From **Carl Sagan. Contact**

[Ellie, when she was three] turned the dial marked "frequency," and came upon a voice talking excitedly—as far as she could understand, about a Russian machine that was in the sky, endlessly circling the Earth. […] Then she thought about the inside of the radio. … What happens inside the radio set when you change stations? What was "frequency"? Why do you have to plug it in for it to work?

[…] In the seventh grade they were studying "pi." …The teacher … said that it was about 3.1416. But actually, if you wanted to be exact, it was a decimal that went on and on forever without repeating the pattern of numbers. Forever, Ellie thought. She raised her hand. It was the beginning of the school year and she had not asked any questions in this class.

"How could anybody know that the decimals go on and on forever?"

"That's just the way it is," said the teacher with some asperity.

"But why? How do you know? How can you count decimals forever?"

"Miss Arroway"—he was consulting his class list—"this is a stupid question. You're wasting the class's time."

No one had ever called Ellie stupid before, and she found herself bursting into tears. […] After school she bicycled to the library at the nearby college to look through books on mathematics. As nearly as she could figure out from what she read, her question wasn't all that stupid.

[…]

As technology developed and the cities were polluted, the nights became starless. New generations grew to maturity wholly ignorant of the sky that had transfixed their ancestors and that had stimulated the modern age of science and technology. […] Ellie would look up at Venus and imagine it was a world something like the Earth—populated by plants and animals and civilizations, but each of them different from the kinds we have here. On the outskirts of town, just after sunset, she would examine the night sky and scrutinize that unflickering bright point of light. She tried to imagine what was going on there.

[…] She arranged to spend free periods and occasional hours after school in what was called "shop"—a dingy and cramped small factory established when the school devoted more effort to "vocational education" than was now fashionable. "Vocational education" meant, more than anything else, working with your hands … Ellie built an encrypting machine. It was rudimentary, but it worked. It could take any English language message and transform it by a simple substitution cipher into something that looked like gibberish.

Building a machine that would do the reverse—converting an encrypted message into clear when you didn't know the substitution convention—that was much harder. You could have the machine run through all the possible substitutions (A stands for B, A stands for C, A stands for D…), or you could remember that some letters in English were used more often than others. **[…]**

Ellie surprised herself by choosing Harvard over the Massachusetts Institute of Technology. She set out to broaden her education, to take as many courses as possible apart from her central interests in mathematics, physics, and engineering. But there was a problem with her central interests. She found it difficult to discuss physics, much less debate it, with her predominantly male classmates. At first they paid a kind of selective inattention to her remarks. There would be a slight pause, and then they would go on as if she had not spoken. Occasionally they would acknowledge her remark, even praise it, and then again continue undeflected.

She was reasonably sure her remarks were not entirely foolish, and did not wish to be ignored, much less ignored and patronized alternately. Part of it—but only a part—she knew was due to the softness of her voice. So she developed a physics voice, a professional voice: clear, competent, and many decibels above conversational. With such a voice it was important to be right. She had to pick her moments. … So she found herself leaning towards quick, sometimes cutting, interventions, usually enough to capture their attention; then she could go on for a while in a more usual tone of voice. Every time she found herself in a new group she would have to fight her way through again, just to dip her oar into the discussion. The boys were uniformly unaware even that there was a problem.

Sometimes she would be engaged in a laboratory exercise or a seminar when the instructor would say, “Gentlemen, let's proceed,” and sensing Ellie's frown would add, “Sorry, Miss Arroway, but I think of you as one of the boys.” The highest compliment they were capable of paying was that in their minds she was not overtly female.

She had to fight against developing too combative a personality or becoming altogether a misanthrope. She suddenly caught herself. “Misanthrope” is someone who dislikes everybody, not just men.

[…] Ellie began to visit the university's modest radio telescope in nearby Harvard, Massachusetts, eventually getting an invitation to help with the observations and the data analysis. She was accepted as a paid summer assistant at the National Radio Astronomy Observatory … She began to think about better ways of detecting faint radio signals. In due course, she graduated cum laude from Harvard and went on for graduate work in radio astronomy at the other end of the country, at the California Institute of Technology.

[…] In her second year at Cal Tech, Peter Valerian returned to campus from his sabbatical year abroad ... There was one slightly disreputable aspect of his scientific career: He was fascinated

by the possibility of extraterrestrial intelligence. […] Valerian would emphasize how we are trapped by our time and our culture and our biology, how limited we are, by definition, in imagining fundamentally different creatures or civilizations. And separately evolved on very different creatures or civilizations. And separately evolved on very different worlds, they would have to be very different from us. It was possible that beings much more advanced than we might have unimaginable technologies—this was, in fact, almost guaranteed—and new laws of physics. … There would be a twenty-first-century physics and twenty-second-century physics, and even a Fourth-Millennium physics.

[…] If we were any more advanced, the extraterrestrials would know about us already. Here we were, just beginning to stand up on our two feet, discovering fire last Wednesday, and only yesterday stumbling on Newtonian dynamics, Maxwell's equations, radio telescopes, and hints of Superunification of the laws of physics.

Valerian was sure they wouldn't make it hard for us. They would try to make it easy, because if they wanted to communicate with dummies they would have to have a fighting chance if a message ever came.

[…] As a topic for her doctoral thesis, Ellie chose the development of an improvement in the sensitive receivers employed on radio telescopes. It made use of her talents in electronics, … and permitted her to continue her discussions with Valerian. … She then installed her new instrument on one of Cal Tech's radio telescopes in Owens Valley and detected, at entirely new frequencies, what astronomers call the three-degree black-body background radiation—the remnant in the radio spectrum of the immense explosion that began this universe, the Big Bang.

[…] After receiving her doctorate, Ellie accepted an appointment as research associate at the Arecibo Observatory, Puerto Rico. With the largest radio telescope on the planet, she was eager to employ her maser detector to look at as many different astronomical objects as she could … A civilization only a little bit in advance of ours might, she thought, be capable of transmitting a hundred megawatts or more. If they were intentionally transmitting to the Earth with a telescope as large as Arecibo but with a hundred-megawatt transmitter, Arecibo should be able to detect them virtually anywhere in the Milky Way Galaxy.

[…]

“Afternoon, Dr. Arroway.”

The lone engineer smiled pleasantly at her, and she nodded back. All 131 telescopes of Project Argus were controlled by computers. The system slowly scanned the sky on its own, checking that there were no mechanical or electronic breakdowns, comparing the data from different elements of the array of telescopes.

If it detected something of interest, it would automatically sound an alarm, altering project scientists in their beds at night if need be. Then Dr. Arroway would go into high gear to determine if this one was an instrumental failure or some American or Soviet space bogey. Together with the engineering staff, she would devise ways of improving the sensitivity of the equipment. Was there any pattern, any regularity in the emission? She would delegate some of the radio telescopes to examine exotic astronomical objects that had been recently detected by other observatories.

The search for extraterrestrial intelligence—everywhere abbreviated SETI, except by those who talked somewhat more optimistically about communication with extraterrestrial intelligence (CETI)—was essentially an observing routine […]

Sometimes, when the air had been laden with desert grit after several consecutive days of sand storms, she would drive up into the mountains to gain a little altitude and atmospheric transparency, get out of the car, and stare at the nearest star system. Planets were possible there, although very hard to detect. Some might be closely orbiting any one of the triple suns. A more interesting orbit, with some fair celestial mechanical stability, was a figure eight, which wrapped itself around the two inner suns. What would it be like, she wondered, to live on a world with three suns in the sky? Probably even hotter than New Mexico.

[…] Why had we received no signal?.. No extraterrestrial civilizations anywhere? All those billions of worlds going to waste, lifeless, barren? Intelligent beings growing up only in this obscure corner of an incomprehensibly vast universe? No matter how valiantly she tried, Ellie couldn't make herself take such a possibility seriously.

[…] Willie approached the command console. He nodded pleasantly to the afternoon duty officer, now collecting his notes and preparing to leave for dinner ...

“As you can see, nothing much. There was a pointing glitch—at least that's what it looked like—“ His voice trailed off as an alarm light flashed decorously on the console in front of them.

On a display marked “Intensity vs. Frequency” a sharp vertical spike was rising.

“Hey, look, it's a monochromatic signal.”

Another display, labeled “Intensity vs. Time,” showed a set of pulses moving left to right and then off the screen.

“Those are numbers,” Willie said faintly. “Somebody's broadcasting numbers.”

“It's probably some Air Force interference… Maybe they're spoofing us for fun.”

There had been solemn agreements to safeguard at least some radio frequencies for astronomy. But precisely because these frequencies represented a clear channel, the military found them occasionally irresistible. If global war ever came, perhaps the radio astronomers would be the first to know, their windows to the cosmos overflowing with orders to battle-management and

damage-assessment satellites in geosynchronous orbit, and with the transmission of coded launch commands to distant strategic outposts…

But they found the westernmost radio telescope had received the signal a full minute before the easternmost, and it soon become clear that it was an object streaking through the thin envelop of air surrounding the Earth rather than a broadcast from some unimaginably different civilization in the depths of space. Almost certainly this one was the same thing.

* * *

Briskly she entered the control area and approached the main console.

“Evening, Willie, Steve. Let's see the data. Good… Oh my, we're looking at Vega. That's a pretty near neighbor... It's not down here on Earth, and it probably isn't from an artificial satellite in a *Molniya* orbit, although we should check that… Check a few individual radio telescopes—the signal strength is certainly large enough—and see if there's any chance this is a hoax; you know, a practical joke by someone who wishes to teach us the error of our ways.”

[…] “Interferometry now rules out a *Molniya*-type orbit, Dr. Arroway.”

“Better and better. Now let's take a closer look at those moving pulses. Assuming that this is binary arithmetic, has anybody converted it into base ten? Do we know what the sequence of numbers is? Okay, here, we can do it in our heads… fifty-nine, sixty-one, sixty-seven… seventy-one… Aren't these all prime numbers?.. No astrophysical process is likely to generate prime numbers. So I'd say—we want to be cautious, of course—but I'd say that by every criterion we can lay our hands on, this looks like the real thing.”

[…]

The single paragraph was delivered to astronomical centers all over the world. In a few major radio observatories—in China, the Soviet Union, and Holland, for example—the message was delivered by teletype. As it chattered in, it was scanned by a security officer or some passing astronomer, torn off, and with a look of some curiosity carried into an adjacent office. It read:

ANOMALOUS INTERMITTENT RADIO SOURCE, DISCOVERED BY ARGUS SYSTEMATIC SKY SURVEY. EVIDENCE AMPLITUDES ENCODE SEQUENCE OF PRIME NUMBERS. FULL LONGITUDE COVERAGE URGENTLY NEEDED.

PLEASE CALL COLLECT FOR FURTHER INFORMATION IN COORDINATING OBSERVATIONS.

E. ARROWAY, DIRECTOR, PROJECT ARGUS, SOCORRO, NEW MEXICO, U. S. A.