A Morning With Philip Morrison

Exploring the Extraterrestrial Mind

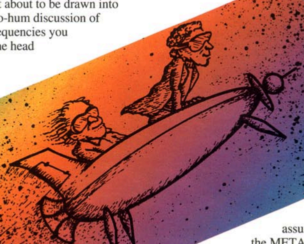
by Paul Horowitz

On a gorgeous day last spring (Thursday the 13th of June, to be exact), the author spent a stimulating morning with Professor Philip Morrison and Dr. Michael Davis, discussing the Search for Extraterrestrial Intelligence (SETI). Phil is a pioneer in SETI, having co-authored with Giuseppe Cocconi the oft-quoted 1959 paper in which the idea of interstellar communication at the wavelength of neutral hydrogen emission (21 centimeters) was first proposed. He has continued to be a prime mover in SETI, delighting even the most experienced hands with his sharp insights and surprising perspectives. Mike is the director of the Arecibo Observatory in Puerto Rico; its 1,000-foot (300-meter) diameter makes it the largest radio telescope on Earth.

We were warmly greeted by Phylis Morrison, who delighted, as always, in showing new visitors Phil's Swiss-made funicular—a motor-driven contraption capable of effortlessly lofting Phil and his wheelchair along the contours of a spiral staircase. As received from the factory, its considerable elegance lay hidden. But Phylis has replaced the gray metal exterior of its machinery with Plexiglas, thus revealing its beautifully crafted inner workings.

We spread out in the second-story greenhouse, where I expected the discussion to focus on narrow technical issues, such as the optimum receiver bandwidth and resolution to design into our next-generation search apparatus. This seemed natural, especially since two weeks earlier Phil had chaired a meeting, held by The Planetary Society, at which I had presented the rationale for a new pair of search systems: a 100-million-channel, dual-beam, all-sky search of moderate resolution (BETA I), to be followed several years later by a 6-billion-channel, high-resolution search (BETA II).

But that was not to be. Instead we took off in Phil's rocket ship for a quick tour of the galaxy and a look into the minds of those other galactic beacon engineers (if any!). Phil wanted to explore something *new* in SETI this morning, and he wasn't about to be drawn into yet another ho-hum discussion of how many frequencies you can fit onto the head of a pin. Here's how it went.



Phil pulled out a little rectangle of paper (it looked like the remnant of one of those business reply cards that serve mostly to make awkward the process of thumbing through magazines), on which he had ecologically interleaved a few notes to himself. He began by saying that we might do well to stop worrying so much about the search variable of *wavelength*, and assume instead that an interstellar beacon would most likely be transmitted at a guessable wavelength (for example, the famous 21-centimeter line at which neutral hydrogen emits naturally). Furthermore, the transmitting civilization would finesse the problem of Doppler shifts of the received wavelength (caused by the relative motions—on the order of some hundreds of kilometers per second—of stars in our galaxy). They would do this by pre-adjusting their transmitting frequency to compensate for their own motion relative to the remarkable "rest frame of the universe"—the frame of reference of the 3-degree-Kelvin radiation left over from the Big Bang. (These fundamental assumptions of the META search are laid out in the July/August 1987 issue of *The Planetary Report.*)

Instead, Phil suggested, we should worry more about the poorly explored variables of pulse width (the duration of each transmission) and duty cycle (the average percentage of time that the signal is on). And how do we guess reasonable values for these unknowns? Easy—the travel time of the message sets a natural time scale!

Phil then proceeded to carry out a minor subdivision of galactic real estate. Consider only "good" stars, he suggested—say, spectral type G5, solitary, late generation, similar to our Sun. That takes us from an initial stellar population of something like 400 billion down to a mere billion, give or take a factor of 5. Now, let's stay away from the central area of the galaxy, say 10,000 light-years from the center—it's too violent there. That leaves a flattened disk going out from 10,000 light-years to perhaps 40,000 light-years—not many stars are out beyond that (think of a 45-rpm record, with its large hole in the center). That's the galactic real estate we're interested in, SETI-wise.

Let's divide this peculiar shape into neighborhoods, so we can have local town meetings. The galactic thickness sets the scale, something like 2,000 light-years. We imagine the disk sliced radially into roughly 50 sectors (think of slices of a pie), each further sliced at right angles every 2,000 light-years (think of eating a slice). Altogether you've now got about 1,000 neighborhoods, each with about a million good suns. Within each neighborhood, a message takes a millennium or less to reach its destination.

Looking at our handiwork, we see a progressive scale of distances, perhaps better appreciated as a progression of time scales required for a round-trip message: about a millennium for a communication within our local neighborhood, 10 millennia for a message within our slice of the galaxy, 100 millennia for a message anywhere within the galaxy, and 10 million years for communications with the local group of galaxies.

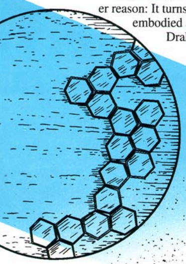
Now for the deductions about probable pulse widths and repetition times. Whatever creatures may inhabit the galaxy, we all live by the same laws of physics, and we all share the same galactic geography. It was the universal quantum mechanics of the hydrogen atom that led Cocconi and Morrison in 1959 to their brilliant insight that galactic species might well meet at hydrogen's natural frequency of 1,420,405,751.768 vibrations per second, or 1420 megahertz (still one of META's favorite stomping grounds). Phil wanted to coax another prediction from nature—this time about the complementary variable of time.

First, the minimum duration of a pulse. The argument is a bit involved, but fascinating: It's a curious property that the shorter a pulse, the wider its inherent spread of frequency. Numerically, the bandwidth (in hertz) is about the reciprocal of the pulse width (in seconds). As my colleague Ed Purcell likes to say, "If you play a 1/32nd note on a tuba, it doesn't much matter which note you play." A related fact about the galaxy: Disembodied hydrogen atoms (free electrons and free protons) also cause radio signals to spread out in frequency, although for a completely different reason. SETI pioneer (and Planetary Society advisor) Frank Drake and his student George Helou first looked into this in connection with SETI, and they concluded that the galaxy permits very narrow frequencies to be sent—as narrow as a few thousandths of a hertz, but no narrower. In SETI, narrow is good because (1) it is distinctive, (2) the received signal overcomes cosmic noise better for the same transmitted power and (3) narrow signals from space look different from narrow signals generated on Earth, because of the effect of Earth's rotation (the Doppler effect).

So, the argument goes like this: An extraterrestrial civilization would not want to squander the benefits of the narrowband properties of the galaxy by transmitting too short a pulse. How short should the pulse be? The reciprocal of the Drake-Helou bandwidth, which works out to a few hundred seconds, if the transmission is at the hydrogen frequency.

We can get some insight into *upper* limits for the pulse width by figuring that our engineers on the transmitting planet would like to send signals toward each of the million stars in their neighborhood, repeating the performance some reasonable number of times (say, 10) in the thousand years it takes for the signal to get there. In doing that, the transmitter can dwell only 1,000/(10x1,000,000) years on each target—that's about an hour.

That's an interesting result for another reason: It turns out that the same disembodied atoms that cause the Drake-Helou effect also give rise to radio scintillation, analogous to the atmospheric scintillation that causes the twinkling of starlight, and that radio twinkling has a time scale not of fractions of a second (as with starlight), but of a good part of an hour. So an hour-long transmission (a very long pulse) is likely to outlast the fading effect of galactic scintillation, and therefore will appear quite intense for a portion of the time, whereas a significantly shorter pulse might fall victim to a deep fade-out.



Were we falling prey to faulty reasoning here? Our argument so far assumed that the extraterrestrials would send a signal to only one target at a time. But if they were really advanced, it would not be difficult for them to build many transmitting antennas, so they could target many stars at once.

At this point I put forth a favorite idea: Our use of large radio-astronomical dishes, each with a single receiver able to detect signals from only a single point in the sky at one time, is really a transient phase in our technological maturation. These antennas are like cameras in which we put only a tiny speck of black-and-white film in the focal plane. Our technology is getting better: Newer spectrometers cover a wider range of wavelengths (color film). And we are beginning to use a few simultaneous receiving systems (a few specks of film).

As our technology improves—and we are becoming adept with little things made from silicon—we'll be able to omit the large reflecting dish entirely, instead using the surface of a vast array of silicon wafers as the antenna itself, connected directly to the underlying silicon receivers. This is a phased array, able to form multiple simultaneous radio beams. Not only are the interconnections part of the silicon, even the power is generated by the silicon itself! There it is, a dry lake bed tiled with glistening purple checkerboards of silicon, quietly receiving radio signals from a multiplicity of directions. It could also be a transmitter, of course: Sunlight delivers a billion watts per square kilometer.

We liked our futuristic new silicon toy, and quickly began using it. Stepping into the role of advanced alien beacon engineers, we decided to transmit multiple beams continuously to known planetary civilizations—these are messages, for which we use perhaps half our transmitter power. The other half we use for contacting new civilizations, by successively sending an intermittent beam in their directions. These are the pulsed transmissions we invented earlier, visible to the radio antennas of primitive civilizations as a flashing beacon, beckoning for an eventual reply.

These elegant, metallic purple planes patiently do their electromagnetic chores, carrying on multiple dialogues with established partners, perhaps finding a new one once in a hundred millennia. Long periods of sameness, punctuated by occasional newness. Here I mentioned the model of pulsars: many similar ones, then a new class—an optical pulsar, a fast binary pulsar, a millisecond pulsar, or urban pulsar-crowding in a star cluster. Phil's model was from a different culture: The popular music of Glasgow, for a long time relatively unchanging, now has exploded with Japanese folk tunes.

How could an object such as our silicon toy survive for millennia? On Earth it takes careful engineering to make something that runs for just a century. Active maintenance would be required. There must be redundant arrays of antennas, free-floating and self-phasing, replaced as they fail. They would illuminate the planetary neighborhoods of good stars, perhaps out to 10 astronomical units (1 AU is the average distance from Earth to the Sun), reaching all good suns in the neighborhood in a human lifetime. If, indeed, this strategy is being pursued by those other galactic beacon engineers, our job is to look at the whole sky continuously, for that literally once-in-a-lifetime signal of unusual strength.

We started scratching down numbers: Could such a signal be detectable with the sort of small—and insensitive—antenna that sees the whole sky? (In an ironic twist of nature not unrelated to the fact that pulses short in time are wide in frequency, big antennas see a small piece of the sky, and vice versa.) "Let's see, roughly 10^{-20} watts per square meter for 10 dB relative to isotropic . . . mumble, mumble . . . need to illuminate a 10 AU disk at range . . . about 10^{28} square centimeters . . . wow, only 10 kilowatts!"

We fiddled with the numbers a bit to allow for proper motions, and still concluded it was easy enough, given those handsome purple alien transmitting planes. (The idea of beacons strong enough to be detectable with small antennas has been elaborated recently by Bob Gray, a Planetary Society member and amateur radio astronomer from Chicago. See his article, "Isotropically Detectable Interstellar Beacons," *Jour. Brit. Interplanetary Soc.*, **43**, 532 [1990].)

We did a last bit of backseat engineering for our alien culture by noting that they could save a few bucks by going to a shorter wavelength, where a smaller antenna would produce the same accurate beam. But as the wavelength gets shorter, the Drake-Helou spreading goes down, and Doppler shifts go up: The number of receiver channels increases in proportion to frequency squared or more! Great, I said—another good reason to embark on the BETA project I've been dreaming about for the last year!

Our musings had spun themselves out, it seemed. And we had come full circle, once again embracing the merits of billion-channel receivers. Phil and Phylis couldn't say good-bye without showing us their latest electromagnetic toy, Sony's pocket-size Pro-80 all-band synthesized radio. We switched it on, and found the electromagnetic spectrum entirely barren! Earth, it seemed, had recently been showered with the byproducts of a particularly violent solar outburst. All shortwave communications over the one-tenth of a light-second that bound our communicative horizon on Earth were blanked out. A fitting counterpoint, I couldn't help thinking, to the soaring communications systems of our morning's imaginings.

Exhilarated and exhausted, we drove off from the Morrisons' house. Mike said, "What a morning! I could never reconstruct *that* argument!"

"But *I* can," I replied, "because I took notes!"

Paul Horowitz is the inventor and instigator of Project META, the SETI program supported by The Planetary Society.

META and BETA

Project META (Megachannel ExtraTerrestrial Assay) is The Planetary Society's full-time, whole-sky Search for Extraterrestrial Intelligence (SETI), carried out at twin sites: the Harvard-Smithsonian 84-foot-diameter steerable radio telescope, in Harvard, Massachusetts, and the 100-foot-diameter radio telescope of the Institute of Radioastronomy in La Plata, near Buenos Aires. It is the most advanced and powerful SETI project now operating.

META's sensitive receivers and sophisticated 8.4-million-channel spectrum analyzer could detect radio signals broadcast intentionally by a civilization like ours orbiting any of the nearest thousand Sun-like stars. More advanced civilizations—with correspondingly more powerful transmitters—could make themselves detectable from the farthest corners of the galaxy, which contains roughly 400 billion stars in a flattened disk 100,000 light-years in diameter.

META has now scanned the northern sky several times in the neighborhood of the 1420-megahertz emission frequency of neutral hydrogen, and once near its second harmonic (2840 megahertz). Its companion in Argentina is now completing the combined full-sky survey, including coordinated observations in the equatorial belt seen by both telescopes.

Since its inauguration six years ago by Steven Spielberg (whose gift to The Planetary Society made its construction possible), META has patiently scanned the sky for the signature of another intelligent civilization. Its detection algorithms include compensation for the effects of rapid astronomical motions; in addition, it uses the unique signature of a changing radio frequency caused by Earth's rotation to discriminate a genuine cosmic signal from terrestrial interference. The good news is that these algorithms work—the search system has rejected almost entirely the radio mumblings (and bellows) of intelligent life on Earth. The bad news is obvious—we have made no detections!

BETA (Billion-channel ExtraTerrestrial Assay) is our planned next step. Close searching in the neighborhood of "magic" frequencies like 1420 megahertz hasn't done the trick. But in those six years technology has advanced nicely, permitting us to cast a much wider electronic net, still within the resources of university research and Planetary Society support. We plan two steps: BETA I will be a 100-million-channel analyzer, hooked to a dual-beam upgrade of the Harvard antenna, that will search the full "water hole" (the 300-megahertz band of microwave frequencies from H to OH^-; see the July/August 1987 *Planetary Report*); BETA II, following five years later, will be a 6-billion-channel analyzer that instantaneously covers the water hole at millihertz ultrahigh resolution.

The BETA searches will constitute the first full water-hole search of the sky, the first dual-beam megachannel receivers and the largest spectrum analyzers on Earth. We expect the continuation of an independent center of excellence, supported by The Planetary Society, to advance the SETI enterprise worldwide, and, through its unique approach, to complement the NASA SETI program now getting under way. And—dare we hope?—given that each successive project provides us with a receiving system far more capable than the last, *one* of these explorations will someday succeed in making the most monumental discovery in human history; might it be BETA? —*PH*

Illustrations: S. A. Smith