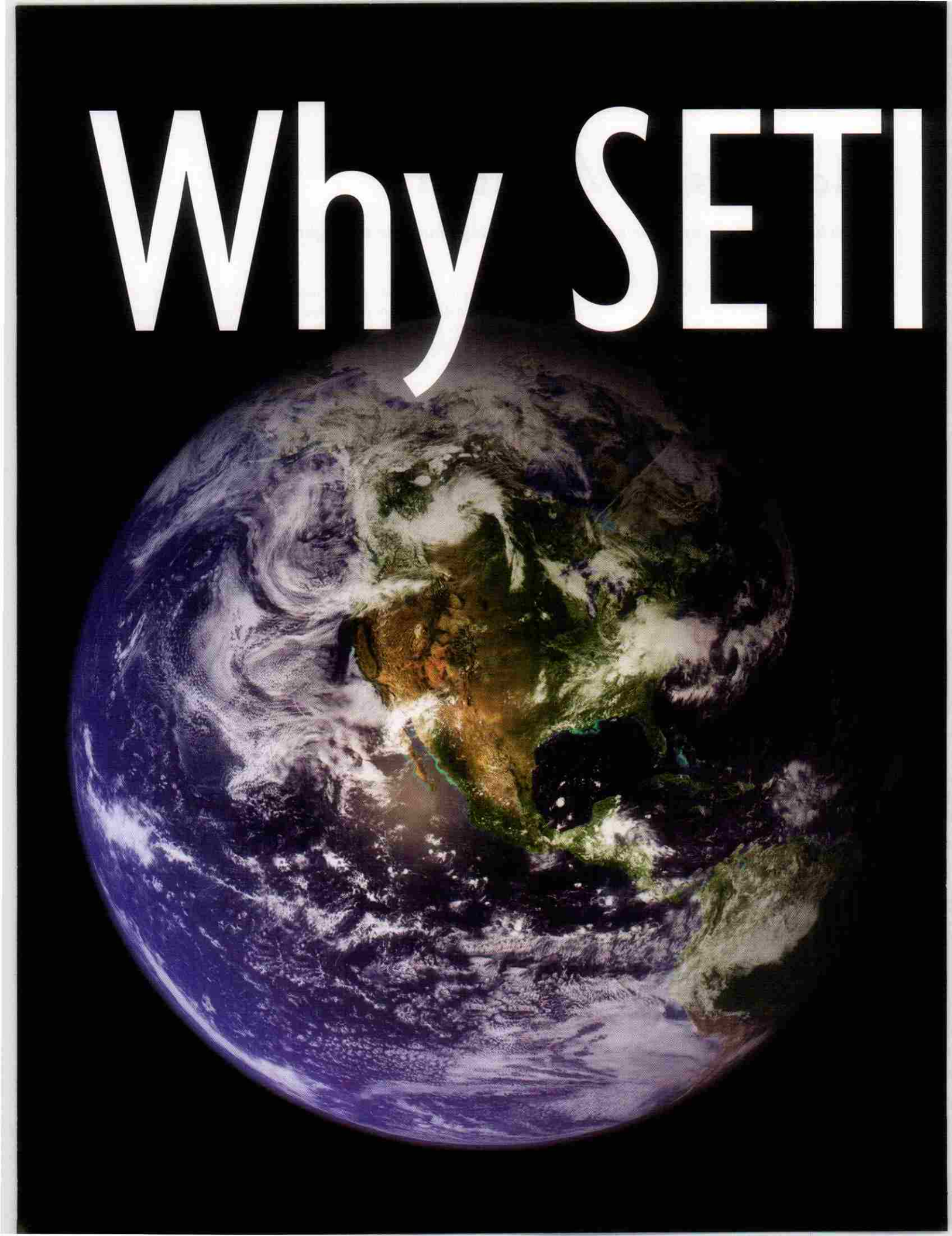
Why SETI



Will Fail

The union of space telescopes and interstellar spaceships guarantees that if extraterrestrial civilizations were common, someone would have come here long ago.

by Ben Zuckerman

Where do humans stand on the scale of cosmic intelligence? For most people, this question ranks at or very near the top of the list of "scientific things I would like to know." Lacking hard evidence to constrain the imagination, optimists conclude that technological civilizations far in advance of our own are common in our Milky Way Galaxy, whereas pessimists argue that we Earthlings probably have the most advanced technology around. Consequently, this topic has been debated endlessly and in numerous venues.

Unfortunately, significant new information or ideas that can point us in the right direction come along infrequently. But recently I have realized that important connections exist between space astronomy and space travel that have never been discussed in the scientific or popular literature. These connections clearly favor the more pessimistic scenario mentioned above.

Serious radio searches for extraterrestrial intelligence (SETI) have been conducted during the past few decades. Brilliant scientists have been associated with SETI, starting with pioneers like Frank Drake and the late Carl Sagan and then continuing with Paul Horowitz, Jill Tarter, and the late Barney Oliver. Even with all their accumulated talent, these investigators have failed to consider the full implications for SETI of all advanced civilizations possessing space telescopes capable of discovering nearby living worlds. A very likely consequence of such discoveries will be interstellar travel to investigate the nature of alien life forms. The fact that, evidently, no technological creatures have come to investigate Earth during the past several billions of years is strong evidence that few such creatures exist in our galaxy.

Using space telescopes similar to those that we will be capable of building in the next century, extraterrestrial civilizations within a few hundred light-years could identify Earth as a living world. Their next step would be to pay a visit to this fascinating planet. This image was obtained with NASA's Terra satellite. Courtesy of NASA/GSFC.

Identifying Living Worlds

Detection of extrasolar Jupiter-like planets and brown dwarfs (see "Brown Dwarfs: The Missing Link," page 8) is all the rage these days. But to find out more about where we rank on the cosmic intelligence scale, we need to learn about the preponderance and properties of extrasolar Earth-like planets. To do this, we need to launch moderate-sized telescopes into space. These space telescopes will probably be interferometers, although scientists and engineers are currently batting around a variety of designs.

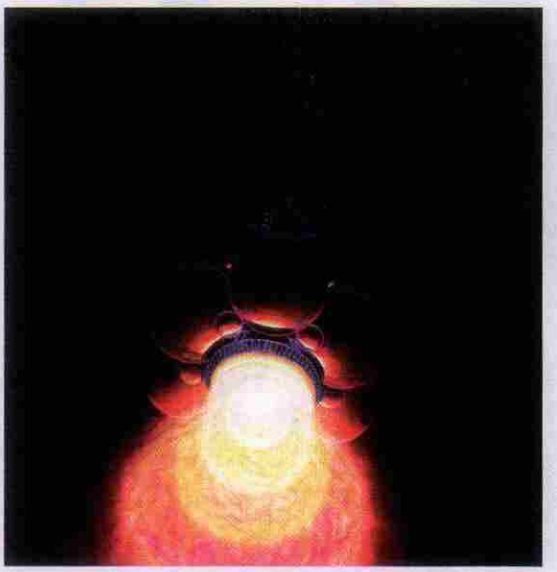
According to the timetable envisioned for NASA's Terrestrial Planet Finder (TPF) mission, in the next 20 years we should witness the deployment of space telescopes capable of spotting Earth-like planets orbiting nearby stars (see "Terrestrial Planet Finder," page 18). As currently conceived, these telescopes will be able to measure mid-infrared spectra of planetary atmospheres and detect molecules such as water vapor, carbon dioxide, methane,

Interstellar Travel Is Inexpensive

SETI proponents often describe the apparently high cost of human space travel to explain how the Milky Way Galaxy could contain numerous technological civilizations while none are present in our solar system. But this perception of "How expensive!" is true only because human "civilization" is seriously out of whack. Should we manage to evolve to a sustainable society before we totally wreck the biosphere, then human space travel will be inexpensive, as the following comparisons clearly demonstrate.

Consider first a human mission to Mars, a wonderful project that would enlighten the spirit and knowledge of all humanity. According to leaders of the Mars Society, such a mission would cost around $30 billion. This may sound expensive, but when one realizes that in a typical year the United States spends 10 times this amount on its military budget, and such military expenditures go on year after year after year, by comparison $30 billion is not much money at all. Unfortunately, a human mission to Mars is very unlikely in the foreseeable future. This huge imbalance in spending between the military, which is wasteful at best and destructive at worst, and something so positive as exploration of Mars, is a sad commentary on our country and the world.

Of course, sending a human spaceship to another star will cost a lot more than sending a few astronauts to Mars. University of Illinois engineer Cliff Singer, in his excellent chapter "Settlements in Space, and Interstellar Travel" in *Extraterrestrials: Where Are They?* (a book I co-edited with Michael Hart) estimates the cost of an interstellar spacecraft propelled by a stream of very high-velocity pellets. The estimated price is 1 million person-centuries (1 million people each working for a century), or roughly $10 trillion. Expensive? Not really, when one considers that this is about the cost of one decade of the worldwide arms race. Is human "civilization" insane or what?



Space artist Don Davis visualizes an interstellar spaceship. Once technologically advanced civilizations discover life-bearing planets around nearby stars, it's inevitable they will build interstellar missions to explore these worlds up close. Courtesy of Don Davis.

Various other forms of advanced propulsion systems are discussed in chapters by Freeman Dyson and Ian Crawford in *Extraterrestrials: Where Are They?* — *B. Z.*

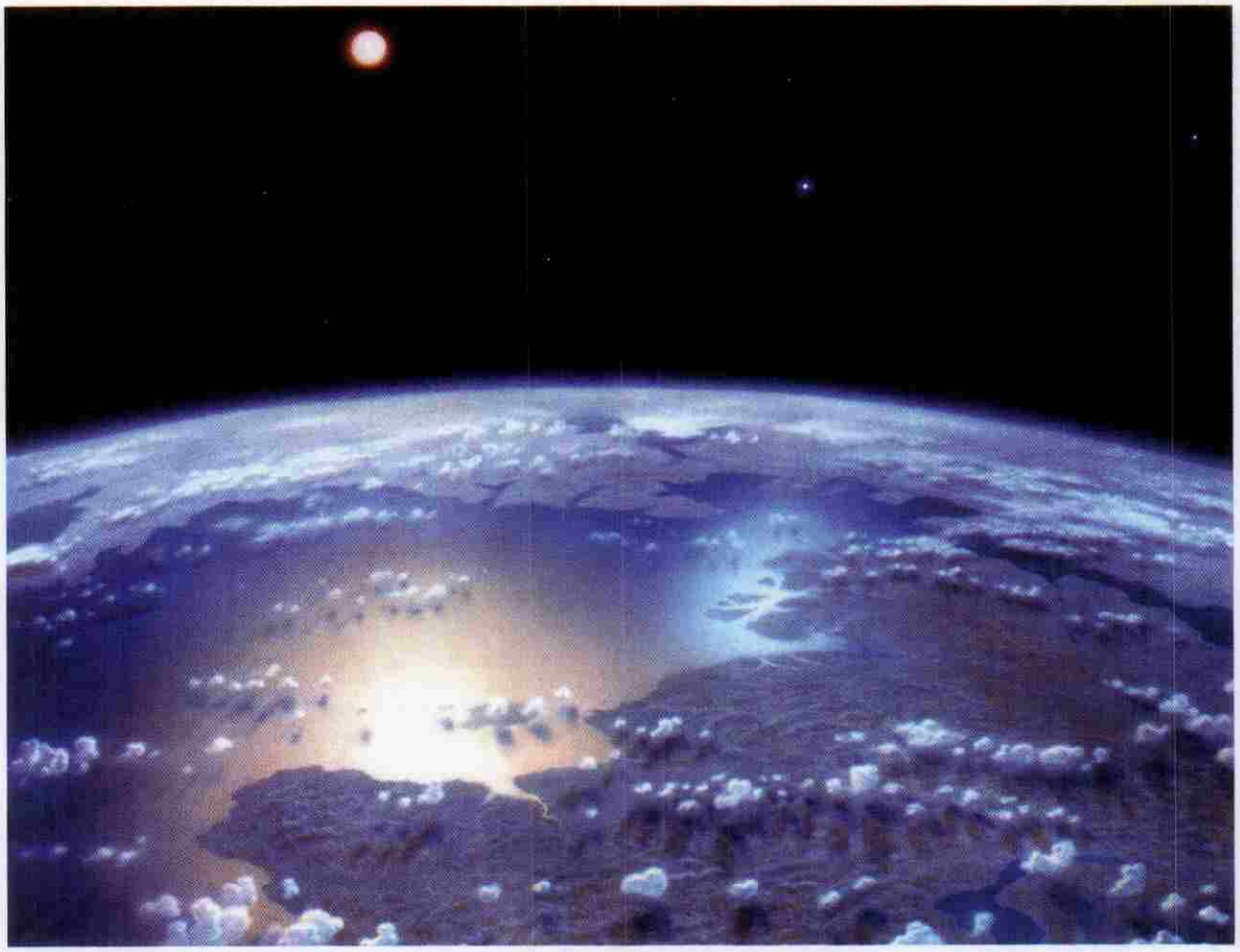
and free oxygen in the form of ozone. In other words, TPF will be capable of identifying life-bearing planets within about 30 light-years of Earth. When technology improves during the coming centuries, the range of such telescopes will no doubt be extended out to 100 or more light-years.

Less than 50 years will separate the beginning of serious SETI efforts and the construction of space telescopes able to detect and study nearby Earths. We therefore live in a unique moment of human history in which we possess powerful ground-based radio telescopes but no TPF. We are an infant technological civilization in this 50 year period, which is an infinitesimal time interval measured in any cosmic context. If we can build TPF so soon after becoming technological and beginning SETI, then other technological civilizations should have little trouble building their own versions of TPF. And SETI pessimists and optimists alike agree that if technological civilizations are numerous in the Milky Way, then a typical civilization must live for a very long time, on the order of millions of years.

Therefore, SETI endeavors should assume that any technological civilization within a few hundred light-years has had space telescopes capable of detecting and studying Earth for quite some time. If the typical technological civilization is 1 million years old, then such a civilization, if it lies within a few hundred light-years, has been studying us with its space telescopes for the past million years. This article will consider some implications of this basic idea.

At present, various radio and optical SETI programs, including the sensitive, ambitious, and relatively expensive Project Phoenix of the SETI Institute, are targeting nearby Sun-like stars. Project Phoenix, led by Jill Tarter, is searching 1,000 nearby stars using telescopes at a pair of widely separated radio observatories to help discriminate against human-made interference. The Phoenix search primarily uses the 305-meter Arecibo telescope in Puerto Rico and the 76-meter Jodrell Bank telescope in Britain.

Rather than hunt blindly for signals coming from nearby stars, the Phoenix team could use its telescope time



Don Davis depicts what a life-bearing planet might look like in a binary system (note the red and blue stars). If humans discover such a world within 100 light-years, our insatiable curiosity will likely compel us to explore it up close. Courtesy of Don Davis.

more economically if it skipped over such stars. Instead, Project Phoenix should target more distant stars that will remain out of range of TPF and its immediate successors — for example stars in the plane of the Milky Way or in the Andromeda Galaxy. Then, a few decades from now, radio and optical SETI programs could intensively focus upon promising planetary systems identified by TPF.

Is E.T. Passive?

Even if TPF discovers a favorably arranged planetary system or, better yet, a living planet whose atmospheric composition resembles that of Earth, the chance that the planet hosts a technological civilization is minuscule. I'll explain why.

Our nearest stellar neighbors have been and will remain our nearest neighbors for a million years or longer. Because the Sun is traveling at about 10 kilometers per second with respect to most nearby stars, it will take millions of years for Earth to move 100 light-years with respect to these stars.

Suppose that a million years ago Earth entered the sphere of detectability of the space telescopes of an advanced civilization on a planet now within 100 light-years of Earth. Using their own version of TPF, the inhabitants would have discovered Earth and the fact that it is a life-bearing planet. They would then have pointed some large telescopes at Earth and tried SETI. But the search would have been fruitless because we technological humans were still a million years in the future.

After decades or centuries of unsuccessful SETI, these extraterrestrials would have a decision to make. They might have decided to sit passively as our planetary system drifted by theirs. Such passivity is implicit in a SETI search scheme outlined by Andrew Howard and Paul Horowitz in which, ironically, TPF would be used to detect "deliberate laser transmissions from a technologically advanced civilization" within about 50 light-years of Earth. But these authors fail to consider that the advanced civilization surely would have discovered our living Earth long, long ago, and Howard and Horowitz certainly failed to consider the likely consequences of such a discovery.

Advanced extraterrestrials would have a more attractive and much more plausible alternative to long-term passivity: They could send an interstellar spaceship that contained themselves, or robots, or both, to explore our living Earth. Everything we know about human nature and history indicates that intelligent creatures will follow this path. Exploration of our solar system began with telescopic observations from Earth. But as soon as we developed the capability, we launched spaceships to explore planets and moons up close because observing from afar is limited and, ultimately, unsatisfying. Without going there, how will we

Terrestrial Planet Finder

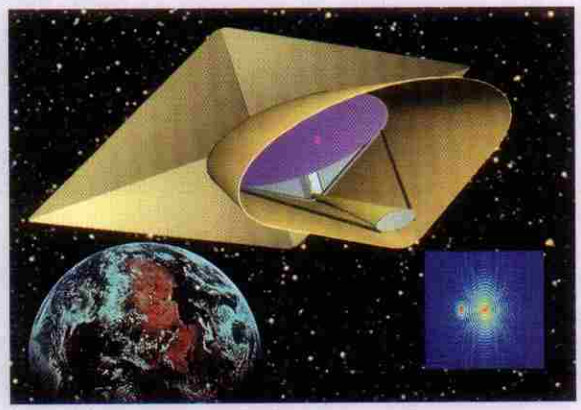
by James Larkin

The Terrestrial Planet Finder (TPF) is an ambitious proposed NASA space mission to detect and characterize Earth-like planets orbiting nearby stars (http://planetquest.jpl.nasa.gov/TPF/tpf_what_is.html). Currently scheduled for launch in 2014, TPF will search for planetary systems out to at least 30 light-years. The exact numbers of targets and distances will depend on TPF's final architecture. It will be required to produce a low resolution spectrum with sufficient sensitivity to identify the basic constituents of a planet's atmosphere. In particular, TPF can look for spectroscopic features of water, carbon dioxide, methane, and ozone, which would be indicative of life.

TPF's enormous challenge can be appreciated when one realizes that Earth is 10 billion times fainter than the Sun at optical wavelengths and would be separated by only 0.1 arcsecond if observed from a distance of 30 light-years (0.1 arcsecond corresponds to half a millimeter as seen from 1 kilometer). To discern such a faint object in such close proximity to a star's brilliant glare, NASA has developed a road map that includes several precursor missions and technology demonstrations.

All concepts for TPF are space-based, but the final design is far from decided. Even the operating wavelength range is still under debate. The mid-infrared offers an important advantage because Earth radiates most of its own light near 10 microns and is only 1 million times fainter than the Sun at this wavelength. But spatial resolution is ultimately set by diffraction effects that become worse linearly with longer wavelengths. So although Earth is brighter in the infrared compared to the optical, an infrared telescope would need to be much larger to separate Earth from the Sun.

Ball's concept for TPF includes a single telescope with a coronagraph to block the light from parent stars, allowing the faint light of attendant planets to emerge. Inset: Ball's TPF could theoretically pick out the faint light of a terrestrial planet (dot on left) by suppressing the light of the host star (center). Images courtesy of Ball Aerospace & Technologies Corp.



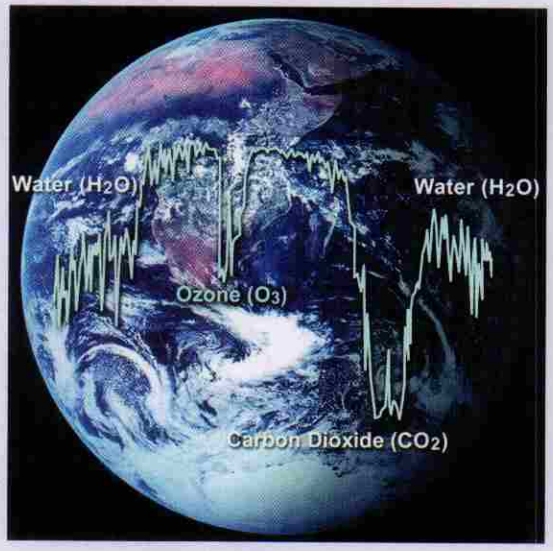
The European Space Agency is considering its own version of TPF, the free-flying DARWIN interferometer. Courtesy of ESA.

For most of TPF's development, NASA has been considering a mid-infrared interferometer. An interferometer combines the light of several relatively small telescopes to achieve the angular resolution (with some caveats) of a much larger telescope.

A planet-detecting interferometer works in a nulling mode, which is somewhat different from the operating mode of traditional interferometers. Instead of combining the light from the telescopes in phase, which would increase the measured brightness of the central source, the light is combined out of phase, which suppresses light from a source directly in front of the telescope. But the nulling doesn't work for sources slightly off-center, so a planet would still produce a signal.

The original concept contained two telescopes mounted on opposite ends of a large boom. For planet detection, however, the interferometer must cancel out the star to about 1 part in a million, which requires not only a very good central null, but also a null that covers the entire disk of the star. Michael Shao of JPL and Roger Angel of the University of Arizona independently showed in 1990 that the use of four or more telescopes will produce a wider null with greatly improved performance.

Great strides have already been taken in developing optical and infrared interferometers both on the ground and in space. NASA has awarded contracts to several aerospace companies to develop TPF concepts. Potentially viable alternatives to an interferometer have also emerged. TPF could be a large optical space telescope with a coronagraph to block a star's light. It could also consist of an optical space telescope with a separate free-flying occulting mask. Or it could be a specially

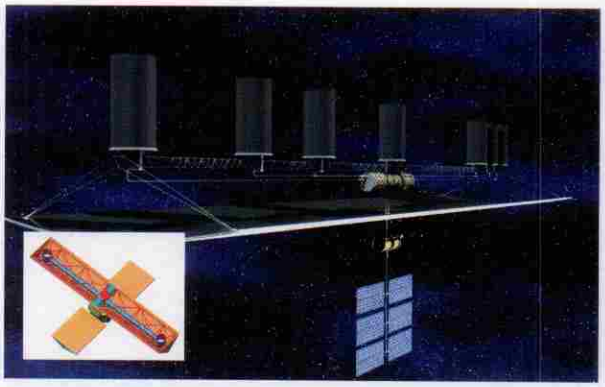


Like TPF, DARWIN could obtain the spectrum of extrasolar Earth-like planets and detect the chemical signature of life: water, free oxygen (in the form of ozone), and carbon dioxide. Courtesy of ESA.

apodized telescope. The European Space Agency is developing a competitive mission concept called DARWIN. We expect an agreement linking TPF and DARWIN, possibly with Japanese participation as well, in the next several years.

NASA's plans do not end with TPF. Several follow-up missions, most notably Life Finder and Planet Imager, promise ever greater insights into nearby planetary systems. These ambitious programs not only offer crude detection of a few tracer atmospheric molecules; they may also produce rough images of planet surfaces showing at least the presence of continent- and ocean-sized regions, and they may be able to identify unambiguously the chemistry of a living biosphere. As mentioned in Ben Zuckerman's article, all of these missions may be possible less than 100 years after the first large radio telescopes. Similarly, a relatively nearby civilization with its own Planet Imager could have seen Earth's continent-ocean dichotomy. It could have seen annual seasonal variations, the coming and going of ice ages, and long-term changes in vegetation patterns, both natural and human induced.

JAMES LARKIN (larkin@astro.ucla.edu) is Associate Professor of Physics and Astronomy at UCLA. He is also a member of the NASA ORIGINS subcommittee, which has responsibility for several NASA science missions, including the Hubble Space Telescope and TPF. He is also a member of the TRW science working group for its portion of the current TPF studies.



Terrestrial Planet Finder's design has not been finalized, but in these concepts from Boeing-SVS and the University of Arizona's Steward Observatory (inset), TPF will consist of several small telescopes mounted on a truss and arranged as an interferometer. Such a telescope could identify life-bearing planets around relatively nearby stars. Large illustration courtesy of Boeing-SVS/Jim Van Allen. Inset courtesy of Steward Observatory.

ever find out whether there is or ever was life on Mars, Europa, or Titan?

Some SETI proponents, notably Frank Drake and Barney Oliver, have disparaged interstellar spaceships as being slow and expensive compared with radio waves. But intelligent beings aren't going to sit around their home planet for millions of years beaming radio waves into the galaxy. They are going to venture out and explore the universe around them. After all, redwood trees, dinosaurs, and whales do not transmit radio waves. So, if we, or technological extraterrestrials, want to discover and study alien life forms, we must physically travel between the stars in spaceships. How else can we ever know if all life is constructed from proteins and nucleic acids, or is carbon based, or uses liquid water for a solvent? If we do not undertake such voyages, then we will forever forfeit the possibility of answering such profound questions for all living worlds that lack a technological civilization, as Earth did for billions of years.

Interstellar Travel

Scientists and nonscientists alike are curious about life in the universe. For example, biologist Penelope Boston, a member of the Mars Society's Board of Directors, stated a few years ago on the Discovery Channel's program *Destination Mars*: "I am a biologist; I have a burning need to know about life in the universe." In 1998, I participated in a NASA-sponsored meeting at Caltech on "Robotic Interstellar Exploration in the 21st Century." The engineers and physical scientists in attendance agreed that if humans decide to fund an interstellar mission, which will cost more than all previous space missions, the motivation will be the prospect of investigating a living world at the end of the voyage. Note that a mere 40 years after Sputnik, NASA was already considering the design, cost, and scientific yield of an interstellar mission (see "Interstellar Travel Is Inexpensive," page 16).

For interstellar travel to become practical, voyages should take a few hundred years or less, with perhaps 1,000 years as an upper limit. Scientists and engineers have proposed a variety of propulsion schemes (such as nuclear

But What About the Zoo Hypothesis?

A well-worn idea in both the scientific and science fiction literature is that "They" are indeed out there, but They are purposely remaining hidden from our view while They keep us under surveillance. In essence, we live in their zoo or wilderness preserve. This "Zoo Hypothesis" implicity assumes that we humans play center stage, otherwise what would They be hiding from?

But as discussed in the main article, if They are indeed out there, the first indication that Earth is an interesting place would have been revealed to them long before we arrived on the scene. Just as the creatures in Sydney, Australia's zoo cannot be observed from New York City, so terrestrial life cannot be observed from even the closest stars. Extraterrestrials must come to our planetary system before they can even begin to think about zoos. Once in the solar system, they will have no reason not to set up shop in the most obvious places, because there is no need to hide from dinosaurs, lizards, trees, insects, flowers, and fish. By the time technological humans appear, the alien space travelers would be sprawling about our solar system and very much in plain sight.

The above argument, which shows that the Zoo Hypothesis should not be taken seriously, is equally applicable to UFOs. Alien creatures would have arrived in our solar system long before technological *Homo sapiens*, so it makes no sense for them to be furtively darting about playing hide-and-seek with humanity.

Then there are the related questions: Would aliens send robots or would they come themselves? In the distant or not-so-distant future, will robots constructed by humans supplant humans as the dominant intelligence on Earth?

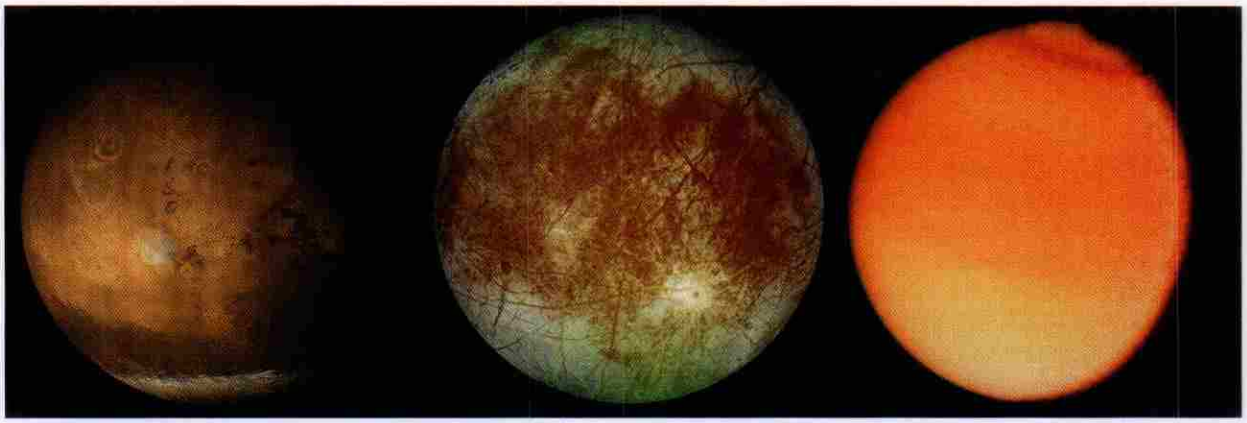
Answers to these questions are not clear cut, but I think that the creatures themselves will come for the following reason. Whether one views a 3D IMAX film on life aboard the International Space Station versus being on the station, or an IMAX film showing someone climbing Mt. Everest versus actually climbing Everest oneself, the films can never match the adventure of in-person exploration and discovery. When I was a youngster growing up in the Northeast, I was excited by picture books of the wonderful desert canyons of the Southwest. As remarkable as these pictures were, they could not begin to hold a candle to the thrills I felt as an adult while exploring in detail canyons in southern Utah and northern Arizona. No matter how smart our robots get, humans are not going to want to miss an opportunity to visit other living worlds. — *B. Z.*

Some people propose that we are being observed surreptitiously by extraterrestrials, like animals in a zoo. But this Zoo Hypothesis makes no sense because the putative aliens would have come to Earth and set up shop long ago.

bombs, pellet streams, and lasers) that could accelerate a spaceship to a few percent of the speed of light. If living worlds are so uncommon in the solar vicinity that the nearest one is farther away than 100 light-years, then exploratory voyages over such long distances will take such a long time that civilizations will probably send robots and frozen embryos in preference to creatures of flesh and blood (or whatever they're made of). Should living worlds be rare, widely separated, and thus difficult to reach with spaceships, then communicative technological civilizations will be rarer still and SETI searches of nearby stars will fail.

But even if living worlds are not rare, SETI searches of stars within a few hundred light-years are doomed to fail because an advanced civilization on any nearby planet would have long ago employed space telescopes to identify Earth as a living planet and would have come to our solar system to investigate Earth. And once here, why leave? Just as the Polynesians who discovered Hawai'i after a long and dangerous voyage across the Pacific did not turn around and return to their point of origin, so representatives of a spacefaring civilization will remain in the planetary systems they choose to explore. After all, it's a long way home.

Thus, the only SETI strategy that makes any sense is to search for signals from distant civilizations, where "distant" is defined as far enough away that Earth has never been discovered as an interesting place by the space telescopes of a putative civilization. Signals received from such distant beings are unlikely to have been generated for our benefit, so detection of extraterrestrial intelligence will likely require luck, and round-trip electromagnetic communications will be slow.



Mars, Europa, and Titan offer the best prospects for finding life in the solar system. Humans won't settle for observing these worlds from afar; we will explore these worlds up close. Mars image courtesy of NASA/Malin Space Science Systems/JPL. Europa and Titan images courtesy of NASA/JPL.

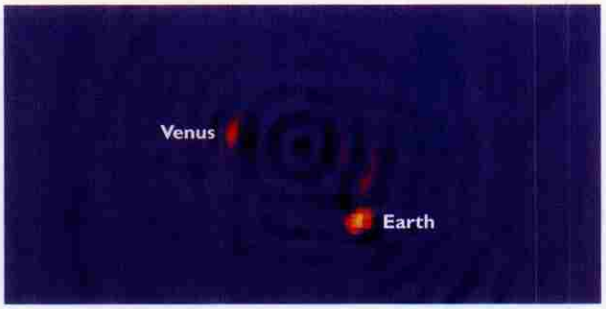
In summary, three simple and plausible postulates have major implications for SETI. First, soon after the development of technology, all civilizations will build space telescopes capable of measuring the atmospheric compositions of Earth-like worlds at distances of hundreds of light-years. Second, intelligent life is curious about other life forms, whether or not that other life is technological. And third, once having used space telescopes to discover a nearby living planet, most if not all technological civilizations will be sufficiently curious to construct interstellar spaceships to visit that planet. If these postulates are true, the absence of intelligent aliens in our solar system is strong evidence that they do not exist anywhere in our region of the Milky Way and SETI searches of nearby stars are destined to fail.

Pessimists Are Optimists and Vice Versa

Regarding the frequency of technological civilizations in our galaxy, the marriage of TPF and interstellar travel may be extended to distant times and places. Oxygen built up in Earth's atmosphere about 2 billion years ago. Following that period, Earth could have been identified as a living world from afar. Any technological civilization that came within a few hundred light-years of Earth during the past 2 billion years would have had to choose between passively floating by (for a million years) and never learning about terrestrial life, or actively sending a spaceship to our solar system.

Even if such an expedition took 1,000 years, this still would have been a very quick trip in comparison to a billion-year wait for humans to show up with radio transmitters. During the past 2 billion years, millions of Sun-like stars have passed within a few hundred light-years of Earth, yet there is no evidence that technological extraterrestrials have ever visited our solar system (see "But What About the Zoo Hypothesis?" page 20). This suggests that very few, if any, technological civilizations existed around these millions of stars. Perhaps the origin of life on Earth was a once-in-a-galaxy fluke, or perhaps life almost never evolves to high intelligence, or perhaps civilizations destroy themselves soon after they develop technology. Although technological life must be exceedingly rare, we currently don't understand astronomy or especially biology well enough to know why.

TPF could take direct images of terrestrial planets up to several dozen light-years away. This simulated image shows what Venus and Earth would look like to an alien version of TPF at a range of about 15 light-years. Courtesy of Boeing-SVS and Olivier Guyon (University of Hawai'i/Institute for Astronomy).



The above picture, which can be extrapolated to the Galaxy as a whole, is completely different from the one painted by William Newman and Carl Sagan in their ambitious 1981 paper "Galactic Civilizations: Population Dynamics and Interstellar Diffusion." There they model the physical dispersal of technological civilizations as a very slow diffusion process for the following reason. Consider a spacefaring technological civilization arising some 200 light-years from Earth. Then, according to Newman and Sagan, "such a civilization will have been intensively occupied in the colonization of more than 200,000 planetary systems before reaching Earth, some 200 light-years away."

Sagan presented a similar argument in his 1980 book *Cosmos*, where he remarked on page 308, "that an advanced interstellar spacefaring civilization would have no reason to think there was something special about the Earth unless it had been here already ... From their point of view, all nearby star systems are more or less equally attractive for exploration or colonization." These statements ignore the power of TPF. Just as ground-based telescopes pointed the way to intensive spacecraft exploration of the most interesting planets and moons in our solar system, so would a TPF show a technological civilization just which of 200,000 nearby star systems are worthy of direct exploration.

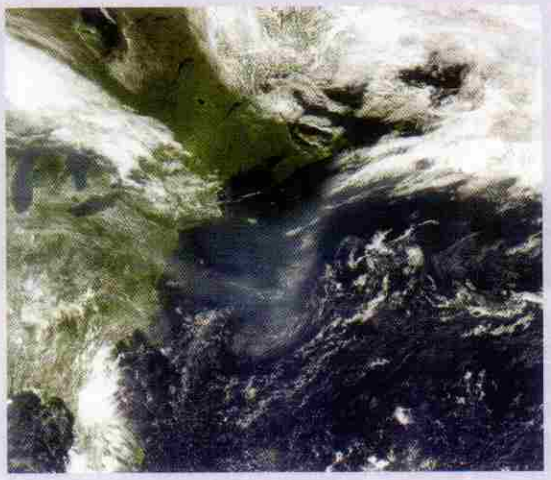
In conclusion, the relevance of TPF to the question posed at the beginning forcefully drives home the limited

Trashing Life on Earth

One of the supreme ironies of our age is that we're beginning the search for life on other worlds at the same time we are trashing life here on Earth. In fact, Earth is now experiencing the worst mass extinction event of the past 65 million years, courtesy entirely of the human species.

Biologists Peter Vitousek and Harold Mooney of Stanford University and Jane Lubchenco of Oregon State University estimate that our single species currently expropriates about 50% of various critical Earth resources (surface fresh water, major marine fisheries, etc.) for our own use, leaving the other 50% for all the other millions of species combined. But with our increasing numbers and increasing per capita impact on the environment, other species will be left with less and less as the 21st century winds along — a biodiversity catastrophe waiting to happen.

When very smart, well-meaning people can't see the forest for the trees, you know we're in big trouble. To cite just two examples, my ophthalmologist, as well as one of the smartest astronomers I know, have each recently remarked to me about how much open space there is in the U.S. They mistakenly assume that the U.S. population can simply grow into these "open spaces." But our country is already running beyond its carrying capacity and the apparent open space is an illusion. These open spaces are used for agriculture, grazing, timber, recreation, and waste disposal, or they are inhospitable deserts and mountain ranges. When one flies over Japan — one of the most densely populated countries and one living far beyond the carrying capacity of the island chain — there appears to be much "open space." But it's an illusion. Every time humans convert "open space" to their own needs, it will be at the expense of Earth's other species. In addition to ethical questions associated with extinguishing non-human life, at some point we risk damaging the biosphere to such a large extent that huge numbers of humans may also die. — *B. Z.*



NASA's SeaWiFS satellite captures smog over the Eastern United States. It is a supreme irony that while humans search for life on other planets, we are making Earth *less* hospitable for life. Courtesy of NASA/GSFC/ORBIMAGE.

predictive powers of scientists and engineers when forecasting our technological future. Like everyone else, Newman and Sagan failed to anticipate the possibility of TPF and its importance in the SETI debate, even though they wrote their paper just a mere decade before TPF became big news in the space astronomy community! This illustrates how foolishly presumptuous it is when SETI proponents exclaim that interstellar travel is impossible or so difficult that it will never happen. "Never" is a very long time. Already, four spaceships (Pioneers 10 and 11, Voyagers 1 and 2) are exiting the solar system less than a century after the airplane was invented.

Technological pessimists take note: Planet Earth has already launched four interstellar spacecraft. Pioneers 10 and 11, and Voyagers 1 and 2 (shown in this artist's rendition), are leaving the solar system, never to return. Courtesy of NASA/JPL.

The ultimate Luddites are those who deny that human destiny is to venture into space, to become the Little Green Men and Women. Rather than being optimists, SETI proponents who deny this future to human beings are the ultimate technological pessimists. While SETI skeptics may envision humans as possessing the most advanced brains in the Milky Way, nonetheless, it is we pessimists who are the true technological optimists.

BEN ZUCKERMAN (ben@astro.ucla.edu) is Professor of Physics and Astronomy at the University of California, Los Angeles. His major scientific interests include interstellar molecules, the birth and death of stars, the origin of planetary systems, and extraterrestrial life. He has coedited six books, including (with Michael Hart) Extraterrestrials: Where Are They? *(Cambridge University Press, 1995).*

SETI's Prospec

Thousands of communicating civilizations could populate our galaxy. And there are plenty of reasons why none of them have visited Earth.

by Seth Shostak

Is there intelligence elsewhere in the Galaxy? Are there other beings who not only can see the stars, but who can also understand where they are and how they work? That's the question today's SETI experiments try to address. A single signal from the cosmos — a sudden burst of photons or a soft radio squeal — would immediately provide an answer.

It is now four decades since the first modern SETI experiment, and we still have not detected and confirmed such a signal. This is reason for some astronomers, including my distinguished opponent Ben Zuckerman, to question the premises of SETI, or simply the likelihood that it will ever succeed. To my mind, this is as if the crew aboard *The Resolution*, Captain James Cook's ship — having sailed for months in search of Terra Australis Incognita — opted to set up debating clubs to argue the possibility that they would ever stumble across the postulated southern continent. In fact, debate would have been far less useful than continuing to sail. Cook's repeated probes into uncharted southern latitudes both constrained the search space and indirectly told his successors where to look next. In 1820, nearly a half century after Cook's forays, Thaddeus von Bellinghausen finally sighted Antarctica. In other words, experiment is better than debate, and that's why SETI researchers continue to deploy their telescopes.

Frankly, it's possible that tomorrow, next week, or next year, SETI will receive a signal that renders all argument about the likelihood of success obsolete and quaint. I personally believe that the telescopes and techniques currently being developed — instruments that will increase by three orders of magnitude the number of star systems scrutinized for cosmic company — are likely to result in the detection of someone else's technology. But that's my opinion. Meanwhile, and in the spirit of interesting pugilistic polemics, I will take issue with some of the rationale Ben Zuckerman has offered in support of his assertion that SETI will fail. After all, he's not only telling us it will fail, he's telling us why.

Planet-Sniffing Telescopes

Ben's fundamental insight is that all advanced civilizations will build telescopes able to detect small planets, and possibly even indications of biological activity, at distances out to a few hundred light-years. To Ben, this fact is obvious, given that we will soon have this capability ourselves. Indeed, having made this point, Ben then advises the SETI community to skip over nearby star systems and direct its scrutiny to more distant arenas. After all, he argues, why waste time investigating local stars until we know if they have Earth-size planets? Even better, he notes that in a decade or two, telescopes such as NASA's Terrestrial Planet Finder (TPF) will be able to sort out the best of these Earth-size worlds by spectroscopically

Since intelligent life has evolved on one planet, it could have sprouted on some of the billions of other planets that populate our galaxy. Yet these planets are separated by enormous distances, making it exceedingly difficult for civilizations to travel between them. Courtesy of NASA/GSFC.

ts Are Bright

analyzing their atmospheres for gases (e.g., oxygen and methane) that would betray the presence of life.

In other words, if you're going to look for extraterrestrials, it helps to know the territory, and by waiting a few decades, SETI researchers will have a list of all the Earth-like worlds around nearby stars. Stars without such planets can be skipped.

But this advice, although apparently reasonable, is not terribly helpful and will soon be irrelevant. While it's true that learning that, for example, a planet around the relatively nearby star 55 Cancri has oxygen in its atmosphere would surely improve its attractiveness for SETI, it hardly stamps it as a gold-plated SETI target. Earth's atmosphere has had an oxygen signature for 2 billion years, and nearly all that time our planet was devoid of sophisticated life. Even if advanced societies survive for tens of millions of years, only 1 in 100 life-bearing planets is likely to sport intelligent aliens right now. This already argues for extending the search beyond the nearest star systems, and in fact, this is being done. New detectors suitable for conducting SETI at optical wavelengths, as well as the extraordinary capabilities of the Allen Telescope Array (see "SETI All the Time," page 29) and its likely successor, the Square Kilometer Array, will shortly swell the list of SETI targets to hundreds of thousands of star systems, and, within a few decades, millions. The overwhelming majority will lie far beyond the "nearby stars" that Ben says waste SETI's time.

If Aliens Are There, They'd Be Here

Having warned against using precious telescope time to investigate nearby stars now, Ben then takes the stance that all star systems out to a distance of a few hundred light-years are guaranteed to be alien-free. His reasoning is as follows: Any advanced extraterrestrials around these stars, wielding planet-sniffing telescopes, will discover Earth and its telltale, biogenic atmosphere. They will fire up their SETI telescopes but will fail to detect a signal because *Homo sapiens* has yet to arrive on the scene. At this point, they will face a quandary of curiosity: The relative motion of stars in the Galaxy ensures that the Sun and its planetary retinue will move out of their local neighborhood within a few million years. Rather than let an intriguing world slip their grasp, these aliens will come to visit. They'll do this in person, as exploration by robots is ultimately unsatisfying. The aliens will want to study our "redwood trees, dinosaurs, and whales" (although it's more likely they will only find our bacteria). Once these visitors arrive on the terrestrial scene, they will not return to whence they came, but lodge permanently on Earth. Because we don't see these alien squatters today, this means they didn't visit in the past, and consequently they're not within manageable traveling range — a distance Ben estimates to be hundreds of light-years.

This line of reasoning is merely a modification of an argument well known in SETI circles: the Fermi Paradox. If aliens can manage interstellar travel (and, after all, such travel does not violate the laws of physics), then at least some of them should have colonized the Galaxy by now. The fact that we don't see any evidence of these supercivilizations is taken by skeptics as proof that no extraterrestrials exist. Ben's logic is simply a truncated version of Fermi's Paradox. He assumes

The Sun's closest stellar neighbor, Proxima Centauri, is the red star in the middle. With new radio telescopes, SETI will be able to leapfrog nearby stars that are within the range of TPF. Courtesy of David Malin, UK Schmidt Telescope, DSS, and AAO.

that technological societies will build their own TPFs and then visit those interesting places (including Earth) that they discover situated within a few hundred light-years.

Even if you buy into this, it still fails to rule out the possibility of finding an ET signal. Suppose that Ben is right: advanced aliens will colonize all biologically interesting worlds within, say, 500 light-years of their home, carving out a "sphere of influence" that's 1,000 light-years across. If 30,000 civilizations are randomly sprinkled throughout the Milky Way's voluminous star fields, then our galaxy will be fully stuffed with such spheres of influence. But if there are fewer than 30,000, there will be areas of the Galaxy that are untouched by the aliens. Frank Drake has frequently suggested that the number of contemporary alien societies in the Galaxy (the N in his famous equation) is about 10,000. If so, and if expansion reaches out hundreds of light-years as Ben has postulated, then the majority of the Milky Way's stars fall in the cracks — in the empty spaces between these inhabited zones — and would be free of curious, colonizing aliens. In this case, there's no reason to assume that, simply because extraterrestrials aren't walking the streets of your neighborhood, they're also absent from star systems that lie more than several hundred light-years away.

Going All the Way

But let's do something Ben has not done, and extend his argument to more than a first generation of interstellar expansion. Suppose the first civilization to build atmosphere-analyzing telescopes spawns colonists that quickly reach out a few hundred light-years. Let's also assume that their descendants do the same. First, they build planet-sniffing hardware of their own and then they venture out a few hundred light-years beyond their colonized homes. Repeat this scenario a few hundred times. Within a few tens

Spiral galaxies like the Milky Way and M83 (shown in this image from the Very Large Telescope) contain hundreds of billions of stars. Given these numbers, many people conclude that intelligent life is common. Courtesy of European Southern Observatory.

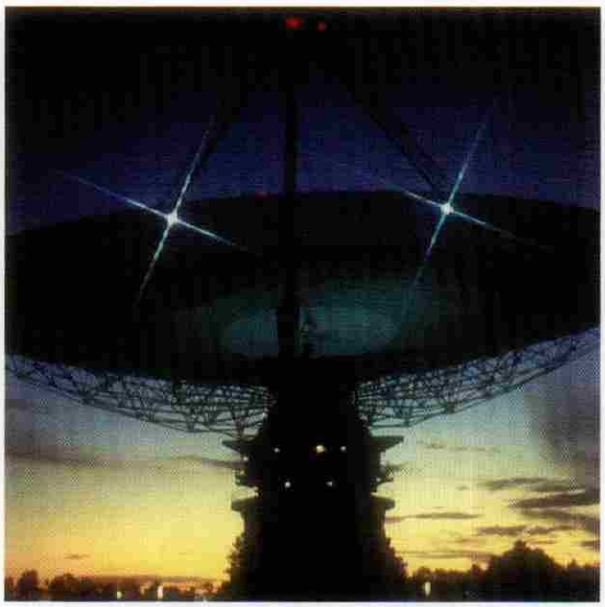
of millions of years, the colonizers will be ensconced on every attractive world in the Galaxy.

If this scenario were realistic, SETI supporters really would have a problem. The aliens or their mechanical proxies should be everywhere. This is, of course, the usual form of the Fermi Paradox, and it has been addressed in a substantial body of literature by folks who have been remarkably inventive in formulating scenarios that explain why such saturation colonization wouldn't take place. It would be both tedious and redundant to many readers to list all of these scenarios here, but they generally fall into three categories: (1) technical, (2) sociological, and (3) radical.

Among the technical explanations, an oft-cited suggestion is that interstellar travel is not as easy as Ben assumes. Aside from the enormous energy costs required to send a single craft to another star at 1% the velocity of light (3,000 kilometers per second), there's also the danger of interstellar material slamming into the nose of the spaceship at this blistering speed. In addition, one should be aware of the magnitude of the effort if large numbers of stars have habitable worlds. Within 500 light-years of us we can find about a million star systems! Ben might argue that only a small percentage of these will have decent planets, but if the number is small, then the probability of worlds with intelligent beings is smaller still. In this case, his whole argument falls apart because the chances that any potential colonizers have sprouted up within a few hundred light-years of us is negligible, even in the past 2 billion years when Earth has had an oxygenated atmosphere. In other words, if this is the case, then the reason we haven't yet detected extraterrestrials has nothing to do with their lack of presence on Earth, but is simply due to the fact that such societies are sparse. That could be the case. Indeed, it's the obvious rationale for increasing SETI's range of reconnaissance.

Among the sociological scenarios for the Paradox we can cite is the historical fact that colonization efforts on Earth have been much more limited than one would expect based on travel times or interest in distant lands. What stopped the Romans (or the Polynesians, etc.) from colonizing every temperate continent? Not travel time, and not a lack of appealing

The 305-meter Arecibo radio telescope in Puerto Rico is the world's largest and most sensitive antenna for detecting radio signals from another civilization. Courtesy of Seth Shostak.



The 64-meter radio telescope in Parkes, Australia, allows Project Phoenix to search for E.T. signals emanating from Southern Hemisphere stars. Courtesy of Seth Shostak.

destinations. Competition, overextensions, or simply a decline in motivation brought a halt to all such efforts. It's also possible that long-lived extraterrestrial civilizations are passive. On Earth, the development of rocketry occurred in roughly the same epoch as the invention of nuclear weapons. Aggressive societies may self-destruct before colonization begins, suggesting that only the less adventurous societies survive. According to this line of reasoning, the oldest alien cultures have managed to rid themselves of aggression and are disinterested in colonization.

It's also worth noting that humans are not uniformly distributed over Earth, but are concentrated in relatively small cities and suburbs. Perhaps the aliens, too, are urbanized, clustered around objects where matter and energy are highly abundant. Our solar system may be an uninteresting desert, relatively speaking, in the vast landscape of the Galaxy.

It is difficult to evaluate the validity of these efforts to explain how the Galaxy could be semi-packed with aliens while still allowing for a bit of empty space (which we inhabit). Ben has apparently given thumbs up to option (3) and chosen one of the two radical explanations for Fermi's Paradox: We are alone. (The other radical explanation, that the aliens are here on Earth, is popular with much of the public, but not with many scientists.) Ben insists that because they're not here, they're not there. This is like deciding that the world doesn't host large animals because (1) despite the fact that big animals could roam the world in short order, (2) you still don't see any in your backyard.

The Debate Continues On-Line

To read Ben Zuckerman's response to this article, and then Seth Shostak's rejoinder, visit www.astrosociety.org/pubs/mercury/31_05/response.html.

Bottom Line

My opponent has presented SETI scientists with two caveats. First, he argues that there's little point in observing nearby star systems now, because we will soon be able to learn which of these stellar habitats have Earth-like worlds. Second, the fact that Earth has not been settled by aliens indicates that none of the stars out to a distance of hundreds of light-years sports advanced societies.

The first point is moot, as SETI researchers are already extending their reconnaissance to greater distances. The second point is merely a special edition of the Fermi Paradox, in which it's assumed that only one generation of colonization will take place. But this argument also becomes less interesting as new telescopes push the radius of SETI searches farther into space. My opponent's arguments could be extended to the more general Fermi Paradox, which envisions a spread of civilization to every galactic nook and cranny. But there are many possible impediments to a thorough colonization of the Milky Way, and to summarily decide that our world has been left alone because there's no one anywhere else in the Galaxy is not logic, but merely conviction.

In short, while it is interesting and edifying to debate the likelihood that we will uncover evidence of thinking beings elsewhere, it is hubris to think that we can decide this issue based on the activities of our own society or the situation of our immediate neighborhood. Cook's sailors might just as well have concluded that Antarctica couldn't exist because there was ice-free water around their ship. It makes more sense to sail on.

SETH SHOSTAK is a senior astronomer at the SETI Institute, in Mountain View, California, and author of Sharing the Universe: Perspectives on Extraterrestrial Life. *A radio astronomer by training, he has spent a dozen years searching the skies for cosmic company. He is sanguine about the chances of success.*