watch," reporting on global participation in planetary exploration.

WASHINGTON: President Reagan's 1984 budget was released in late January and it included a proposed new start for the Venus Radar Mapper Mission (see the September/October, 1982 *Planetary Report*). This VRM would be the first new start in planetary exploration in the last six years. Planned for a 1988 launch, the VRM will be the only U.S. planetary mission, besides *Galileo*, to be launched in the 1980's. The NASA administration deserves kudos for making this Venus mission their number one priority.

Society members may express their opinions on the new start for VRM to the Congressional committees working on the NASA budget and to their own congressmen.

PARIS: The European Space Agency (ESA—a consortium of European nations) is working on twenty candidates for space science missions in the 1990's. Solar system exploration missions under consideration include a Mercury flyby, an asteroid gravity, optical and radar analysis mission (AGORA), a Venus orbiter and a lunar polar observatory. A Mars orbiter, called *Kepler*, is up for a new start this winter and a final decision is expected in March. ESA's space science budget, although smaller than NASA's, is fixed and not subject to political redefinition each year. The European Science Program decides among the proposed projects.

BONN: The West German Space Agency, DFVLR, is considering a proposal by AMSAT, the amateur radio satellite space organization, to build a spacecraft to fly by an asteroid. The AMSAT proposal is one of the finalists being considered for a test payload on the *Ariane 4* rocket. *Ariane 4* is a new version of the European Space Agency's launch vehicle.

PASADENA: The *Galileo* project team has proposed to NASA that they build a spare spacecraft in case there is a problem with the first launch of the reconfigured Space Shuttle/*Centaur*. Their justification for the extra cost of the spare is that, if *Galileo* is successfully launched to Jupiter, the extra spacecraft could be sent to Saturn to do both a probe into the planet and a radar mapping of Titan for a relatively low cost. There are political difficulties with the proposal, now under consideration, but the opportunity to do a Saturn orbiter and Titan probe before the end of the century is exciting. □

Following the reorganization of U. S. Congressional committees as a result of the November, 1982 elections, the chairmen and ranking minority members of the four key space committees are:

SENATE COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION (AUTHORIZING COMMITTEE)
Chairman: Robert Packwood, Oregon
Ranking Minority Member: Ernest Hollings, South Carolina

Subcommittee on Science, Technology and Space
Chairman: Slade Gorton, Washington
Ranking Minority Member: Howell Heflin, Alabama

SENATE APPROPRIATIONS COMMITTEE
Chairman: Mark Hatfield, Oregon
Ranking Minority Member: John Stennis, Mississippi

Subcommittee on HUD and Independent Agencies
Chairman: Jake Garn, Utah
Ranking Minority Member: Walter Huddleston, Kentucky

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY (AUTHORIZING)
Chairman: Don Fuqua, Florida
Ranking Minority Member: Larry Winn, Kansas

Subcommittee on Space Science and Applications
Chairman: Harold Volkmer, Missouri
Ranking Minority Member: Manuel Lujan, New Mexico

HOUSE COMMITTEE ON APPROPRIATION
Chairman: Jamie Whitten, Mississippi
Ranking Minority Member: Silvio Conte, Massachusetts

Subcommittee on HUD and Independent Agencies
Chairman: Eddie Boland, Massachusetts
Ranking Minority Member: Bill Green, New York

The address for the House of Representatives is Washington, D.C. 20515; for the Senate, it's Washington, D.C. 20510.

Help Examine A Mysterious Asteroid:
The Planetary Society's Pallas Project

by Clark Chapman

As asteroids orbit the Sun, they occasionally pass directly in front of a distant star, as seen from the Earth. Very rarely, it is one of the few thousand stars visible to the unaided eye and the star blinks out. Just such an event will happen late in the evening of Saturday, May 28, 1983, when the second largest asteroid, Pallas, passes in front of one of the brightest stars in the small constellation called Vulpecula. The shadow of Pallas, as cast by the star 1 Vulpeculae, will cut a 350-mile-wide swath across the southern United States. If you are in its path, the star—which is between 4th and 5th magnitude—will blink out for up to 45 seconds. (Pallas itself is far away and dark in color, so it is much fainter than the star.)

Planetary Society members can participate in a simple backyard project valuable to our understanding of asteroids. The goal is to watch the star at the appointed time (just before midnight, Central Daylight Time) and to time its disappearance and reappearance as accurately as possible. If enough people across the country make such timings, a map can be made of the outline of Pallas' shadow, which, after all, is the shape of Pallas itself. A number of asteroids and small moons are not spheres; Pallas might be among these.

The project is ready-made for members of The Planetary Society. Normally, an asteroid like Pallas appears as a point of light in even the largest telescopes; the only way to resolve its shape is to study its fleeting shadows cast by starlight. Usually, occulted stars are so faint that complex telescopic instruments are required; with only a few astronomers observing, large gaps are left in our knowledge of the asteroid's shape. Just such an occultation in 1978 showed that Pallas is about 540 kilometers in diameter, but its true shape remains a mystery. A decade ago, the small asteroid Eros occulted a bright naked-eye star, but its shadow was so small that only a few people chanced to be in the right spots to see the event.

This finder chart shows where to find 1 Vulpeculae (circled) amid the stars in the eastern sky on May 28th. The dashed line connecting Vega, Altair and Deneb is the Summer Triangle. 1 Vulpeculae is about 5 apparent Moon diameters to the lower right of the intersection of the Summer Triangle with the extension of the Northern Cross, half-way between Beta Cygni and Zeta Aquilae. Sizes of the dots correspond to star brightnesses; some fainter stars are shown near 1 Vulpeculae. The stars will be much closer to the horizon in western North America.

The Path of Shadow

In May, millions of people will be in the path of Pallas' shadow and *you* could be one of them. Perhaps even more exciting, this event may help show whether or not Pallas has a large satellite orbiting about it, as some astronomers believe. Several years ago, some Arizona astronomers developing a new technique (called speckle interferometry) for taking pictures of very tiny astronomical objects announced that Pallas may have a large moon. More recently, a group of planetary scientists from Harvard obtained similar data, but they doubt that a moon exists. Last year the Arecibo Radar Observatory in Puerto Rico bounced a radar echo off Pallas for the first time, but there was no echo from a satellite. However, radar echoes from distant Pallas are so exceedingly weak that even a sizable moon could have been missed.

May 28th provides an ideal opportunity to discover whether or not Pallas has a moon. Planetary Society members throughout North America (and Central America, too) should look for the star 1 Vulpeculae to blink out for a few seconds anytime within 20 minutes on either side of the predicted time for Pallas itself. Such an observation, if confirmed by several independent observers, would provide the first real proof of an asteroidal satellite. The absence of any evidence for other objects near Pallas, on the other hand, would cast doubt on the earlier reports that Pallas has a moon.

It is very simple to participate in this Planetary Society project. All you need is an accurate watch, good eyes, and a willingness to stay up late on a Saturday night. You should have a small pair of binoculars or opera glasses, too: The star 1 Vulpeculae is not very bright and the sky will be moonlit. Also useful would be a lawn chair so that you can gaze heavenwards in comfort. If you have a portable cassette tape recorder, you could make a permanent record of your observations.

To Find the Star

First, you need to find the star. Use the star-chart printed on this page. It is best to try about two weeks beforehand when our Moon is not in the sky, for practice. In that case, stay up one hour later to see the stars as they will appear two weeks later on May 28. Find the famous "summer triangle" high to the east: the three brilliant stars Vega (Alpha Lyrae), Altair (Alpha Aquilae), and Deneb (Alpha Cygni, which is at the "top" of the Northern Cross). Draw an imaginary line between Vega and Altair; just to the lower right of the point where that line intersects a line drawn down the extended length of the Northern Cross, you will see a faint star. That is it: 1 Vulpeculae! Find some of the other faint stars in the region, too, to be sure you are looking at the right star. 1 Vulpeculae may be found, alternatively, exactly half-way between Beta Cygni, the famous star at the bottom of the Northern Cross, and Zeta Aquilae.

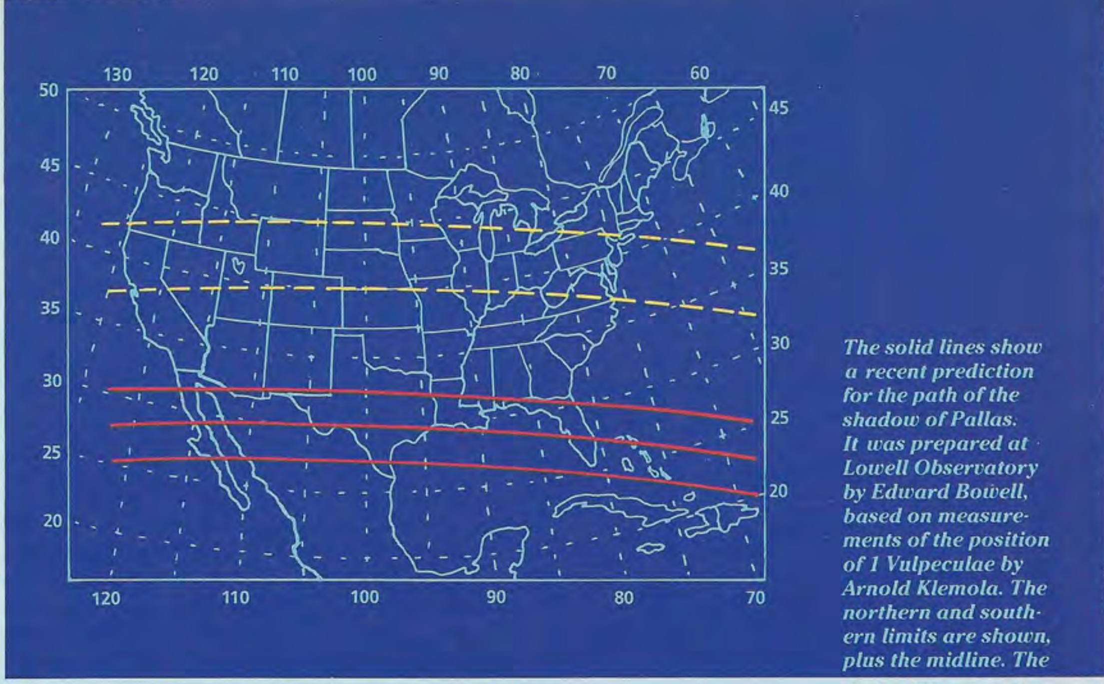
Next, you need an accurate timepiece. You can measure the *duration* of any blink-outs with a stopwatch. But it would also be helpful to know the *exact* times of disappearance and reappearance to the nearest second, or half-second if possible. You can set your digital watch using time signals from the National Bureau of Standards radio station, WWV. It broadcasts continuously at 2.5, 5, 10, 15 and 20 megahertz on shortwave. Inexpensive WWV receivers can be purchased at electronic supply stores. Or you can hear WWV receivers just by dialing 303-499-7111 an hour or two before the event, provided your watch will keep good time until the event. If you record your observations on tape, you or a friend should put some timechecks on the tape within a few minutes of the event: for example, "The time is 11:52...now!"

To be useful, your report must include one more critical piece of information: where you are located. Try to find the latitude and longitude of your observation post to the nearest 10 seconds of arc, if possible, from a good local map (such as the U.S. Geological Survey topographic quadrangles, available at your local library or at a county government office). If you cannot find a map, report the street address or other description of your observing location accurate to at least a quarter of a mile. Mail a report of your observations, *whether you see the star blink out or not,* to Pallas Project, P.O. Box 91687, Pasadena, CA 91109. We will report the results in *The Planetary Report* later this year. Be sure to include the following information:

1) Your name and address;
2) Your observing location (accurate to 10 seconds of arc or ¼ mile;
3) Source of time and estimated accuracy (e.g. "WWV via telephone at 10 p.m., timed with quartz watch accurate to 5 seconds per week; time good to ½ second").
4) Duration when you were attentively observing the star for possible blink-outs (e.g. "Observing from 11:41 p.m. to 12:15 a.m. CDT, except for 1 minute about 12:05").
5) Comment on equipment used (e.g. stopwatch, binoculars, tape-recorder, USGS map), sky conditions (clouds, haze, etc.) and other factors that will help us evaluate your report. For *each* observed blink-out of the star, if any, provide the following information (or report that no blink-outs were observed):
6) Duration of disappearance, in seconds, and estimated accuracy (e.g. "34½ seconds, accurate to ½ second").
7) Disappearance time.
8) Reappearance time.

Predictions

It is not possible to predict accurately the path that Pallas' shadow will take. Two possible paths are shown on the accompanying map; the southern path is more likely. It is possible that the path will miss the United States entirely. Better predictions will be available in May. Call the Planetary Society Information Line (213-793-4328 from east of the Mississippi, 213-793-4294 from west of the Mississippi) during the week before the event for recent up-dates on the most probable path. Remember that *anyone* may be in the path of a satellite of Pallas!



The solid lines show a recent prediction for the path of the shadow of Pallas. It was prepared at Lowell Observatory by Edward Bowell, based on measurements of the position of 1 Vulpeculae by Arnold Klemola. The northern and southern limits are shown, plus the midline. The dashed lines are the limits from an earlier prediction; although that path is probably too far north for Pallas itself, the shadow of a satellite (if Pallas has one) might pass anywhere on the map.

The predicted times for the event are not likely to be in error by more than a minute or two. The shadow should hit the east coast about 12:56 a.m. EDT (0456 GMT) in the early morning of May 29; it will exit the west coast of California or Mexico about 3 minutes later, 9:59 p.m. PDT, May 28. Whether or not you choose to hunt for the satellite, you should be watching carefully for the Pallas event from about 12:50 to 1:05 a.m. EDT.

I cannot guarantee that the project will be a success. We may be unlucky and the shadow may pass across the Gulf of Mexico, beyond even the Planetary Society members observing from Florida and southern Texas. Some members will certainly learn firsthand an observational astronomer's frustrations with clouds. But there is an equally good chance for success by hundreds or thousands of Planetary Society members who will be participating in an unprecedented exploratory project right in their own backyards.

An Unusual World

Pallas is an unusual world. It was discovered 181 years ago by Heinrich Olbers, a German astronomer who proposed that the asteroids are pieces of a broken-up planet. We now believe that asteroids are small bodies that somehow failed to form into a larger planet. Pallas may provide one of the most important clues about why an asteroidal planet never formed. The clue is in the 35° tilt of Pallas' orbital plane to the plane of the ecliptic. The tilt is so great that Pallas is sometimes twice as far above the average plane of the planets as the Earth is distant from the Sun! Once, when the solar system was a swirling cloud of gas and dust, all the solid particles that began to grow were caught up in the gas flow and travelled about the Sun in nearly perfect, non-tilted circular orbits. When asteroid-sized bodies grew in places where the Earth and Venus were to form, they bumped into each other gently and "stuck." In the asteroid belt, however, such bodies were somehow stirred up into tilted and oblong orbits, so that they now collide with each other at velocities of several kilometers per second. Such explosive collisions result in disruption, not accumulation. That is why no planet formed from the asteroids in the gap between Mars and Jupiter.

While most asteroids have orbits that are somewhat tilted and eccentric, Pallas is an extreme case. Most hypotheses about processes that could have stirred up the asteroids fail for Pallas. It could hardly have been bumped into such an extreme orbit. More likely, Pallas had a close encounter with a massive, planet-sized body, whose gravity deflected the asteroid into its remarkable orbit. Presumably the other asteroids were deflected by more distant encounters with that body, or by encounters with similar but smaller bodies. What were such large bodies doing in the asteroid belt? Where are they now? Several theories for the formation of the planets have attempted to account for such bodies, but more information is required. Perhaps more knowledge about Pallas, and about any satellites it may possess, will help answer these questions about the birth of our planetary system.

Clark Chapman regularly writes the column "News & Reviews" for The Planetary Report.

Society Notes

by Louis Friedman

New Book on the Planets—*The Planets,* a new *Scientific American* book, is being published under the direction of The Planetary Society. The state-of-the-art in planetary science is presented in a collection of articles from *Scientific American,* selected by Society Vice President Bruce Murray. The articles cover the spectacular results of the latest U.S. spacecraft missions: *Mariner 10*'s study of Mercury and Venus, the *Pioneer* survey of Venus, the *Viking* investigations of Mars, and the *Voyager* journeys through the systems of Jupiter and Saturn. Society President Carl Sagan provides the foreword and Dr. Murray has written the introduction and the concluding chapter, "The Future." The authors are donating the royalties from their articles to The Planetary Society in support of our work. Society members may obtain the new book by using the order form on the next page. The price, discounted 30 percent for members, is $8.50 in soft cover and $14.50 in hard cover (prices include shipping and handling).

Mars in 3-D—The Planetary Society is now offering the film, "Mars in 3-D," for sale or rent. The movie focuses on the technical and scientific achievement of NASA's *Viking* mission and the contributions of a large group of scientists, engineers and support personnel. "Mars in 3-D" conveys the excitement of planetary exploration by combining computer image processing, animation and stereo movie technology. Scenes include stereo photographs of Mars acquired by the *Viking* Orbiter, the operation of the *Viking* Lander at the Jet Propulsion Laboratory, and the Martian surface in three dimensions at both landing sites.

"Mars in 3-D" runs for 23 minutes on a 16mm sound movie projector and is especially useful for schools and museums. 3-D viewing glasses are supplied with the movie. The purchase price for the movie is $120.00, and includes 50 pairs of glasses. Rental copies are available for $25.00 per showing for non-profit use. Contact the Society, P.O. Box 91327, Pasadena, CA 91109, for further information or to order "Mars in 3-D."

Society SETI Begins—Dr. Paul Horowitz' Planetary Society/Harvard SETI experiment went into operation on March 7, 1983 (see pages 4 & 5). The Planetary Society hosted a news briefing and reception at Harvard's Oak Ridge Observatory as the search equipment was turned on. On March 6, Society members in the Boston area attended a SETI symposium conducted by Drs. Sagan and Horowitz.

Information Line—The Society's information line continues to keep members informed of the latest Society events. We update it once a month. Upcoming events are: the Central Connecticut Spacefest in May; the Futureworld exposition in Los Angeles; a forum in Houston; a lecture series in San Diego, and a lecture in Dallas. For details and late-breaking news, call 213/793-4328 from east of the Mississippi, call 213/793-4294 from west of the Mississippi.

Meeting in Hawaii—Vacation in Hawaii with the Astronomical Society of the Pacific (A.S.P.) The A.S.P. is holding its annual meeting in Kona, Hawaii on June 13–17 and, with The Planetary Society, will be co-sponsoring public meetings at the University of Hawaii in Honolulu on June 18. Society members have been invited to join the A.S.P. and the Western Amateur Astronomers at the Keauhou Beach Hotel in Kona. Prices for rooms begin at $35.00 for single or double occupancy at the Keauhou and, if a large number of Society members wish to attend, the King Kamehameha Hotel may also provide reasonable rates.

For information and a registration packet, send a self-addressed stamped envelope to: Summer Meeting, Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122. □

(continued from page 2)

freightage would be prohibitively high; it would be much cheaper to synthesize proteins in the amino acid sequences favored by extraterrestrial gastronomes than to muster a luncheon expedition to Earth.

We are unlikely to understand a message from another civilization.

On the contrary, because the message is transmitted by radio, the transmitting and receiving civilizations will have at least radiophysics, radioastronomy and radiotechnology in common.

Because the laws of nature are the same everywhere, science itself should provide a means of communication even between beings that are physiologically very different. I suspect that the decrypting of the message, if we are so fortunate as to receive one, will be much simpler than its acquisition.

It would be "demoralizing" to learn that our science is "medieval."

By the standards of the next few centuries, at least some of our present science will of course be considered medieval, provided we are not so foolish as to destroy our civilization. To go beyond present science is one of the goals of science.

Students are not commonly plunged into fits of despair on turning the pages of a textbook and discovering that there is some further topic, known to the author but not yet to the student. Usually, the student assimilates the new knowledge and, following an ancient human tradition, continues to turn the pages.

History records the depredations ruthlessly visited by slightly more advanced civilizations on slightly less advanced ones.

Certainly. However, all major radioastronomical SETI programs are intended to listen, not to transmit. Those who worry about the supposed dire consequences of extraterrestrials' learning of putative intelligence on the planet Earth might consider directing their concern to the organizations that are transmitting powerful signals into space—military radar facilities and commercial television networks.

One wonders what the extraterrestrials will make of us if these are the characteristic signs of human intelligence that are casually and continuously broadcast at the speed of light to our neighbors in the dark of space.

CARL SAGAN
Professor of Astronomy and Space Sciences,
Cornell University, Ithaca, N.Y., January 2, 1983

Static in the Cosmic Club —*Jan. 9, 1983*

SETI, the Search for Extra-Terrestrial Intelligence, was recently endorsed by a slew of Nobel scientists and others who affirmed that the quest "assumes nothing about other civilizations that has not transpired in ours." That argument is ingeniously disputed by Frank Tipler, a physicist at Tulane University.

The television and radar leakage from our civilization, he writes in Science magazine, is too weak to be detectable on any but a few nearby stars. Only a deliberately transmitted message could be received in the universe beyond. But we haven't sent one. If other civilizations have been equally uncommunicative, says Mr. Tipler, there is no hope of detecting them. The search can succeed only if its basic assumption—that the aliens have done nothing different than we—is incorrect, and the aliens have been broadcasting hello signals.

Carl Sagan, an astronomer at Cornell and proponent of the search, dismisses the argument as a quibble: It is technically possible for such a message to be sent out, he says; it just hasn't been. When we fretted a few weeks ago that astronomers might stir up predacious entities in the dark crannies of the universe, Mr. Sagan wrote us not to worry: the extra-terrestrial search program is "intended to listen, not to transmit." But if they are like us, wouldn't those other civilizations also prudently refrain from broadcasting their whereabouts?

The search now being undertaken cannot prove we are alone in the universe, and has only a small chance of finding alien life if it exists. That would be a bad bet for most experiments. But SETI is more than just an experiment: it's an affirmation of our right to belong to the cosmos, even if we be the club's only member. Besides, how dumb we would look if senior members had been hailing us for eons and we'd never noticed. SETI is an important and worthwhile endeavor, even if some of its premises are unavoidably anthropomorphic. □

The Solar System in Pictures and Books

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	PRICE	QUAN.	TOTAL
Voyages to Saturn by David Morrison – Description of both Voyager Saturn encounters, with color photographs.	**$14.00**		
Voyage to Jupiter by David Morrison and Jane Samz – Description of both Voyager Jupiter encounters, with color photographs. 199 pages.	**$10.00**		
Pioneer: First to Jupiter/Saturn and Beyond by Richard O. Fimmel, James Van Allen and Eric Burgess – Illustrated accounts of two Pioneer missions. 285 pages.	**$14.50**		
Beyond the Atmosphere by Homer E. Newell – History of the United States space program. 500 pages.	**$14.00**		
Voyager 1 Encounters Jupiter – An illustrated booklet with the best pictures of Jupiter from Voyager 1. 40 pages.	**$ 5.00**		
Voyager 1 Encounters Saturn – An illustrated booklet with the best pictures of Saturn from Voyager 1. 40 pages.	**$ 5.00**		
The Planets: A Cosmic Pastoral by Diane Ackerman – A collection of poems about the planets. 159 pages.	**$ 4.00**		
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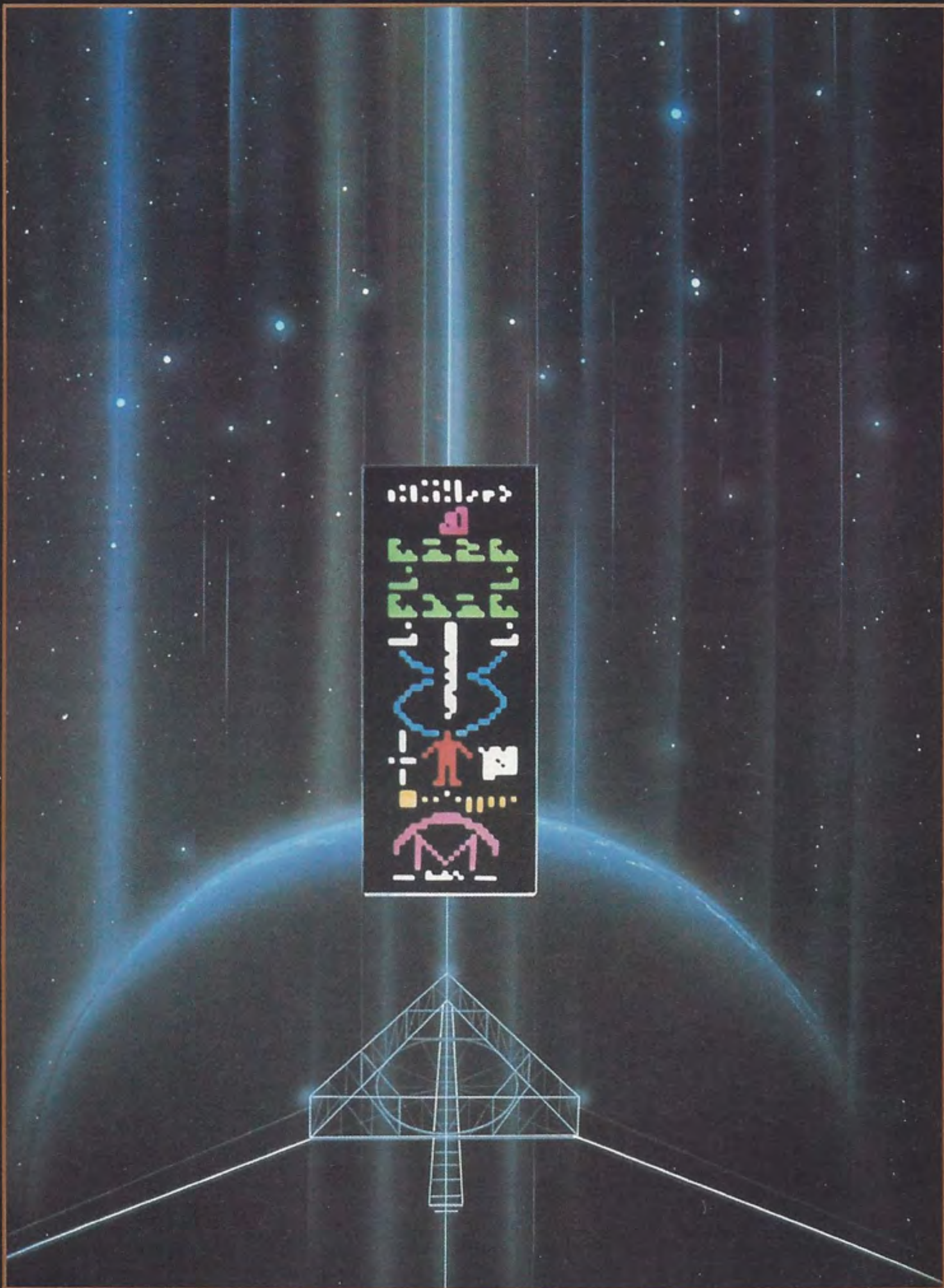

SYMBOLS IN SPACE—
In 1974, the staff of the Arecibo Observatory, led by then-director SETI pioneer Frank Drake, designed and transmitted a radio-encoded diagram to the globular star cluster, M13. This transmission symbolized our technological capacity to make interstellar radio contact with other civilizations. The diagram was coded as a string of binary pulses that, when reassembled, showed rough images of the atoms and nucleotide bases of life on Earth, DNA, a human being and the Arecibo radio telescope.

Brian Sullivan is an artist/production designer at Flandrau Planetarium in Tucson, Arizona.

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