ISSUE 10

Is It Worthwhile to Continue the Search for Extraterrestrial Life?

YES: Frank Drake and Dava Sobel, from *Is Anyone Out There? The Scientific Search for Extraterrestrial Intelligence* (Delacorte Press, 1992)

NO: A. K. Dewdney, from *Yes, We Have No Neutrons: An Eye-Opening Tour Through the Twists and Turns of Bad Science* (John Wiley, 1996)

ISSUE SUMMARY

YES: Professor of astronomy Frank Drake and science writer Dava Sobel argue that the search for radio signals from extraterrestrial civilizations has only just begun and that scientists must continue to search because contact will eventually occur.

NO: Computer scientist A. K. Dewdney maintains that although there may indeed be intelligent beings elsewhere in the universe, there are so many reasons why contact and communication are unlikely that searching for them is not worth the time or the money.

In the 1960s and early 1970s the business of listening to the radio whispers of the stars and hoping to pick up signals emanating from some alien civilization was still new. Few scientists held visions equal to Frank Drake, one of the pioneers of the search for extraterrestrial intelligence (SETI) field. Drake and scientists like him utilize radio telescopes—large, dish-like radio receiver-antenna combinations—to scan radio frequencies (channels) for signal patterns that would indicate that the signal was transmitted by an intelligent being. In his early days, Drake worked with relatively small and weak telescopes out of listening posts that he had established in Green Bank, West Virginia, and Arecibo, Puerto Rico. See Carl Sagan and Frank Drake, "The Search for Extraterrestrial Intelligence," *Scientific American* (May 1975).

There have been more than 50 searches for extraterrestrial radio signals since 1960. The earliest ones were very limited. Later searches have been more ambitious, culminating in the 10-year program known as the High Resolution

Microwave Survey (HRMS). The HRMS, which began on Columbus Day of 1992, uses several radio telescopes and massive computers to scan 15 million radio frequencies per second. New technologies and techniques continue to make the search more efficient. See Seth Shostak et al., "The Future of SETI," *Sky & Telescope* (April 2001).

At the outset, many people thought—and many still think—that SETI has about as much scientific relevance as searches for Loch Ness Monsters and Abominable Snowmen. However, to Drake and his colleagues, it seems inevitable that with so many stars in the sky, there must be other worlds with life upon them, and some of that life must be intelligent and have a suitable technology and the desire to search for alien life too.

Writing about SETI in the September-October 1991 issue of *The Humanist*, physicist Shawn Carlson compares visiting the National Shrine of the Immaculate Conception in Washington, D.C., to looking up at the stars and "wondering if, in all [the] vastness [of the starry sky], there is anybody out there looking in our direction. . . . [A]re there planets like ours peopled with creatures like us staring into their skies and wondering about the possibilities of life on other worlds, perhaps even trying to contact it?" That is, SETI arouses in its devotees an almost religious sense of mystery and awe, a craving for contact with the *other*. Success would open up a universe of possibilities, add immensely to human knowledge, and perhaps even provide solutions to problems that our interstellar neighbors have already defeated.

SETI also arouses strong objections, partly because it challenges human uniqueness. Many scientists have objected that life-bearing worlds such as Earth must be exceedingly rare because the conditions that make them suitable for life as we know it—composition and temperature—are so narrowly defined. Others have objected that there is no reason whatsoever to expect that evolution would produce intelligence more than once or that, if it did, the species would be similar enough to humans to allow communication. Still others say that even if intelligent life is common, technology may not be so common. Richard C. Teske, for example, in "Is This the E.T. to Whom I Am Speaking?" *Discover* (May 1993), argues that the geological processes that have supplied humans with the raw materials of technology—metals—are too unlikely to have been repeated elsewhere. A similar criticism is that technology may occupy such a brief period in the life of an intelligent species that there is virtually no chance that it would coincide with Earth scientists' current search. Whatever their reasons, SETI detractors agree that listening for extraterrestrial signals is futile.

In the selections that follow, Drake and Dava Sobel discuss Drake's first search for messages from distant stars (Project Ozma). Today's technology, the authors state, has made it possible to duplicate all of Ozma's work in a fraction of a second, making it that much more probable that Earth will soon make contact with extraterrestrials. A. K. Dewdney discusses several reasons why he believes that listening for extraterrestrial signals is a waste of time and money.

Frank Drake and Dava Sobel

YES

No Greater Discovery

My scientific colleagues raise their eyebrows when I speculate on the appearance of extraterrestrials. But about 99.9 percent of them agree wholeheartedly that other intelligent life-forms do exist—and furthermore that there may be large populations of them throughout our galaxy and beyond.

Personally, I find nothing more tantalizing than the thought that radio messages from alien civilizations in space are passing through our offices and homes, right now, like a whisper we can't quite hear. In fact, we have the technology to detect such signals *today,* if only we knew where to point our radio telescopes, and the right frequency for listening.

I have been scanning the stars in search of extraterrestrial intelligence (an activity now abbreviated as SETI, and pronounced *SET-ee*) for more than thirty years. I engineered the first such effort in 1959, at the National Radio Astronomy Observatory in Green Bank, West Virginia. I named it "Project Ozma," after a land far away, difficult to reach, and populated by strange and exotic beings. I used what would now be considered crude equipment to listen for signals from two nearby, Sunlike stars. It took two months to complete the job. With the marvelous technological advances we have made in the intervening years, we could repeat the whole of Project Ozma today in a fraction of a second. We could scan for signals from a *million* stars or more at a time, at distances of at least a *thousand* light-years from Earth....

Until the late 1980s, the fact that we had not yet found another civilization, despite continued global efforts and better equipment, simply meant we had not looked long enough or hard enough. No knowledgeable person was disappointed by our inability to detect alien intelligence, as this in no way proved that extraterrestrials did not exist. Rather, our failure simply confirmed that our efforts were puny in relation to the enormity of the task—somewhat like hunting for a needle in a cosmic haystack of inconceivable size. The way we were going about it, with our small-scale attempts, was like looking for the needle by strolling past the haystack every now and then. We weren't embarked on a search that had any real chance of success.

Then many people began to grasp the nature and scope of the challenge, the consequent investment required to succeed, and the importance of success

From Frank Drake and Dava Sobel, *Is Anyone Out There? The Scientific Search for Extraterrestrial Intelligence* (Delacorte Press, 1992). Notes omitted.

to all humanity. They pushed relentlessly for a serious search. And won. The National Aeronautics and Space Administration (NASA) committed $100 million to a formal SETI mission spanning the decade of the 1990s, making the work a priority for the space agency and guaranteeing that coveted telescope time will be devoted to the search.

Now, after all our efforts over the past three decades, I am standing with my colleagues at last on the brink of discovery.... I see a pressing need to prepare thinking adults for the outcome of the present search activity—the imminent detection of signals from an extraterrestrial civilization. This discovery, which I fully expect to witness before the year 2000, will profoundly change the world....

I want to show that we need not be afraid of interstellar contact, for unlike the primitive civilizations on Earth that were overpowered by more advanced technological societies, we cannot be exploited or enslaved. The extraterrestrials aren't going to come and eat us; they are too far away to pose a threat. Even back-and-forth conversation with them is highly unlikely, since radio signals, traveling at the speed of light, take *years* to reach the nearest stars, and many *millennia* to get to the farthest ones, where advanced civilizations may reside. But one-way communication is a different story. Just as our radio and television transmissions leak out into space, carrying the news of our existence far and wide, so similar information from the planets of other stars has no doubt been quietly arriving at Earth for perhaps billions of years. Even more exciting is the likelihood of *intentional* messages beamed to Earth for our particular benefit. As we know from our own efforts at composing for a pangalactic audience, reams of information about a planet's culture, history, and technology—the entire thirty-seven-volume set, if you will, of the "Encyclopedia Galactica"—could be transmitted (and received) easily and cheaply.

As a scientist, I'm driven by curiosity, of course. I want to know what's out there. But as a human being, I persevere in this pursuit because SETI promises answers to our most profound questions about who we are and where we stand in the universe. SETI is at once the most technical of scientific subjects, and also the most human. Every tactical problem in the search endeavor rests on some age-old philosophical conundrum: *Where did we come from? Are we unique? What does it mean to be a human being?...*

[W]e have only just begun to search.

So many individuals I meet seem to think that we have already searched the sky completely and continuously over the past thirty years. The deed is done, they assume. And since we found nothing out there, to search further is to beat a dead horse. But in fact, the combinations of frequencies and places to look have hardly been touched.

In my historical analysis; the search for extraterrestrial intelligence divides itself into four eras. The first dates back at least three thousand years, to the time when people started contemplating the universe....

I trace the start of the second era to the coming of the Copernican Revolution in the sixteenth century. That was when astronomers such as Kepler and Galileo, who used a real telescope, recognized that some of the other objects in the Solar System were planets similar to the Earth. Scientific observations could now support the philosophical argument in favor of other life in the cosmos—and perhaps even within the Solar System....

The third era began in 1959–60, when scientists first employed quantitative measures to compute the strength of possible signs of life crossing interstellar space. In other words, we made precise calculations of the detectability of alien signals, and acted on them. Projects—beginning with [Cornell physics professors Philip] Morrison and [Giuseppe] Cocconi's proposal to search for radio waves and my strategy for Project Ozma—sprang from a greater knowledge of the universe and a real sense of the numbers involved. For the first time, SETI embodied philosophical, qualitative, *and* quantitative elements. Scientists conducted some sixty "third era" extraterrestrial searches in the 1960s, 1970s, and 1980s. Most of these, however, were low-budget productions, done with leftover funds in borrowed time on equipment built for other purposes.

The fourth era, which starts now, is not only quantitative, it is also, finally, *thorough*. The projects of the 1990s represent the most exhaustive probing to date of the cosmic haystack. Here I am referring especially to the NASA SETI project....

My involvement in SETI activities has actually increased over the years, because SETI itself has grown so much. It occupies more people than ever before, and demands more of their time. Jill Tarter, for example, is the first astronomer to work full-time as a SETI scientist. When she isn't fully engaged in her role as project scientist, the senior scientific position in the NASA SETI project, she is in Washington, explaining the project to congressional representatives. Paul Horowitz runs a close second in activity. Despite his teaching duties at Harvard, Paul has had one search or another in progress since 1977. In some years he devotes nearly 100 percent of his time to these efforts—masterminding a new project and then personally soldering the thousands of joints that hold the equipment together....

I finally got my turn to meet Paul in 1977, when he was already a full professor of physics at Harvard....

A short time later,... Paul accepted a 1981–82 NASA Ames fellowship, which enabled him to work on SETI at the Ames Research Center and at Stanford University. He joined the Ames-Stanford group trying to create a SETI machine that could analyze a huge number of separate channels—128,000 of them, more than anyone had ever been able to monitor simultaneously....

The sheer number of channels in this multichannel analyzer was a big advance in itself, but Paul also made the components portable, so they could be packed up in three small boxes and hand-carried to any observatory, anywhere in the world. The system, which he dubbed "Suitcase SETI," traveled first to Arecibo [Ionospheric Observatory in northern Puerto Rico, home of the largest radio telescope ever built]. After examining 250 stars with it, Paul took it back to Harvard in 1983. He hooked it up to the same telescope I had partially built and calibrated in my student days—the one I had used to observe the Pleiades for my doctoral thesis. Suitcase SETI's rambling days were over at that point. Portable though it was, it never ventured out of Harvard's Oak Ridge Observatory again, A new name, Project Sentinel, recognized the fact that Paul's multichannel analyzer was now connected to a dedicated telescope, with funding from The Planetary Society to run a permanent SETI facility.

In time, Sentinel begat "META-SETI"—the Megachannel ExtraTerrestrial Assay—which boosted the number of channels from 128,000 to more than 8 million.... Paul needed the extra channels, he said, to respond to a new concept put forward by Phil Morrison, who had reminded him in a letter that everything in the universe is in motion....

Intelligent radio signals from distant civilizations could [therefore] be expected to arrive shifted in frequency, just as the starlight from distant suns is shifted toward the red or the blue end of the optical spectrum by stellar motions. There was no way to predict which way a signal's frequency would shift without knowing how its home star was moving. Thus a message transmitted on the hydrogen frequency could wind up far above or far below that frequency by the time it reached a radio telescope on Earth.

With META, Paul could scrutinize myriad frequencies in the vicinity of the hydrogen line and sift through them, narrow bandwidth by narrow bandwidth, on millions of channels at once to detect the displaced signals.

In 1991 Paul set up a second META, also financed by The Planetary Society, called META II, in the Southern Hemisphere, at the Instituto Argentino de Radioastronomia in Villa Elisa, Argentina. This allowed Argentinian astronomers led by Raul Colombo to observe the portion of the southern sky that's not visible from Cambridge. META II opened up very important new regions of the Milky Way as well as a clear line of sight to the two galaxies that are the Milky Way's nearest neighbors: the Magellanic Clouds. Now, with META and META II thriving, Paul is already dreaming of BETA. This would be a new system ("It'll be *betta* than META," he promises), with one hundred million channels.

Paul has obviously done more searching, with more sensitivity, than anybody who preceded him, so it shouldn't be too surprising to learn that he's actually heard things through his systems. Indeed, Paul has records of about sixty signals that are all excellent candidates for being the real thing. But Paul's searches run themselves, automatically. By the time he recognizes the candidates in the recorded data, hours or days later, it's too late to check them. Looking for them later proves fruitless, as they are no longer where they were. No doubt the civilizations are still there—if that's what made the signal—but they've stopped talking, at least for the moment.... If only Paul's strategy included a human operator who could double-check the signals on the spot! However, Paul has severe budget constraints, and I know that he can't afford to pay someone to sit there through the long nights and wait.

The new NASA SETI Microwave Observing Project will change all that, because I'll be sitting there myself. Or Jill will, or some other radio astronomer who will be able to react immediately to chase down a candidate signal the moment it appears. This project, which has been in various stages of planning and development since 1978, is just now beginning its methodical hunt. Because of its great power and sensitivity, it outstrips all previous search activities combined. Three days' operation can accomplish more than was done in the preceding three decades. Indeed, it gives me a strange chill to acknowledge that it takes this new setup only one one-hundredth of a second to duplicate what Project Ozma did in its full two hundred hours. . . .

What does NASA SETI have that no other search had? The short answer is "everything." It has everything that early searches had, and everything we could think of that had never been done before.

Like Ozma, NASA SETI scrutinizes a group of relatively close, Sun-like stars for signs of intelligent life. But where Ozma had only two targets, NASA SETI has one thousand. This much more extensive "targeted search," however, is still only half the mission. The other half is an "all-sky survey" that repeatedly scans the whole grand volume of outer space for alien signals from any star, anywhere. Our dual search strategy deals with two alternate possibilities for our cosmic neighbors: Either the easiest aliens to detect are right nearby (targeted search), or they are very far away but very bright (all-sky survey and targeted search).

Like the Ohio State project, NASA SETI is an ongoing endeavor that will run for years. But unlike the low-cost efforts that preceded it, this project fought for and won a total of more than $100 million in federal funding. While other searches started up and faded out without so much as a nod from NASA, this one enjoys the same position as a mission to send a small spacecraft to another planet. Mission status means that SETI is supported all through NASA management, right up to the topmost level.

Like META and META II, NASA SETI spans the globe and the heavens. It utilizes at least five telescopes—at Arecibo, Green Bank, the Observatoire de Nançy in France, the Goldstone Tracking Station in California, and an identical NASA tracking station at Tidbinbilla, Australia. It is the first truly global cooperative effort to search for interstellar signals.

Unlike . . . Suitcase SETI, NASA SETI is no backseat or part-time visitor. It constitutes the largest single program running at Arecibo and will soon dominate a fully dedicated telescope at Green Bank. It employs more than one hundred people, including a rotating team of radio astronomers who stand ready to respond to candidate signals in real time.

Most American searches until now have sought narrow-band signals on magic frequencies, such as the hydrogen line. We call them "magic" because they seem to have some real rationale for being logical channels of communication. Part of their magic is that they occupy quiet regions of the electromagnetic spectrum. What's more, the hydrogen line, considered the most magical frequency of all, is such a fertile field for making general discoveries in radio astronomy that scientists of all civilizations probably keep close tabs on it. Thus, a signal on that particular frequency should have the greatest chance of being detected. The hydrogen line is the frequency Morrison and Cocconi suggested in their original paper, and the actual frequency searched in Project Ozma. . . .

Magic frequencies have special appeal, but even human beings disagree as to which ones are best. . . . The point is, any search based on a magic frequency assumes first of all that extraterrestrials are broadcasting on a chosen frequency, and furthermore that we can know what that frequency is.

The NASA SETI project makes no such assumptions. It scans most of the frequencies in the waterhole that penetrate the Earth's atmosphere. This means we'll have a much greater chance than ever before to detect a message, whether the aliens choose a frequency for convenience' sake or some numerology of their own. Our new equipment frees us from the need to select just one or two frequencies from among the vast field of possibilities. . . .

META set a world's record with 8 million channels, but NASA SETI has 28 million. At the core of its hardware is a device called a multichannel spectrum analyzer (MCSA in NASA's beloved alphabet soup), which divides the incoming radio noise into 14 million narrow-band channels. The MCSA also combines the signals from several adjacent channels to create another 14 million broader bandwidths, just in case the extraterrestrials use them.

The MCSA relies on ultra-advanced software to make sense out of the millions of data points pouring in every second. Software analyzes the data, looking for patterns that reveal intelligence—and that could not possibly be intercepted as fast or as well by human intelligence. The human operator, whose presence is so important to me, steps in *after* computers sound the alarm that a candidate signal has just been detected. . . .

In the course of gushing about the great power of NASA SETI compared to any and all of its predecessors, I've dropped several huge numbers, referring to everything from frequencies and sensitivities to dollars and cents. That said, do I really need one more quantitative comparison to make my point? Would it really clarify things further to say that NASA SETI is a ten-millionfold improvement over past efforts? Maybe not. Maybe the more important thing to say now is that the magnitude of our current efforts creates so much promise that we find ourselves contemplating what we should do when we actually receive signal evidence of extraterrestrial life. When and how do we inform the people of Earth?

John Billingham [a former aerospace physician with England's Royal Air Force] has probably given more thought to this delicious dilemma than anyone else. Working with other members of the SETI committee of the International Academy of Astronautics (IAA), he has drawn up a "Declaration of Principles Concerning Activities Following the Detection of Extraterrestrial Intelligence." It lists all the steps to be taken to verify the authenticity of a signal and inform the proper authorities that extraterrestrial word has been heard.

This document has been approved or endorsed by every major, international, professional space society, including the IAA, the International Institute of Space Law, the Committee on Space Research, Commission 51 of the International Astronomical Union, and Commission J of the Union Radio Scientifique Internationale. In essence, Billingham's protocol says, *Make sure you've got something; then tell EVERYBODY.*

I've spoken at some length about how one goes about checking a candidate signal for authenticity—how to establish extraterrestrial origin, and how the special hallmarks of artificiality can distinguish a signal as being of intelligent design. But to announce to the world at large that you've made the greatest discovery in the history of astronomy—perhaps in history, period—takes an even wider margin of certainty.

On the NASA SETI project, you probably can't ask another observatory to help you verify your findings. If the long-awaited signal is intercepted at Arecibo, and it is weak, which is the most likely possibility, then no other observatory in the world could make the desired verification. This is because Arecibo has the greatest collecting area of any telescope, as well as the Gregorian feed and other specialized equipment. Even the other participants in NASA SETI, in France and Australia, will not match Arecibo's wide range of frequency coverage. And if the signal did fall within their frequency range, they might lack the sensitivity to hear it. Arecibo is so much more sensitive than the others—ever so much more capable of picking a faint, fragile *"We are here!"* out of a welter of cosmic noise.

In lieu of interobservatory checks and balances, the people at Arecibo (I hope I'm one of them when this happens) will have to spend several days checking and rechecking their data, locating the signal, if possible, a second, third, and fourth time rather than risk setting off a false alarm. After several days, however, repeated observations would build up a chink-free wall of evidence that would justify going public....

Hard upon detection of an intelligent signal, there follows the delicate matter of a reply to the civilization that sent it. I've thought a lot, of course, about what to say in that happy situation. I have waited a lifetime for the opportunity, and the waiting has not diminished my confidence or my enthusiasm. I can't be specific about it, though, because when you really think about it, the only answer to the question "What do you say?" is "It depends."

It depends on the nature of the signal and what it's telling us. It depends on the world's reaction. It depends on the distance the message traveled, because we couldn't establish true dialogue with civilizations far removed from us—only lengthy monologues, crossing each other eternally in the interstellar mail. It depends on whether we can understand it. Certainly no stock reply, prepared in advance and stashed in someone's file cabinet, could match more than one of the infinite possibilities for the message's content. Certainly any reply should be crafted on a worldwide basis, and only after lengthy deliberation by knowledgeable individuals.

I have a recurring dream in which we receive our much-anticipated intelligent signal from across the Galaxy. The signal is unambiguous. It repeats over and over, allowing us to get a fix on its source, some twenty thousand light-years away. The signal is... apparently dense with information content. It is so full of noise, however, that we can't extract any information from it. And so we know only that another civilization exists. We cannot decipher the message itself.

If this dream becomes real, such documented detection of alien signals will, of course, be big news in itself. It will be a call to action, too, beckoning us to do whatever is required—build a much larger radio-telescope system, for example—to obtain information about that civilization, to learn whatever secrets the extraterrestrials will share with us.

Indeed, our response to a message from an alien civilization may thus be a response to the *situation* instead of an actual reply to the senders. We will tell the world at large what has happened, and that we're taking the next step

by building better equipment to understand the message we've received. How I would love to have to go to Congress with a budget request for that project. I don't imagine I'd encounter much opposition....

I do not wonder *whether* this will happen. My only question is *When?*

The silence we have heard so far is not in any way significant. We still have not looked long enough or hard enough. We've not explored a large enough chunk of the cosmic haystack. I could speculate that "they" are watching us to see if we are worth talking to. Or perhaps the ethic exists among them that rules, "There is no free lunch in the Galaxy." If we want to join the community of advanced civilizations, we must work as hard as they must. Perhaps they will send a signal that can be detected only if we put as much effort into receiving it as they put into transmitting it. NASA SETI is the beginning of the first truly meaningful effort to demonstrate the sincerity of our intentions.

Thus, the lesson we have learned from all our previous searching is that the greatest discovery is not a simple one to make. If there were once cockeyed optimists in the SETI endeavor, there aren't any now. In a way, I am glad. The priceless benefits of knowledge and experience that will accrue from interstellar contact should not come too easily. To appreciate them, we should expect to devote a substantial portion of our resources, our assets, our intellectual vigor, and our patience. We should be willing to sweat and crawl and wait.

The goal is not beyond us. It is within our grasp.

A. K. Dewdney

NO

Surfing the Cosmos: The Search for Extraterrestrial Intelligence

It was noon, April 8, 1960. The recently completed 85-foot radio telescope dish at Green Bank, West Virginia, had just lost the star Tau Ceti below the horizon. Steering motors hummed and the great dish swung grandly to the south along the horizon until, like a great ear, it listened to another star, Epsilon Eridani. Up in the control room, radio astronomer Frank Drake and his colleagues listened eagerly to sounds coming from a loudspeaker. The sounds enabled the astronomers to hear the signals being intercepted by the dish.

Gathered in the 85-foot parabolic surface, electromagnetic waves, some of them from Epsilon Eridani and some from much further away, reflected to the focus of the dish where a large cylindrical housing sheltered a precisely tuned amplifier. The signals from the amplifier were fed to a chart recorder in the control room and, of course, to the speaker. It was a propitious day, the dawn of Drake's dream of intercepting messages from an alien civilization.

Called Project Ozma, the dream reflected Drake's conviction that somewhere out there, alien intelligences were transmitting helpful messages to less developed civilizations or, failing that, were at least inadvertently broadcasting their radio and television programs. Given the air of anticipation that surrounded the inaugural evening of Project Ozma, Drake and his colleagues can perhaps be forgiven for what happened next:

> [S]carcely five minutes had passed before the whole system erupted. WHAM! A burst of noise shot out of the loudspeaker, the chart recorder started banging off the scale, and we were all jumping at once, wild with excitement. Now we had a signal—a strong, unique pulsed signal. Precisely what you'd expect from an extraterrestrial intelligence trying to attract attention.

To check that the source of the signal really was Epsilon Eridani, Drake had the telescope taken off the target. The sound disappeared, meaning that this star (or a planet near it) may actually have been the source. Unfortunately, when they returned the telescope to track the star, the noise had disappeared.

An even more significant incident followed on the heels of the first one: One of the telescope operators told a friend about the signal and the friend

contacted a newspaper. Before Drake knew it, he was deluged by calls from the media demanding to know what had happened.

"Have you really detected an alien civilization?"

"We're not sure. There's no way to know."

This answer could not have been better calculated to raise curiosity about the incident still further, guaranteeing a great deal of publicity for Project Ozma. A better answer would have been, "As far as we know, the anomalous signal originated right here on Earth." Both responses are true, of course, but the second would have a more chilling effect on the media. Drake, after all, was no stranger to anomalous signals.

At the tender age of twenty-six, he had been observing the Pleiades star group when a new signal suddenly appeared on his chart recorder. Drake recalls:

> It was a strikingly regular signal—too regular, in fact, to be of natural origin. I had never seen it before, though I had repeated the spectrum measurement countless times. Now, all of a sudden, the spectrum had sprouted this strong added signal that looked unusual and surely of intelligent design.... I still can't adequately describe my emotions at that moment. I could barely breathe from excitement, and soon after my hair started to turn white.

Drake never succeeded in recapturing the signal and today suspects that it may have been a military aircraft.

Since the exciting early days of extraterrestrial probing, Project Ozma has been succeeded by SETI, the search for extraterrestrial intelligence. Sponsored by NASA, the National Aeronautics and Space Administration, the SETI project, along with similar schemes, has absorbed over a billion dollars in congressional appropriations. Is the money well spent? The project has had and continues to have many critics, but few have gone to the heart of the matter.

As I will show in a later section, the problem with SETI lies at the very beginning of the scientific method—the hypothesis. Not only is it unavoidably geocentric, it is essentially nonfalsifiable. There is a troublesome formula, moreover, that is supposed to make the hypothesis seem more reasonable. As I will also show, the formula is a two-edged sword that actually argues against the hypothesis.

At this writing, none of the SETI projects have revealed so much as a whisper of alien intelligence. This has not stopped Drake from going out on a limb. He seems eager to "prepare thinking adults for the outcome of the present search activity—the imminent detection of signals from an extraterrestrial civilization. This discovery, which I fully expect to witness before the year 2000, will profoundly change the world."

When confronted with the failure of SETI programs up to this point, Drake wisely opines, "Absence of evidence is not evidence of absence."

Scanning the Skies

Radio telescopes supplement ordinary optical telescopes by giving us a picture of the cosmos by the light of radio waves. I say "light" because radio waves are just another part of the great electromagnetic [EM] spectrum, which also includes light waves....

Many of the stars that appear as sharp points in the light telescope map also show up as blobs in the radio telescope map. This means that such stars not only emit light, they emit radio waves. By the same token, some of the radio sources that show up in the radio maps have no visual counterparts, or if they do, turn out to be clouds of gas, regions of violent galactic activity. Radio telescopy has been an invaluable tool in learning more about the structure of our own galaxy and that of other galaxies, not to mention a string of amazing discoveries such as pulsars and quasi-stellar objects, or quasars.

Nevertheless, the relatively long length of radio waves makes it very difficult to get much resolution out of a single telescope. Indeed, the signal from a radio telescope is essentially one-dimensional, like a sound track. The signal from an optical telescope is, of course, two-dimensional—a picture. These days, radio astronomers squeeze more resolution from their instruments by using several receivers at widely separated locations, as if to construct an effective dish that has the same dimensions relative to radio waves that optical mirrors do in relation to light waves.

Consider a typical dish as it tracks a distant star. Radio waves pour onto the dish from all directions. Some of the radiation comes from the Earth itself, stray radio or television broadcasts, ham radio operators, taxi dispatchers, truckers on CB radios, cellular phone callers, direct-to-home-satellite broadcasts, and so on. These signals, the only evidence we have of intelligent life so far, all come from the planet Earth. They sometimes bedevil the life of normal radio astronomers.

Electromagnetic waves of more natural origin arrive from the ionosphere, where energetic particles from the Sun collide with molecules of air at the very top of the Earth's atmosphere. Electromagnetic waves also come from radio sources in our own solar system, such as Jupiter and the Sun. From beyond the solar system, faint waves arrive from other stars in our own galaxy, from pulsars, and from stellar clouds. Other ripples, ancient and feeble, arrive at the great dish from other galaxies, not to mention those primordial sources, the unimaginably remote quasars.

Life is nevertheless relatively easy for the normal radio astronomer who has techniques for eliminating many kinds of interference from earthly sources. He or she may listen largely undisturbed for the random hiss of ancient stars and galaxies or the repetitive clicking of a pulsar. But the radio astronomer who searches for intelligent life must stand this rationale on its head, listening for the whispers of intelligent transmission amid a welter of natural electromagnetic hisses, clicks, chirps, and buzzes. The SETI astronomer is even more bedeviled by earthly signals. They tend to sound just like the thing he or she is searching for.

Is it just possible that somewhere, among all the radiation flooding the dish from a myriad of sources, one or two indescribably faint signals amount to whispers from distant and ancient civilizations? Perhaps the signals patiently repeat the recipes for astounding scientific and technical breakthroughs, as some SETI enthusiasts have dreamed.

In the meantime, even as radiation from a multitude of sources pours onto the dish, a kind of reverse process goes on. All of those television and radio signals that interfere with the radiation from outer space are themselves zooming away from Earth in all directions at the speed of light. In their entirety, the signals form a vast, expanding ball of radiation. Since radio broadcasts began about ninety years ago, the radius of that ball of radiation is now about ninety light years. It is large enough to contain a few hundred stars in our near galactic neighborhood, albeit still tiny compared to our galaxy as a whole. It is nevertheless possible, of course, that a technological civilization on Alpha Centauri or Ophiuchus has picked up our broadcasts, including enough episodes of *The Three Stooges* to place the Earth in a state of permanent galactic quarantine.

The point of that rapidly expanding sphere of programming has certainly not escaped the SETI theorists. Other civilizations with the ability to monitor electromagnetic radiation should be able, sooner or later, to hear our signals, however faint. Should we not, by the same token, be able to pick up the signals of other civilizations? The prospect has an unquestioned fascination about it. Imagine what an alien signal might be like, the very stuff of science fiction! But is it science? Or is it fiction? In particular, is Drake behaving like an apprentice?

In this case, it all depends on the hypothesis and your opinion of it. As the well-known astronomer Carl Sagan once speculated, the sheer numbers of stars in our galaxy lends enormous weight to even the most slender estimates of probability for the evolution of technological civilizations elsewhere: What is the chance of Earth-like planets? What is the chance of life spontaneously emerging on such a planet? Even small probabilities, when multiplied by the enormous number of stars out there, turn into something almost definite. The hypothesis is this: Given the near-ubiquity of life in our galaxy, some life forms have surely developed intelligence, including the ability to communicate by radio waves. Such waves should be detectable by suitable receivers right here on Earth.

There are a few minor flaws in this hypothesis and one major one. The minor flaws involve unstated assumptions that enter the hypothesis....

The hypotheses of the theoretical physicist or cosmologist "work" because the model is precise and one can tell, almost as soon as new observational evidence arrives, whether it confirms the model or not. If the speculation was far-fetched to begin with, the physicist should not be too surprised if further observations fail to confirm the model.... [A] hypothesis must be falsifiable.

Consider now the scientist who looks up at the night sky and asks the age-old question, Is there anyone out there? The question seems perfectly reasonable. It means, Is there another race of beings, living somewhere else, whom we would call intelligent? Apart from the fact that we as yet have no formal scientific definition of intelligence..., most people think they know intelligence when they see it, at least among fellow human beings.

Perhaps the best laboratory in which to consider alien cultures is right here on Earth. Consider a country that is dominated by Zen Buddhism, for example. Many people would say that the Zen monk represents a very high level of human development (without being exactly sure what that means). If the world were full of Zen monks, however, we would be very unlikely to have radio. The technology would contribute very little to the insights necessary on the fivefold way, and one could argue that the technology and its development would constitute a completely unnecessary distraction from the real work of the monk, which is to rid himself of attachments to things of the world. As for advice from beyond, Zen monks have all they can handle in advice from the teacher.

With the peculiar myopia that characterizes Western culture, we have come to regard our own development as more or less inevitable, an extension of the Darwinian imperative into the technocultural realm.

The real question is What is the chance of a Western-style scientific-technological civilization developing out there? The "Western" qualifier is crucial, for we in the Western world may be living in a spell, trapped in yet another aberrant vision of our place in the universe, one no less misleading than the pre-Copernican idea of a central Earth. If the sorcerer is under a spell, he will hardly do better than the apprentice!

Live by the Formula, Die by the Formula

The unquestioned pioneer of the SETI project is the well-respected radio astronomer Frank Drake. Early in his career as a radio astronomer, Drake developed an interest in the possibility of life on other planets, particularly intelligent life. He became intrigued, some might say obsessed, with the prospect of intelligent beings broadcasting radio signals into space, signals that we on Earth might intercept—to our infinite advantage.

Intuitively, Drake understood that with 200 billion stars in our galaxy, there might be a very good chance that someone out there was already sending the very signals he dreamed of receiving. To put the project on a quantitative footing, Drake devised the equation below. To some people it may appear complicated, but mathematically speaking, it could hardly be simpler. The right-hand side of the equation consists merely of a bunch of variables all multiplied together:

$$N = R^* \times Fp \times Ne \times Fl \times Fi \times Fc \times L$$

The equation attempts to estimate the number N of "radio civilizations" in our galaxy. A radio civilization is simply a race of intelligent beings that have developed the ability to broadcast and receive messages via electromagnetic radiation, and do so on a regular basis. The equation estimates the number N by taking into account a variety of factors in the product:

R^*: number of new stars that form in our galaxy each year
Fp: fraction of stars having planetary systems
Ne: average number of life-supporting planets per star
Fl: fraction of those planets on which life develops
Fi: fraction of life forms that become intelligent
Fc: fraction of intelligent beings that develop radio
L: average lifetime of a communicating civilization

At first glance, the equation seems perfectly definite. If you happen to know the value of each variable, you can come up with a pretty good estimate for N. If the estimate you arrive at is reasonably large, you may use the equation to squeeze endless amounts of money out of Congress to support a search for intelligent life. The equation, after all, is mathematical, and that means real science.

An estimate of the number R^* is based on an assumed rate of star formation of about ten a year. This is an extremely crude estimate based on current observations of regions where stars appear to be forming in our galaxy. The actual number has undoubtedly varied enormously over time, particularly in the remote past. For the Drake formula, it's all uphill from this point on.

The fraction *Fp* of stars having planetary systems is completely unknown. Although a few relatively nearby stars are suspected of having very large Jupiter-like companions or planets that are nearly stars in their own right, we have yet to observe a single star with a planetary system even remotely like our own. Period. It follows that we haven't the slightest idea what the real value of *Fp* might be, and any "estimates" would better be called wild guesses.

If we haven't a clue how many stars have planetary systems, then we're even more in the dark about the average number *Ne* of life-supporting planets per star. Some of them may well have such planets. Perhaps they all do. Perhaps our sun is the only such star. We simply have no idea.

Will a "life-supporting planet" ever develop life? I'm not sure how a planet could support life if it didn't already have it. The Earth has oxygen, for example, only because photosynthesizing organisms evolved here a long time ago and eventually filled the atmosphere with this (for us) vital gas. Perhaps the rather silly variable *Fl* should be set equal to 1 and simply dropped from the equation.

As you will see from a glance at the remaining variables, it gets worse.

The fraction *Fi* of life forms that become intelligent is even less well known, if that is possible, than the previous variables. What do we mean by "intelligent," anyway? As you may have already discovered . . . , we're not even sure what we mean by our own "intelligence"! Once again, my guess for this variable is as good as Frank Drake's.

The fraction *Fc* of intelligent life forms that develop radio is likewise completely unknown and pointless to estimate. Finally, the lifetime L of the average radio civilization is the only variable about which we have any information, and that information may be about to improve. We know, for example, that our own radio civilization has existed for about ninety years. There is a real possibility that it may reach one hundred. In any case, this sample of one is our only basis for an estimation of L.

How do Drake and his disciples use the formula? Here are two examples that have appeared in popular magazine articles on the subject. I have no doubt that the guesses come directly from the SETI school.

$$N = 10 \times 0.3 \times 1 \times 0.1 \times 0.5 \times 0.5 \times 10^6 = 125{,}000$$
$$N = 10 \times 1 \times 1 \times 1 \times 0.01 \times 0.1 \times L = 0.01 \times L$$

In the first guess, L was given a value of 10^6, or one million years. The second guess refused to assign a definite value to L, which is strange, considering that we already know more about L than the other variables. Nevertheless, using the value for L from the first equation in the second, we get a more conservative estimate:

$$N = 10{,}000$$

That's still quite a few radio civilizations. Why haven't we heard from any of them yet? We might find the answer by taking a closer look at ourselves, in particular, and our probable destiny as a radio civilization. It is not nuclear holocaust that will seal our fate as a spherical broadcaster of invaluable cultural and scientific information to the cosmos, but the incredible inefficiency of antenna broadcasting!

As every radio engineer knows, broadcasting electromagnetic waves in all directions at once is an enormously wasteful way to transmit information. Although the emissions from standard mast antennas can be directed somewhat in the form of lobes, only the tiniest fraction of broadcast energy ever reaches receiving antennas. The evidence is now very clear that the Earth is rapidly fading as a source of electromagnetic energy. Increasingly, we transmit radio and television signals by cable, not to mention the exponentially increasing Internet traffic on phone lines and fiber-optic cables. An even more powerful trend involves the broadcast of television signals toward Earth from satellites, signals that are completely absorbed by the ground. The Earth may be about to vanish as a radio source.

If this is true, then 100 might be taken as a perfectly reasonable estimate for the crucial variable L. In this case, plugging the new value for L into the last equation . . . , we get

$$N = 0.01 \times 100 = 1$$

That must be us.

Another implication of current developments in the dissemination of information points up another minor flaw in the Drake hypothesis. Increasingly, radio signals between points in deep space will be beamed ever more precisely at the target receivers, somewhat like a laser beam. This would make their reception by nontargeted civilizations increasingly less likely. Can anyone believe that these vastly "superior" alien civilizations would themselves employ any method so incredibly wasteful as spherical broadcasting to communicate with each other? The implications for SETI enthusiasts are clear: Don't hold your breath waiting for that magic signal.

Finally, there may well be radio signals that SETI will eventually intercept but the signals will present us with an enormous headache. Seemingly intelligent, they will only be meaningful to beings of a similar mindset, whatever that might mean. Neither I nor anyone in the SETI team can imagine what a distinctly inhuman mentality might be like.

POSTSCRIPT

Is It Worthwhile to Continue the Search for Extraterrestrial Life?

The modern, high-tech version of SETI, the High Resolution Microwave Survey (HRMS), almost never came to pass. As Donald Tarter, of the International Space University, in "Treading on the Edge: Practicing Safe Science With SETI," *Skeptical Inquirer* (Spring 1993), writes, "SETI's recent history has been one of fighting for scientific respect and then fighting for funding. . . . SETI has been so frequently ridiculed and singled out as [a program that could be eliminated by budget-cutting congressional members] that officially SETI no longer exists." He then notes that, shortly before NASA began its current search for extraterrestrial intelligence, the name was changed to HRMS.

However, the name change did not solve the problem. A year after HRMS was born, the budget was cut. By October 12, 1993, the $1 million a month needed to sustain it had been eliminated from the budget by a House-Senate conference committee. It was not the sort of arguments raised by critics such as Dewdney that defeated HRMS; it was image. SETI smacked too much of science fiction and Hollywood. It might not be terribly expensive—the cost of a single space shuttle flight could pay SETI's bills for several years—but whatever it cost seemed to the budget cutters pure waste when compared to the many other programs and problems requiring funds.

Yet SETI is not dead. The July 2000 issue of *Scientific American*, for example, features a special section entitled "Searching for Extraterrestrials," in which the prospects for extraterrestrial contact are analyzed by Ian Crawford, in "Where Are They?" Andrew J. LePage, in "Where They Could Hide," and George W. Swenson, Jr., in "Intragalactically Speaking." Many scientists disagree with those who believe that humans are probably alone in the universe and who say that the search for intelligent extraterrestrials is not worth the effort. So do many nonscientists. The private SETI Institute has raised millions of dollars, much of it from leaders of California's computer industry.

Another effort worth noting is that of the SETI League (`http://www.setileague.org`), which is recruiting owners of obsolete satellite TV dishes (3–5 meters in diameter; new dishes are much smaller) to connect the dishes to home computers and let them listen to the sky as part of Project Argus. See Marcus Chown, "The Alien Spotters," *New Scientist* (April 19, 1997). Still another is SETI@home (`http://www.setiathome.ssl.berkeley.edu`), which has turned the project into a computer screensaver. It sends the raw signal recordings out to over 3,000,000 personal computer (PC) owners (as of June 2001), whose computers analyze the data whenever they are not busy with other tasks. The hope is that the massed power of so many home PCs will prove more sensitive than the supercomputers that are used elsewhere.