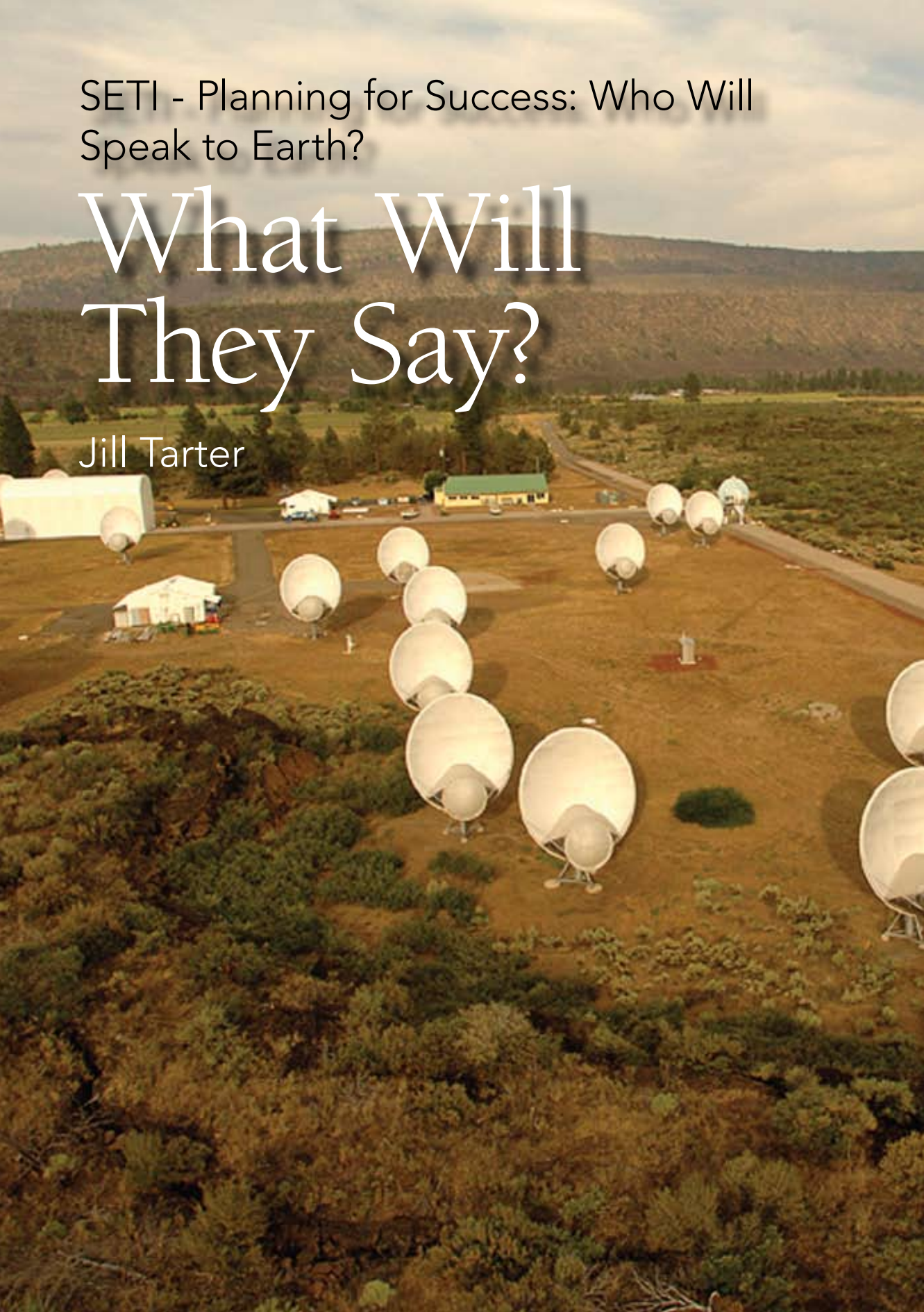
SETI - Planning for Success: Who Will Speak to Earth?

What Will They Say?

Jill Tarter



Planning for the successful detection of a signal from extraterrestrial intelligence covers the territory from making sure there is champagne on ice at the observatory to trying to figure out how to hold a global conference where all cultural, historical, religious, political, and creative traditions, that are embodied by humans on planet Earth, can be represented in a discussion of whether and how we might reply. Science fiction and the motion picture industry have provided lots of scenarios depicting the aftermath of signal detection, many are unrealistic, many are not very satisfactory, almost all reflect the political tensions around the globe at the time they were created. What should we, the scientists who are attempting to detect a signal, set out as our protocol for behavior? At the SETI Institute, we've spent some time thinking about these questions; both before 1993 when we were funded by NASA (a federal agency), and after, as we raise private and corporate contributions to continue the search efforts.

The protocol fluctuates over time, as we have more experience with false-positive detections,

as our search efforts evolve, as humans around the world becomes more aware of our exploratory research, and as technology flattens the world and offers both solutions and challenges to global communication. This chapter will give an overview of current plans, and future projects, all of which are based upon the conviction that information about the detection of a signal and any information encoded within a signal are the property of all humankind. Furthermore, it is important to state up front that in those places in this chapter where opinions are presented, usually in the absence of data, the opinionated statements strongly reflect the biases and views of the author, a scientist who continues to be impressed by the tyranny of light speed – it's currently impossible for us to get 'There' and it may be hard for 'Them' to get here.

Introduction: The Arecibo Message

In 1974, the large radio telescope in Arecibo, Puerto Rico was upgraded with both a new surface of perforated aluminum panels and a new radar transmitter working at a frequency of 2380 MHz. To mark the completion of the upgrade project, Frank Drake, then the Director of the Observatory, decided to hold a commissioning ceremony during which the radar transmitter was used to transmit a message to space. The Arecibo telescope does not point very far away from the zenith direction, and the ceremony and transmission were timed to coincide with the arrival of the Governor of Puerto Rico. This meant that the direction towards which the message was transmitted was a large globular cluster of stars called M13 that happened to be overhead at the appropriate moment, even though those stars were more than 25,000 light years away, and any inhabitants of that region would not receive the message until the year 26,974 AD! The message consisted of 1679 bits (1's or 0's represented by the switching between two closely spaced frequencies) and was repeated twice, lasting only a few minutes. More about the content of that message later, for now it is the act of sending a message that is of interest. Perhaps Prof. Drake chose such a distant target because he anticipated the possibility of negative reaction to the message transmission. And there was a lot of reaction. The most prominent critic of the Arecibo message transmission was the British Astronomer Royal, Sir Martin Ryle, who wrote to Drake and the newspapers complaining that it was "very hazardous to reveal our existence and location to the Galaxy; for all we know, any creatures out there might be malevolent - or hungry." This criticism ignores the fact that it is already too late to conceal our presence; the Earth has been 'leaking' signals into space for nearly a century, via our broadcast radio and TV signals. However, Prof. Ryle's comments do mark the inception of a discourse on the merits of active transmission vs. passive SETI listening. In turn, this discourse raises the questions: if we ever decide that it is appropriate to transmit, either ab initio or as a reply to a message received in the future, then who should speak for Earth and what should they say? These are big questions, and of the type not routinely discussed in the course of doing scientific research – but they come to the forefront very quickly when the science is SETI. Is Ryle right, was Drake putting the Earth (and you and me) in great peril by transmitting the Arecibo message?

All Intelligent Civilizations Are Not Equal

Should active transmission be a part of SETI? SETI research is currently being carried out in several locations worldwide, occasionally even in Australia. I work at the largest of these research facilities, the SETI Institute, a non-profit corporation in Mountain View, California. We have grown steadily since we opened our doors in 1984, and now typically have about 150 people working at the Institute, but only a handful work with me in the Center for SETI Research. The rest of my colleagues pursue astrobiology in the Carl Sagan Center for the Study of Life in the Universe, or education and public outreach in our E/PO Center.

In 1997, the SETI Institute convened a series of workshops that, among other things, seriously discussed the appropriate guidelines for interstellar discourse. The results of those discussions are part of a book, titled SETI 2020.

The workshops attempted to set out a roadmap for the activities to be pursued by the Center for SETI Research at the SETI Institute over the next two decades. One of the participants, Prof. Paul Horowitz from Harvard University, summed up the reality of our terrestrial situation as follows: 21st century humans have an asymmetric relationship with the universe; we are a very young technology (~100 years) in a very old galaxy (~ 10 billion years) – any technology that we can detect is going to be much older than we are, and we should follow their lead. That asymmetry led the workshop participants to these detailed conclusions :

- If or when we achieve contact with another civilization, it will certainly be more technologically advanced than we are. Contact with a less technologically advanced civilization is not now a possibility. In fact, any civilizations we contact are statistically likely to be far more advanced. When the evolution of planets and their attendant technologies require billions of years, it is unlikely that two technological civilizations will be synchronized to better than a million years.
- If it happens at all, there always has to be a first contact between two technological civilizations. Statistically, it is extremely unlikely that our first contact with an ETI civilization will also be its first contact with an ETI civilization. Thus the advanced technology we detect will have experienced this type of encounter many times before. It already may have established a galactic protocol for information interchange, to which ab initio transmissions by Earth will have no chance of adhering. Thus we justify our asymmetrical listen only strategy by recognizing our asymmetrical position amongst galactic civilizations. We are among the youngest!
- Transmitting is a more expensive strategy than receiving. Within the next two decades, the parameter space explored for signals can be extended by the compounded growth rate of many technologies. Transmissions could benefit from these same exponential improvements in technology, but with the limited resources likely to be available during this same period, we could not add significantly to the high power of our leakage radiation. As that leakage abates or becomes more noise-like this argument loses its force. Transmission will not be rewarded for decades, perhaps centuries, because of the great distances and round-trip travel times for signals. Our resources are constrained, and it is thus prudent to pursue a passive program of exploration that might provide a positive result within years.

  So far, this has all been a set of relatively straight forward scientific arguments. The SETI Institute has had no difficulty adopting these points of view, and they guide the approach that we take in our SETI observing programs today – listen only. But the participants included one more bullet that moves beyond strictly scientific argument, and that's where things get interesting.
- Transmission is a diplomatic act, an activity that should be undertaken on behalf of all humans. We lack the cultural maturity to accomplish such a cohesive action. Some Working Group participants felt strongly that this active strategy should not be embarked upon unilaterally, without consultation and consent. While most of the participants believed that transmitting now would be merely harmless and wasteful, a few members felt that transmissions should not be carried out without international consultation and approval by appropriate international administrative bodies.

Well, I guess that NASA never read the SETI 2020 report. On February 4, 2008, to celebrate the 50th anniversary of the founding of NASA, and the 40th anniversary of the day the song was written, NASA used a Deep Space Network transmitter to send the Beatles' song "Across the Universe" in the direction of the North Star, Polaris. Again this message only lasted a few minutes, but did NASA Administrator Michael Griffin join with Frank Drake in putting our planet in permanent peril? Not really, these short duration stunts have literally no probability of being intercepted. Did Administrator Griffin undertake this transmission on behalf of all humans? I don't remember being consulted, were you? And that's the more serious question.

The SETI 2020 workshop participants suggested that 'international consultation and approval' should be sought prior to undertaking a transmitting strategy, and they assumed that such approval would come from 'appropriate international administrative bodies'. In much earlier scientific discussions conducted under the auspices of the International Academy of Astronautics and the International Institute of Space Law, scientists, diplomats, and lawyers interested in SETI had drawn up an informal protocol with the impressive title "Declarations of Principles Concerning Activities Following the Detection of Extraterrestrial Intelligence " which also presumed a measure of international approval. In that protocol, the text of Article 8 stated "No response to a signal or other evidence of extraterrestrial intelligence should be sent until appropriate international consultations have taken place. The procedures for such consultations will be the subject of a separate agreement, declaration or arrangement." Most scientific teams conducting SETI observations adopted this protocol as their own policy. In 2000 the United Nations Committee on the Peaceful Uses of Outer Space was informed of this protocol, and documents were formally filed away, perhaps for action at some future time. Today, we still have no global form of governance, there are no appropriate international administrative bodies that can speak for all humans. Nevertheless, in ways not imagined even a decade ago, all humans may soon be able to speak for themselves using social-networking technologies that are rapidly becoming global in what appears to be a viral, and unstoppable spread. Before too long, it will be possible to have a global conversation with all cultures, traditions, ideologies, and points of view participating. And note that it will be YOUR generation that is having this conversation, not MINE. I can raise the issues in this chapter and encourage you to prepare to answer them, but it is you and the rest of the younger global inhabitants that will need to feel your way forward towards an outcome that represents all humans. It will take a while, and I think that technology will continue to assist the process in unforeseen ways (Twitter and its descendants might do this), but you probably have time to be deliberate.

Although it could happen tomorrow, detection of a signal that raises the question of a reply will probably require a lot more searching than we've done to date. And no, I don't think that they will arrive in shiny spaceships any time soon (and there's no solid evidence that they've done so in the past either!) But you might be interested to know that at this very moment, messages are deliberately being broadcast into space by dozens of entrepreneurs, who have acquired access to decommissioned telecomm transmitters around the globe. What messages are they sending? The transmissions are the personal wisdom, philosophies, hopes, fears, and fantasies of those individuals that the various marketing web sites have persuaded to part with some cold hard cash. I'm not kidding; search the internet for yourself. But I wouldn't waste your money. There is little chance that your message to the cosmos will be received. Those transmitted signals are relatively weak, and they are far too ephemeral to represent a realistic active-SETI transmission program. It is the short-lived nature of these and previous transmission activities that convinces me that a realistic, active-SETI program is far in the future, even if a global conversation should conclude that it's a good idea.

Humans, at this stage of our evolution, aren't very good at conceiving and fulfilling five-year plans, and our success with 100 or 500-year plans is pretty pathetic! If we Earthlings plan to conduct a systematic, active-SETI program, it will be necessary to keep at it for many thousand years, or more. That's because a transmission program that lasts n years will generate signals that travel through space, at a rate of one light-year (~ 9.5 trillion kilometers) per year, growing weaker as they propagate and spread out, until they reach a potential recipient who is d light years away. The signals will be detectable by that recipient for only n years. That means that during the evolutionary history of the potential recipient, they must be looking at Earth, with the right receiving tools, during the n-year window that the signals present themselves. Unless n is a very big number, the chances that the recipients are looking Earthward when our signal arrives will be very small (see Figure 1).

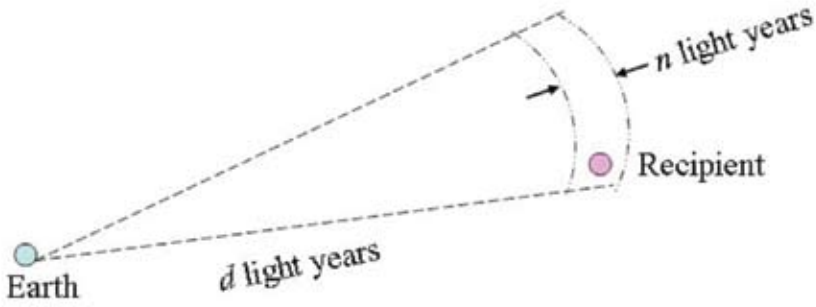


Figure 1: Diagram of a signal beamed towards a distant receiver, lasting only n years.

Therefore, I think that active-SETI programs will have to wait until humans "grow up" enough to be able to conceive and execute very long term projects.

Are other scientists dealing with these kinds of questions? A close parallel in terms of moral, ethical, and risk-appraisal discussions are the very active debates now taking place within the small portion of the scientific community involved in Planetary Protection. Among the astrobiologists at the SETI Institute, there are some researchers who worry about the potential for forward and backward contamination of life on Earth due to the planned robotic and human explorations of other bodies in our own Solar System. Although we now contemplate the possibility of microbial life in the briny oceans beneath the frozen ice surfaces of the giant moons of Jupiter (Europa, Ganymede, and Callisto), and perhaps even Saturn's tiny moon Enceladus, the focus of concern over contamination is primarily Mars. Might microbes brought back from Mars threaten life on Earth, or might terrestrial organisms brought to Mars by human and robotic explorers contaminate that planet and threaten any native Martian life forms? If life exists in liquid aquifers beneath the frigid desert surface of Mars, might it pose a danger to life on Earth?

Do humans have the right to 'terraform' Mars in order to make that planet more habitable for us? One way to improve the chances for survival of the human race, and protect it against a future, civilization-ending impact from a giant asteroid might be to spread humans to at least one other planet. We're looking hard at Mars as that destination. Just because we can do so, should we do so? In truth, we've already made similar decisions for planet Earth. We are routinely destroying rain forests and other habitats in order to benefit some groups of humans economically, at the expense of an uncounted number of species of life that we have yet to discover in those wild habitats. If we eliminate unique and undiscovered forms of life on this planet, then there should be no reason not to do the same on Mars. Or if we decide to preserve Martian life forms because they are precious, then shouldn't we preserve precious, as yet unknown, life forms on Earth? These are not questions that any of my colleagues and I debated when we were in graduate school, but scientific exploration is taking us in new directions, and as a result we need to expand the boundaries of what it means to do science.

How Do You Speak To An Alien?

Let's return to the 1974 Arecibo message. A nice explanation of the components of the Arecibo message appears on the Wikipedia web site http://en.wikipedia.org/wiki/Arecibo_message. As previously mentioned, the message consisted of 1679 bits, and the transmission was repeated twice. The repetition is important, because it lets the recipient know that they got it all. The number of bits is important because it helps to decode the message. 1679

is the product of two prime numbers 23 x 73. Our concept of numbers and mathematics encourages us to think that any extraterrestrial technology will have a way of counting, and that numbers will be prime in their numbering system as well as in ours. On this planet we have now documented an isolated Amazonian community whose language and thought patterns do not include this sort of detailed numerology, there are no words for the quantity of objects or specific numbers. But these people have not constructed transmitters or receivers for interstellar communication. Our bias is that mathematics will be universal for any technological civilization, but we should try to remember that it is in fact a bias. Our stereoscopic, binocular vision system provides us with depth perception, and the evolution of our brain and our training allow us to interpret two-dimensional representations, or abstractions of information. This may not be a universal capability of all technological civilizations either, but we find it hard to imagine any other way of perceiving detailed information, and so the Arecibo message incorporates this bias as well. What can you do with the product of 23 and 73? You could take a linear string of 1679 bits and rearrange it into 73 columns and 23 rows, or 73 rows and 23 columns to make a two-dimensional picture, using two different colors for the two different binary bits. In the case of the Arecibo message, the choice of 23 columns (see Figure 2) yields a definite pattern, even if not an obvious message, whereas a 73-column display looks pretty random.

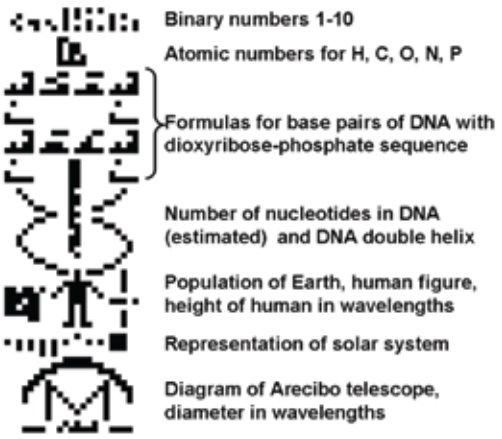


Figure 2: 1974 Arecibo message arranged in 2-dimensions, and decoded.

So what did the Arecibo message say? In addition to assuming that we have mathematics in common with the recipients trying to decipher this message, the message also made use of the fact that anyone receiving the message would have had to detect it with a radio telescope and would realize that the message had been transmitted at a particular radio frequency, or wavelength (wavelength = c/frequency = 12.6 cm, where c is the speed of light). The wavelength therefore is a shared unit of measurement, a common ruler. So the message starts out (if your custom is to read from top to bottom) with a counting lesson, showing the graphical, binary representation of the numbers 1 to 10. These numbers are then used to give the atomic numbers of the biogenic elements H, C, N, O, P – the stuff our DNA is made from! Next comes the formulas for the base pairs of Adenine, Thymine (A-T), and Cytosine, Guanine (C-G) along with the dioxyribose-phosphate backbone of DNA, and a representation of its double helix structure, and an estimation of the number of nucleotides in the human genome (not yet sequenced when this message was sent). The population of humans on Earth (only 4 billion in 1974), a human stick figure with a measurement bar indicating the human is 14 wavelengths tall. A cartoon of our solar system, with the third planet from the Sun offset towards the human, indicates where the message came from. Finally (or first if your custom is to read bottom up) the spherical Arecibo telescope and the transmitted message rays are depicted with a blatant brag that it is 2430 wavelengths in diameter. A pithy message, perhaps not easily understood; also perhaps not what you might have chosen to tell others about us. We've made a few more attempts, not with transmitted signals, but with greeting cards carried by spacecraft.

In 1972 and 1973, NASA launched the Pioneer 10 and 11 spacecraft to explore Jupiter and Saturn. But they didn't stop there; these spacecraft had sufficient energy to allow them to leave the solar system and travel towards the stars (slowly – it will be millions of years before

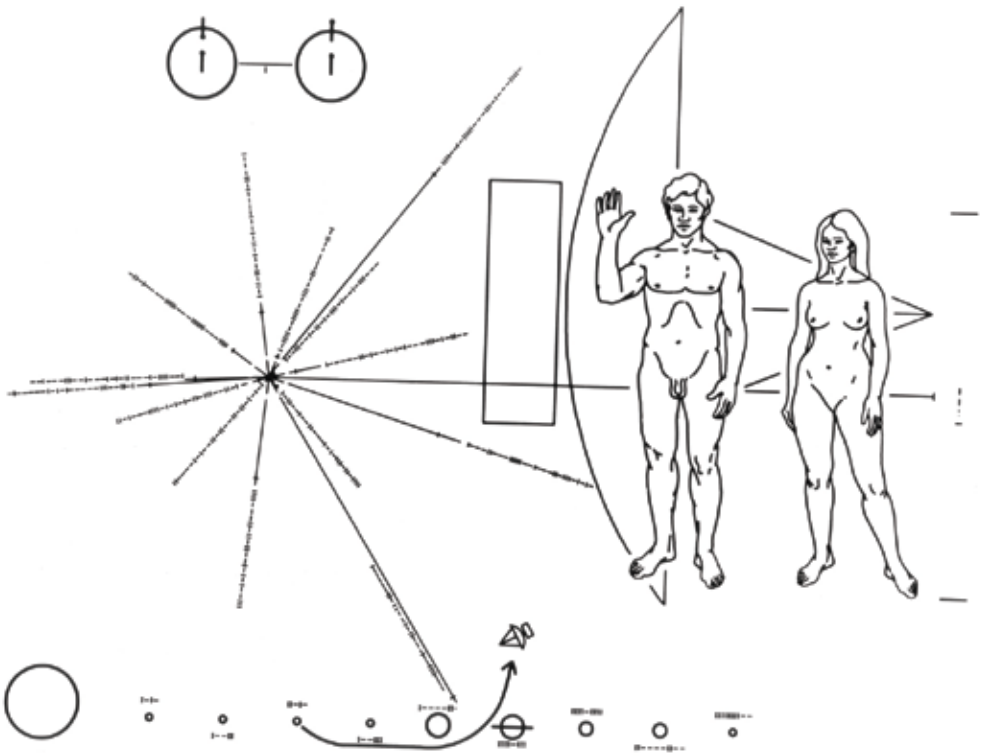


Figure 3: Plaque attached to Pioneer 10 and 11.

either vehicle approaches a star). Once it was understood that these objects would travel into interstellar space, Carl Sagan convinced NASA to include a plaque on each to send a message to any distant technologies that might happen to discover them (see http://en.wikipedia.org/wiki/Pioneer_plaque). These plaques include a handy ruler, though this time it isn't based on the frequency of a radio transmission, but rather the frequency of the fundamental spin-flip transmission of the hydrogen atom (1420 MHz or a wavelength of 21 cm) which is the most abundant and simplest element in the universe. Figure 2 has a diagram of the space-craft with humans beside it for scale and their height given in wavelengths. The human male has his hand raised in greeting (or perhaps it means something else to those who might eventually find it). The solar system is shown with an indication of the spacecraft's trajectory. The 14-legged spider is actually a map that says where and when in the galaxy this craft was launched. The key to deciphering the map is to realize that radio astronomical pulsars each have unique periods for their pulses, and that with age pulsars spin down and their pulse rates slow. The directions from the map center show the radial directions away from Earth in which the pulsars lie, the length of the line represents their distance, and the binary code along each line gives the precise pulse period (in time units of 1/frequency = 7 x 10-10 sec) at the epoch of spacecraft launch. There is a 15th leg, without a binary period, and that shows the distance and direction from Earth to the Galactic center. In the early 1970's much of the public and media seemed more concerned with the naked bodies on this plaque than with the content of the message!

In 1977 NASA reused this pulsar map, and the hydrogen line as part of the covers for a two golden records containing the sights and sounds of Earth that were attached to the Voyager 1 and 2 spacecraft (the offend-ing naked humans occur only in the encoded information on the record itself, see http://

en.wikipedia.org/wiki/Voyager_Golden_Record). The Voyagers also left the solar system after completing a grand tour of the outer planets, and since they are traveling faster than Pioneer 10 and 11, they are now the most distant objects made by humans, and their trajectories will take them to the vicinity of nearby stars in less than 100,000 years. Since a record afforded much more opportunity for including information about us, a committee chaired by Carl Sagan was created to decide upon the content. The record contains greetings from the children of Earth in 55 different languages, as well as a message of peace from the then President of the United States, Jimmy Carter. 90 minutes of music, believed by the committee to be a fair representation of the musical history and traditions of Earth, are included for the discovers' listening pleasure (should they have ears or other appropriate acoustical sensors), as are dozens of natural and human-created sounds of the planet. 115 drawings and photographs are encoded as analog signals on the record (the record cover explains how to recreate the images), and these can be viewed at http://voyager.jpl.nasa.gov/spacecraft/sceneearth.html. In true form, the committee created an edited, approved, and highly biased view of life on Earth; it is hugely biased towards humans, with little regard for the enormously important and diverse microbial community with which we share our world, or the other animals, but then it is the humans who built the spacecraft. The image set contains no poverty, hunger, disease, war, pollution, deforestation, overcrowding, or any other indication of a less than perfect world. We can expect that if the Voyagers are ever found by another technological civilization, and the contents of the record are ever deciphered, they will probably realize that we were putting our best foot forward. Quite apart from the technical difficulties, and the truth in advertising issues, the images that are included tell us humans a great deal, but they require a shared contextual background for interpretation. We take that context for granted, indeed it is very difficult to ignore or unlearn what it is we've evolved to interpret. Perhaps young children have the best capacity for ignoring what they 'know' and seeing these images as others, who are not us, might do. As an example take one particular image of sprinters in the Olympics, rather than seeing the image as depicting great athletic prowess, a child might ignore the notion of distance perspective and see instead two species; the big and the

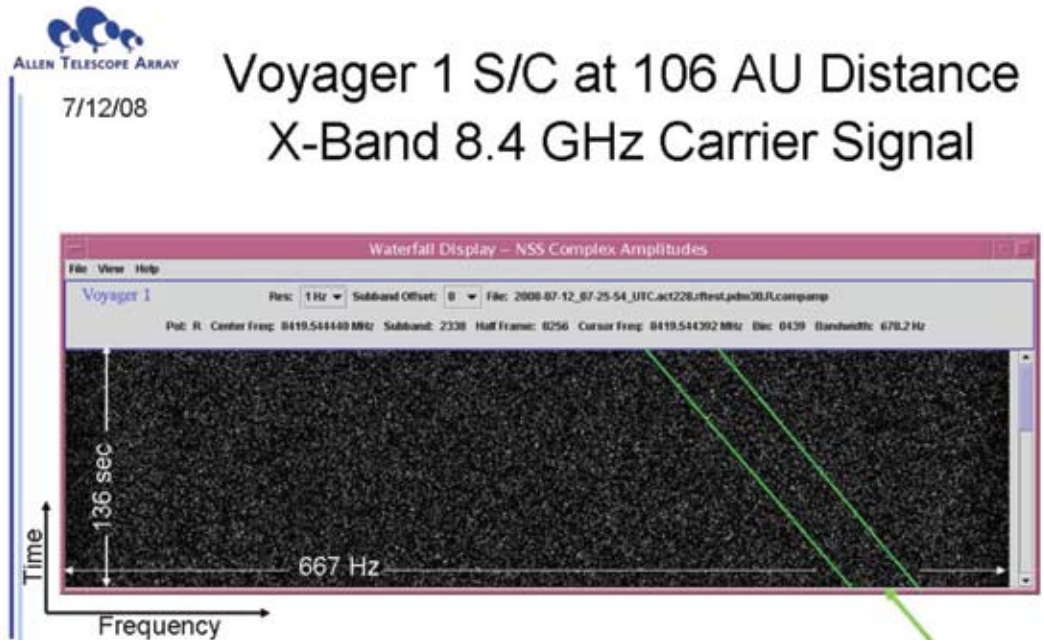


Figure 4: Successful detection of the carrier signal from the Voyager 1 spacecraft at a distance of 106 AU

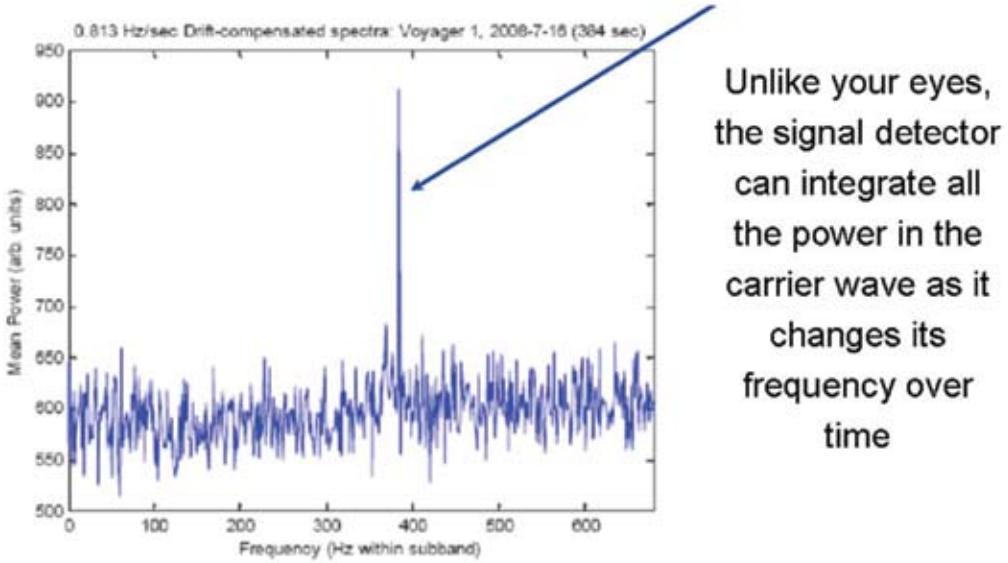


Figure 5: Detection of Voyager 1 signal with software detection algorithm.

small. The big species is strange because it is not quite bilaterally symmetric; each individual has only 1 ½ lower limbs, and it isn't always the same side that is missing half a limb. And of course most children can delight in the fact that this home planet has invented anti-gravity, because none of the big species is touching the ground! As the committee members confessed, this exercise was as much an effort intended for humans as for extraterrestrials. Billions of years from now, when the Sun has evolved into a red giant and the Earth has been consumed within its atmosphere, the Voyagers will preserve this flattering encapsulation of the aspirations of those who built these craft.

At the SETI Institute, we have another relationship with Voyager 1 – we use it as our fiducial or standard candle on the sky. Because it is so far away, the carrier signal that it emits to enable NASA to track its motion, and downlink its data, arrives at the Earth as a very faint signal moving on the sky at nearly the same rate as the distant stars. In fact that's what we might expect a signal from ET to look like, and we've built very sensitive signal detection equipment to detect such emissions. As we have been commissioning the Allen Telescope Array over the past year, we've pointed our 42 dishes at this spacecraft repeatedly to insure that our beamformers and control and detection software are all working like they should. Figure 4 presents a 'waterfall plot' showing a small piece of the spectrum surrounding the Voyager 1 signal as a function of time. Each point on this plot represents a 1 second observation with spectral channels that are each 1 Hz wide. The Green lines are intended to focus your eye in the right place. This signal is hard to detect with the naked eye, but Figure 5 illustrates that it is easily detected with the SETI special purpose signal detection software – assuming everything is working properly. Some day we hope to detect such a signal from someone else's technology.

Earth Speaks

In 2009, the SETI Institute participated in the Kids Science Challenge contest [http://www.kidsciencechallenge.com/], in which young students were challenged to help us figure out ways to make our search for ET better. The winner, Kamau Hamilton a 6th grade student from New York City, suggested that extraterrestrials might not speak English, so that we should plan on communicating with the sounds of Earth. He was too young to have

known about the Voyager golden record, but he independently came up with the same idea. We invited Kamau to record sounds of Earth that hadn't existed in 1977, and we used his visit to the SETI Institute to launch a web-based project we've been thinking about for a long time. This is a first tiny step towards holding a global conversation to answer the questions: who will speak for Earth and what should they say? My colleague, Douglas Vakoch a social scientist, has been wondering whether there are any cultural universals (ideas, practices, memes) that can be found in every human group around the globe, now and perhaps throughout time – things that really belong in a message to ET if we want to define who we are. Earth Speaks [http://earthspeaks.seti.org/] is a web site on which we've posted Kamau's sounds of Earth. Now people around the world are encouraged to contribute their own sounds, peculiar to their locality, and their ideas of what we should say or would like to say in a message to an extraterrestrial to this web site. We don't have any plans to actually transmit these messages, rather the content of these submissions are being categorized and tagged with key words and with region of origin as part of a research project to uncover cultural universals. The posts have been fun to read, one of my early favorites ended with "… Also, don't kidnap us and poke us. We hate that."

Now that you have finished this article, you can help us plan for success. Please go to the Earth Speaks website and let us know what you think should be contained in a message from humans to extraterrestrial intelligence.