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Jill Tarter

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INTRODUCTION

Marie Clement

Graduate Student

Good evening, and welcome to tonight's Jessie and John Danz endowed public lecture with Jill Cornell Tarter. I am Marie Clement, a graduate student in the chemistry department and a member of the student organization, Women in Chemical Sciences. Before we introduce tonight's speaker, I want to share some background about the generous gift to the University of Washington that allows the Graduate School to host the series: the Jessie and John Danz Endowment. This visiting professorship program was created in 1961, with a bequest from the estate of Mr. John Danz. When he was just four years old, Mr. Danz immigrated to Seattle with his family from Russia in 1881. As a youth, he grew up with a deep understanding of hardship and poverty. After working in a variety of positions, including as a newsboy, cow hand and traveling merchant, Mr. Danz entered the motion picture business and became a very successful businessman. Always regarded as an independent and unorthodox thinker, John Danz was self-educated and read widely and liberally. He was fascinated by scientific developments and liberal religious movements, especially humanism. In creating this endowment, his goal was to bring to the University of Washington distinguished men and women who have concerned themselves with the impact of science and philosophy on man's perception of a rational universe. Mr. Danz's wife, Jessie, shared this vision and augmented the endowment with additional gifts throughout her life. Joining us tonight is the granddaughter of Jessie and John Danz, Carolee Danz.

So I'd also like to take a moment to thank the Graduate School and the UW Alumni Association for putting this event together. All of their hard work makes this lecture series look easy. And a special thank you to the astronomy and astrobiology departments for contributing their time as unofficial sponsors to this event. Thank you. I'd also like to give a shout out to the high school group that we have here from I think Port Angeles or Port Archer. I'm not sure. Anyway, it's great to see young minds here. It's really great. Yeah.

So our speaker tonight is Dr. Jill Cornell Tarter. Jill Tarter holds the Bernard M. Oliver chair for SETI, the Search for Extraterrestrial Intelligence at the SETI Institute in Mountain View, California. Tarter received her Bachelor of Engineering Physics degree with distinction from Cornell University and her master's degree and Ph.D. in astronomy from the University of California Berkeley. She served as project scientist for NASA SETI program, the High Resolution Microwave Survey, and has conducted numerous observational programs at radio observatories worldwide. Since the termination of funding for NASA SETI program in 1993, she has served in a leadership role to secure private funding to continue this exploratory science. Tarter's work has brought her wide recognition in the scientific community, including the Lifetime Achievement Award from Women in Aerospace, two Public Service Medals from NASA, Chabot Observatory's Person of the Year award, Women of Achievement Award in the Science and Technology category by the Women's Fund and the San Jose Mercury News and the Tesla Award of Technology.

She was elected an AAAS Fellow in 2002, and a California Academy of Science Fellow in 2003. In '04, Time Magazine named her one of the 100 most influential people in the world, and in '05, Tarter was awarded the Carl Sagan Prize for Science Popularization. In 2006, Tarter became a National Advisory Board Member for the Center of Inquiries Office of Public Policy in Washington, DC. And she was also awarded the 2009 TED Prize for sparking global change, as well as being the inspiration for the main character of Carl Sagan's novel *Contact*. So, yeah, that's a lot. So yeah, please join me in welcoming Dr. Jill Cornell Tarter to Seattle.

FEATURED SPEAKER

Jill Tarter

Bernard M. Oliver chair for SETI

Well, thank you. Thank you so much. And although he's not here, I'd like to thank Dean Eaton and Yvette Moy, the director of the series and Marie Clement for inviting me to present a talk to you tonight. As Professor Woody Sullivan's writings have made abundantly clear, the pioneering work of Karl Jansky and all of the radar research that was done during World War Two provided the 20th century with some incredible tools, that is radio telescopes that could try and answer, old, old human questions: Are we alone? So, I've been really privileged to spend a scientific career helping to try and build new tools, better instruments that could perhaps, find this answer. We haven't succeeded yet. But we're trying hard. And I'd like tonight to tell you the story of that search and its rationale. And I'd also like to challenge all of you to change your perspective, your perspective about who you are, and how all of us fit into the universe. And I think that it's really important to our long-term future, that we all do that.

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So, our collective story began billions of years ago, 3.8 billion years, in a, in a cosmic explosion of unimaginable energy and density. Our Milky Way galaxy was born about 10 billion years ago. And you and I are intimately connected with those long-ago times and places because it actually takes an entire cosmos to make a human. Right? We humans trace our lineage not just back through the centuries and generations of our families, not just back through the millennia of human civilization, with our buildings and our art and our experiments and different kinds of governance. Not just back the millions of years since we branched off from the great apes, not just back the 2.4 billion years, during which the Earth's atmosphere has been perfused with oxygen, thanks to the labors of cyanobacteria, not just back to the origin of our solar system and our sun, about 5 billion years, but billions of years before that, to the explosion of a massive star, which left detritus in the space between the stars, such as this example of a modern supernova remnant, this detritus that could be recaptured and recycled into a new generation of stars and planets and perhaps life. It's taken us humans millennia to piece together this story.

And today we're still on that journey to try and figure out who we are, why we are and of course, who else there might be. We now comprehend ourselves as living on a very fragile island of life in a universe full of possibilities. And we're just now beginning to appreciate the astonishing possibilities elsewhere, as well as here on Earth. And we're beginning to understand that all of these possibilities have a lot to say about our future and how that future turns out may well depend on us embracing and understanding very deeply this story.

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So extremophiles, organisms that live in environments that you and I could not possibly tolerate, places which, when I was a student, I was told no way. No way there could be any life. In boiling battery acid, frozen and ices, deep beneath the, the ocean, on the floor of the ocean where the crust is cracking open and there's superheated steam and high pressures and no sunlight and kilometers down into the crust of the planet. But in fact, extremophiles have shown us that life can flourish in all of these niches and many more. And it's evolved to be extraordinarily well-suited to these environments. And it flourishes there. And this study of extremophiles over just the past few decades is leading us to wonder whether out there in the cosmos, there might be more habitable real estate than we once might have imagined. And so we're beginning to explore those other environments. And as we pry open the door to the cosmos, we're trying to test these various possibilities. So here, here's Mars, the planet Mars, the surface of that frozen desert up close and personal. Brought to you by the Curiosity Science Lab. Now, Curiosity was not built to find life on Mars. It was built to tell us whether the conditions that we think are necessary for life might ever have existed on this planet and perhaps still exist today somewhere beneath this hostile frozen desert.

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Now, we know that early Mars was wetter and warmer for significant periods of time. And perhaps as life was getting started on this planet, maybe life got started on Mars. Or maybe there's even a possibility that we're Martians. Seriously, I'm not kidding. Life might have started early in the history of Mars when it was wetter and warmer and then in the early solar system, things were not quite as docile and well-controlled as they are now. And rocks, big rocks, crashed into each other. And a large enough impact on Mars might have launched a small rock containing microbial life that could have survived for millions of years, as it traveled between the planets and was finally captured by the Earth's gravitational field. And maybe that seeded life here. It's a possibility. We certainly do know that Earth and Venus and Mars exchanged rocks early in our history. We have pieces of Mars sitting in our sample labs across the country. We know they’re pieces of Mars because of the nature of the gases that are trapped inside those rocks. So, Mars is one possibility and if it doesn't turn out that life ever started there, maybe we have to look farther out in our solar system. And not just to planetary surfaces, but to the giant moons, the giant moons of Jupiter. So Europa, about the size of our moon, Ganymede, Callisto, all of which have frozen surfaces. But beneath that icy crust, we think there are salty, liquid water oceans. If life started in an ocean here, four and a half billion years ago or a few billion years ago, perhaps life has also started there. Going farther out, there's this marvelous large moon of Saturn, Titan, which actually has liquid lakes on its surface. Now, it's so cold that those lakes aren't water. They're organic ethane, for example. But maybe organic chemistry is very happy there. And maybe at a slow rate, there could potentially be some chemistry that's turned into biology. We'd like to explore those lakes. And even tiny little worlds like this. Enceladus, another icy moon. Who would have thought that such a place might be of interest? But indeed, it's extremely exciting. From the south pole of Enceladus, we see these cryovolcanoes, these eruptions of ices, and maybe something else from beneath the icy crust where there is also even on this small world, a liquid ocean. And we think that this same kind of thing might even be happening on the Jupiter's moon, Europa. And if these plumes are predictable, and can be relied on, perhaps, instead of having to figure out how we're going to melt or drill or penetrate the icy crust of the moon and do it in a way that’s sterile so we don't bring life with us as we're going to investigate whether there might be any life there, maybe we could just fly through these plumes and collect some of that material. So that's an exciting possibility that, that scientists are beginning to explore and think about, could this be an easy way to explore the oceans under some of those frozen worlds? We have a lot of possibilities in our solar system and there are possibilities beyond.

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What about planets orbiting other stars? Well, before 1995, we didn't know whether there were any planets orbiting any stars like our sun. We had found a couple of bodies in orbit around a dead star, the whole, the remains of a massive star, a pulsar. But in terms of normal garden variety, what we call main sequence stars, we hadn't a clue about planets until 1995 and we found the first one and it was a huge surprise. Right? Astronomers got a big wake up call that day, when we understood that a planet about as massive as Jupiter was circling a star, so close to the star, called 51 Peg, that it only took 4.3 days to complete an orbit around the star. That's pretty close. Takes Earth a year to go around the sun. So, that was our first aha moment, because, you know, we've been making extrasolar planetary system models in our computers for quite a while. That was pretty interesting. We put the input parameters in and we looked at what came out and all the planets were going around in nice well-behaved orbits in a flat plane and they had the gas giants on the outside and the little rocky planets on the inside. And so we were fully expecting to find extrasolar planetary systems that looked very familiar. 51 Peg didn't look anything like that. And it is a fantastic reminder that when you have an example of only one, you better be very careful how you extrapolate to the realm of possibilities from just that one example.

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So this is a spacecraft called Kepler, which we launched in 2009. And ground based studies had been routinely, once 51 peg was discovered, 51 Peg had been routinely telling us about massive planets in orbit around nearby stars. But we launched the Kepler spacecraft to look for small Earth-sized planets. And it does it by staring at a group of stars in one location on the sky about 100 square degrees. So those rectangles represent where the Kepler spacecraft is staring or was staring above the plane of the Milky Way where there are lots of stars. And it would be like I stared at all of you individually at the very same time and waited for one of you to blink. I saw that. Well, it turns out that stars might blink if you looked and measured their total brightness carefully enough if a planet passed in front of the star in its orbit around the star, and Kepler was designed with a CCD movie camera that has 93 million pixels, and it stares continuously at 170,000 stars. And it turns out that indeed, a lot of those stars blink. So, in the time that Kepler was active in its main mode of observing, up until a little more than a year ago, Kepler had discovered thousands of exoplanet candidates orbiting the 170,000 stars and with ground based surveys and statistical methods 100, or I’m sorry, 1,019 of those have actually been confirmed as being actual real, we know they're exoplanets, and most of the others will turn out to be exoplanets as well. And there are a few of them that are of special interest to those of us who think about life beyond Earth. And it represents a real chauvinism that we have.

So life as we know it requires liquid water. So we are particularly interested in planets that are located at just the right distance from their parent star so that if they had an atmosphere they would be at the right temperature to support liquid water on their surfaces. And depending on how you exactly define that distance, on the order of 100 or so planets that are in the habitable zone, think of it as the Goldilocks region surrounding their stars. And so these might be of special interest to astrobiologists, and SETI scientists. In fact, astronomers can't stand it now that we've got more than one example, we're trying to make top 10 lists, right? And so you can go to a site that's run by the University of Puerto Rico and we're trying to take information about exoplanets, which we don't see. Ever seen a picture of these? All artists conception, all imagination, and about which we may know, their size and their mean density and we know the distance from the star and we know the type of star. And so we start speculating about how Earth-like these planets might be. And it's fun to do and you should keep an eye on this kind of thing because it isn't going to be very long, I think, before we'll know enough about some exoplanet around a nearby star to begin thinking that it's really another Earth. And I'm particularly proud to talk about a discovery made by one of my colleagues at the SETI Institute Elisa Quintana, who found the first Earth sized, Earth sized planet in the habitable zone surrounding its star, but that star's smaller than the sun so the habitable zone is closer to the star than the habitable zone in our solar system which runs roughly between the distance of Venus and Mars. So Kepler 186f is much closer to its smaller star, but could be habitable. It's a nice open question, something to keep our eyes on.

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And, as I said, when you have an example of only one, you have to be really careful about predicting other examples and not letting your biases totally give you a wrong result. So one of the great things about Kepler is that it's found not only stars that have planets around them, but it's found stars that have planetary systems, multiple planets. And now we get to look at all these other examples of ways to make planetary systems. And it's something sometimes like making sausage, it's not very pretty, the details get a bit messy. And you know, it's interesting, planets don't always stay where you make them. They have a tendency to wander in and sometimes they wander out. So having all of these dynamical examples is allowing us to learn an enormous amount about how we make planetary systems and that example of one is also a really good thing to keep in mind when we start talking about life. Because we have only one example, we have life as we know it, and it's all related on this planet. And so we have to make sure that we don't allow our biases to constrain our thinking about possibilities too strongly.

Of course, we have to use what we know to make reasoned guesses and advances. We can't just ignore what we know and say anything is possible. But we really need to think about life in a far more organic, systematic connected manner than we tend to. We now have a pretty darn good understanding at the molecular level about how evolution actually works. Yeah, our language is still loaded down with phrases like the ascent of man and the pinnacle of evolution, and it's all wrong. It is all wrong. And it is a position of privilege that nature actually does not share with us. We are a part of an enormously complex tree of life and we're only one small part and there is no sense in which evolution has worked to produce us. We have evolved to suit an environment just as all these other forms of life have done. So I challenge you right now, I challenge you to think about what it means to say we, we are here. And now, that really mean? Well, we're here, right? We know that, and you use Google Earth. And now you're comfortable with understanding that you're here in Seattle, the Pacific Northwest, and if, if you weren't the altitude of low Earth-observing satellites, you'd see yourself here. And since 1968, when Bill Anders took this Earthrise photograph as he was coming over the backside of the moon, in an Apollo spacecraft, we've really begun to understand that we are here on a planet in space. And this actually, I think this is the iconic image for the whole environmental movement. And it is the right way to see ourselves. But let's continue, the Cassini spacecraft, look back through the rings of Saturn and it saw us here, there's a little dot there. And we're all there. All of us. Right? And before that Voyager One, as it was going on its way out of the solar system looked back and it saw this pale blue dot, immersed in Zodiacal dust. That's us. We're here. And we're here. The outskirts of a great spiral galaxy.

Now this is not a picture of the Milky Way galaxy. Nobody's been outside to take one. But it is a comparable, as they say in real estate. This is a comparable. So we're here, not even in the center, we're out at the edge. And we now know that we are one, only one, of something like 400 billion stars in this galaxy. And our galaxy is here. Now that is a real image taken by the Hubble Space Telescope, the Deep Field, staring for hundreds of days at a blank spot in the sky. But it isn't so blank is it? All of those bits of light are galaxies, galaxies filled with hundreds of billions of stars, and ours is one of them. And as you look at this picture, remind you that as we look farther out in space, because of the finite speed of light, we're actually looking back in time. And so, that means that we have to say our now also has this bigger context that I started the story with, the billions of years through which our universe has evolved and will continue to evolve. And we come to the realization and only very recently that all we can see, and that what astronomers have been studying for 400 years since the invention of the telescope, amounts to about 4% of the mass energy of this universe. The other 96%, well we call it dark matter, dark energy. Here's a clue: Dark is just a code word for we don't have a clue. We don't know what this stuff is, we can infer its existence from our observations, or perhaps it's going to turn out that fundamentally, we don't yet understand gravity in enough detail.

But what I need to impress upon you right now is that we are part of a larger story. We are in fact, the living and breathing products of a 10-billion-year lineage of wandering stardust.

Okay, you and I we’re what happens when primordial hydrogen and helium evolves for so long, it begins to ask where it came from. That's us. We are stardust, we are made of star stuff. And in this context, I think it makes ever more sense to ask, is it really just us? Are we really alone in this colossal sea of matter and energy and chemistry and physics? Is it? Well with homage to a pretty good science fiction film about 15 years ago, if we are, then it seems like an awful waste of space. But what if we're not? What if somewhere out there somebody else is asking, and hopefully answering these same kinds of questions. What if they look up at the sky and see the same stars, which is from the other side? Could it be that the discovery of another older culture out there in the cosmos might be what it takes to inspire us to find a way to survive, to survive our own increasingly uncertain technological adolescence.

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So 50 years ago, this human journey of exploration, to find answers to these big questions, took a turn, started down a new path with these radio telescopes and the exploratory science that we call SETI, the Search for Extraterrestrial Intelligence, began using radio telescopes. And today we continue with radio telescopes, but we also use optical telescopes. And what are we doing? We're listening and looking for evidence of somebody else's technology. Technology is our proxy for intelligence. If we find some evidence of technology out there that's modifying its environments, in ways that we can sense over the vast distances between the stars, we're going to infer, at least at some time, the presence of intelligent technologists. Let's think about time. So we're using the tools of the astronomer to search for someone else's technology and to some greater or lesser degree, our technology is detectable by a more advanced technology out there. And we might detect a vast communications network, or some huge shield directed to guard against asteroid impacts, or something totally unforeseeable might generate signals that at radio and optical wavelengths if we searched systematically enough, we might find.

But it's also true that technologies change over time, the laws of physics and chemistry, we don't think they change. But what we understand of them changes and our ability to sense them changes. And so in fact, what we're doing today, the best we can with our radio and optical telescopes may in fact, be obsolete in terms of some advanced extraterrestrial technology. I mean, after all, this is the 21st century, and they may be using zeta rays. But in the 21st century, we haven't yet discovered zeta rays, much less built zeta detectors. Haven't done it, can't do it right now. And if that's the way other technologies are communicating across interstellar distances, then what's our strategy? Our only strategy is to do what we know how to do, and hopefully use that as part of the process of staying around and surviving to become older and then discover zeta rays and begin to them. So in SETI we always reserve the right to get smarter. And I can't promise that SETI is going to succeed tomorrow or ever because I don't know whether there are any other extraterrestrial technological civilizations, say that seven times, out there. It's a question I'm trying to answer. But the answer to that question, if they're there is going to depend on the main distances between such technologies, us being one of them. And it's not only a mean distance in space, I'd like them to be close by so I can hear them, but it's a mean distance in time. So, if technological civilizations arise and flourish, and then do themselves in, in a very short time, on the cosmic stage, then they're never going to be two technologies, us and someone else, close enough in space and aligned in this deep time history of our galaxy for SETI to succeed.

So, the longevity of technologies is incredibly important here, which is why Phil Morrison, the coauthor on the 1959 paper in nature, on SETI, the first sort of marks are scientific origins. That Phil had this wonderful way of saying that SETI is the archaeology of the future. Now archaeology because if there's any information about the transmitting technology, embedded in the signal we receive, it will have traveled at lightspeed very fast, but not infinitely fast, over long distances, so when we receive it, it's going to tell us about their past. But if we receive it, it tells us in fact, that on average technological civilizations survive and last for a long time, and therefore, we can have a long future. And so that's actually my second message of the night. Not only are you stardust, but that SETI may be one way of giving us some information about the fact that it's possible to have a long future. So, we've been at this for a bit more than 50 years. And we've tried, but we've used tools mainly optimized for astronomy. We're beginning now to have our own tools. And so we haven't actually explored much of the cosmos. In fact, if you could equate the space that we might need to explore to find a signal to the volume of the Earth's oceans, well, then we've looked at about one eight-ounce glass. Not much. That's bad news.

On the other hand, the good news is our ability to explore glasses. Faster, bigger glasses, is really increasing exponentially, just like so many other opportunities because of the improvement of primarily computational capabilities. So we're now building new tools in northern California near Mount

Lassen, we have built the Allen Telescope Array thanks to Paul Allen, who founded the first phase of construction and all of the technology development for this array. And someday we hope to have maybe 350 telescopes. Today we have 42. Now, if you're going to stop short of 350, can you tell me any better number than 42 for this business? Alright. So there are some incredibly unique technologies that are incorporated into this telescope and we can improve our ability to search not only by building more telescopes, and by improving the receiving technology, the feeds and receivers to lower our system temperature, but by increasing our computational rate, so this is a Moore's Law telescope. Right now, we take in far more data than we can process. Mid life, a couple of decades from now, we'll probably be well balanced with the available data and beyond that we'll end up being data start. So we're going to improve this telescope in many ways over the future. And let me just show you what the planet Mars looks like to our SETI receivers.

Okay, not what you expected. No big red surface, right? No rocks. This is what we call a waterfall plot. Frequency increases along the horizontal direction and time increases vertically and each of those little dots is a sample of a frequency time cell and the brightness of the dot tells you how much power was detected. And most of it looks like noise, right? Most of it is noise. Cosmic noise, noise in our receivers, our instrumentation. But they're obviously, I don't have to tell you there are non-noise components there. And I said it's the planet Mars, sometimes it's when the Mars Reconnaissance Orbiter, and Mars Express happened to be on our side of the planet and transmitting data down to the DSN. So, we can see these engineered signals very clearly at Mars. We can also see them at the edge of the solar system. The Voyager One spacecraft is now leaving the solar system and going into interstellar medium. When it was 106 astronomical units away, that is 106 times as far away as the sun is from the earth, we detected it. Have you found it yet? Can you see it? It's kind of hard with your eye. But our computer algorithms have no problem, right? That's a six-sigma detection for our system.

So, this technology works over vast distances, at least to the edge of our solar system now, it's another few thousand times to the nearest star. And it gets harder and harder to see the kinds of signals that we generate as you go out to interstellar distances. But this is what my team at the SETI Institute does with the Allen Telescope, Array but we're certainly not the only folks that are doing SETI today. There's a very active group at UC Berkeley. Many of you may know them, because they're the ones about 12 years ago who brought you SETI@home. How many of you use SETI@home as screensavers Yeah, right. What a clever idea. Now it did not, SETI@home did not invent distributed computing. And they didn't actually have this idea. It was an idea that was actually bought up by a gentleman at Microsoft, who came to Woody Sullivan over here in the Astronomy Department who then came looking for SETI data and we said, "No, not us.

We do our signal processing in real time. We don't save any data." Then went to Berkeley, their Serendib program, which had lots of data that they were having a hard time getting through and they developed this wonderful app called SETI@home, which was so sexy that it put distributed computing on the map. It is the first prototype of a huge suite of citizen science projects that you can do today with your own computers. You can fold proteins for cancer research, you can count craters for NASA, you can do, you can rearrange bits of papyrus, try and decipher that. All kinds of wonderful things. SETI@home was really the first. And it's still going. It now takes its data from a seven beam feed at Arecibo, the world's largest telescope. And from the GBT in Green Bank, West Virginia, the world's largest steerable telescope, right? So they work on recorded data and because they have all of the CPU availability that you provide, they can look for lots of patterns. They started with the kinds of things that the Allen Telescope Array does in real time, started with that and then expanded it as the CPU became available to look for different patterns and frequency and time. So we're also beginning in Europe, a low frequency array called LOFAR, we're beginning to use that to do SETI, to look for signals that maybe aren't constant but are transient and we need to be able to survey the sky.

In Italy, there is a SETI Italia program that uses the 64 meter telescope at Medicina. It piggybacks on that. And down at JPL, who used to be part of the NASA SETI project until Senator Bryan terminated those funds and then NASA actually had to get out of the SETI business. Once they could take a telescope off the campus out of the DSN and put it into an educational center called the Goldstone Apple Valley Radio Telescope, GAVRT, then they developed a sky survey scanning program that can be done by high school students to look for signals from distant technologies. And an effort started in Japan on the 50th anniversary of Frank Drake's initial project Ozma search back in 1960. To get optical and radio telescopes around the world to coordinate observations of the same object in the sky, to see if maybe that would end up providing detections. So far not. We have recently, no, we had at the turn of the century, about 2000, detectors that could count photons, optical photons, visual photons at a very fast rate. So they could tell how many photons arrived every nanosecond, every billionth of a second into the telescope. At the turn of the century, those came out of the military, became declassified, became cheap enough so that we could begin to use those as SETI detectors. So when the radio we look for engineered signals that are compressed in frequency, those lines that you saw that were very narrow band on waterfall plots, I showed you, in optical we do something different. We use broadband white light, all the visible frequencies, and we look for time compression, we look for something that pulses, a bunch of photons that show up within a nanosecond and during that nanosecond, they outshine their star. And so we began to build optical SETI detectors at Berkeley, at the Leuschner Observatory. Here, this picture in the middle, Shelley Wright, when she was an undergraduate at UC Santa,, built an optical SETI detector as her senior thesis project. That's pretty cool. That's pretty impressive. On the other hand, you have to understand this young woman had a business on the side of making Van de Graaff generators for museums, right. So she was, she's a very good instrumentalist. Optical studies being done outside of Sydney and Campbelltown at a small pair of optical telescopes.

It's being done at Harvard, with a purpose built, a specially built telescope and arrays of CCD so that they can actually do a survey of the sky rather than targeting objects and the bottom picture is from a French prototype of an optical SETI survey. Now, optical SETI is great. But if you're an optical photon and you're trying to go between the stars, you run into these awkward dust particles in between the stars and you get scattered or you get absorbed. If your wavelength gets longer, if the size of your photon essentially gets bigger, then you can not see these little dust particles quite so much. And so working in the infrared or even better, the radio, you're free of the dust between the stars and so a signal can be detected over longer distances. So here on Mount Wilson, Charlie Towns, whose memorial service I went to last weekend, sad, has built a three element interferometer that works in the infrared. UC Berkeley folks are equipping this with SETI detectors. Here, Shelley Wright, now no longer an undergraduate at Santa Cruz but a, a faculty member at UC San Diego and she’s building a new optical infrared SETI detector to go on the telescope at Lick Observatory. And in the bottom you see a spacecraft called WISE, which has made a survey of the infrared universe. And there are a number of groups at Penn State and at Cal Poly, that are scanning through all of that infrared data looking for extreme examples of what an advanced technology might look like in the infrared.

The bottom left picture is an artist's conception of what we call a Dyson sphere, individual reflectors or collectors in orbit around a star to capture all the light from the star and provide it as energy to some technological civilization on a planet also orbiting that star. And if that's sphere is very complete, you may never see the star, much less the planet, but what you would see is the warm glow of the backsides of all of those collectors, the heat from that collection process, right, or if you take that and so, Nick Kardashev, Soviet astronomer, came up with a classification scheme decades ago. A Kardashev 1 civilization, kind of like us, we're not quite at one we’re maybe point seven, right is a civilization that can manipulate all of the starlight that lands on its planet. Kardashev 2, it can manipulate all of the starlight from its star, the power, Kardashev 3, let's take that even further, it can manipulate or utilize all of the power radiated by its Galaxy. So, we're doing very large data searches to see if we can find any evidence for these kinds of things in the survey data from the WISE spacecraft. So what can these kinds of things find that we're doing now?

If you were very, very lucky, and things lined up exactly, and you were looking at exactly the right time and exactly the right way, remember all those caveats, we could detect our strongest laser on the planet that's a petawatt laser in the National Ignition Facility at Livermore, right? If it were focused by a 10 meter telescope and focused on us, and we were trying to receive it with a 10 meter telescope from 1,000 light years away, in the radio, if you take our strongest transmitter, that's the planetary radar at Arecibo, it has an effective isotropic radiated power of not a petawatt, but two times 10 to the 13 watts, about a factor of 100 less. Again, if we were in it's beam, and we were looking at exactly the right time, we could detect it with an Arecibo equivalent out to 1,000 light years. Now, I told you that longevity was the key to success in this game. How long does a civilization, a technological civilization, continue to transmit signals? Well, within 1,000 light years, there are about a million stars. And if I were to search those million stars, and I wanted to have a chance of detecting a technological civilization, the math, I won't do it here, and it's very astronomical mathematics, like factors of 10 don't matter, but we're talking about longevity of maybe 100,000 years or more. So that's kind, that's the kind of place and space that we're exploring. In the future.

Well, JWST is going to launch in 2018. Yes, yes. Right. And it's going to be able to look, um, bio signatures, not really, but it's advertised as such. It is actually going to be able to take spectra, transmission spectra, of hot Jupiter's close to their stars. Maybe we will learn something that has, that can tell us about life. But bio signatures, that is, something that says you can't have that spectral feature in the atmosphere of a planet if there isn't biology on the surface, no smoking gun. This is a long-term process to be able to infer the existence of life remotely by the, the influence it has on the chemistry of its atmosphere. It's not going to be easy. It's not going to happen soon. But with SETI, there are some things coming online that in fact might give us some evidence of technology. Right, the TMT is a 30 meter telescope. The EELT is the European Extremely Large Telescope, I think it's now at 42 meters. Well, I mean, that's as opposed to the overwhelmingly large telescope, the OLL. These are, well, they, they blasted the top of a mountain for the TMT and the ELT is funded and, and LSSST, the Large Synoptic Sky Survey Telescope is coming online and it might show us some artifact that we can only explain in terms of technology.

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So, we want to put optical infrared SETI detectors on larger pieces of glass than we've had in the past to be able to find fainter signals. And in the radio, well, the Chinese are building something called FAST. It's a super Arecibo, our largest telescope right now is 305 meters across. In Puerto Rico, FAST will be 500 meters across. They want to do SETI. There is an international, oops, I didn't mean to do that yet, there's an international collaboration called the Square Kilometer Array. It's the ATA on steroids and steroids instead of 342 or 300, it's got 3,000 telescopes, right? It will hopefully be built in the 20s in a combination of the Kalahari Desert in South Africa, and the deserts of Western Australia. And then this telescope, Colossus, which is an idea of Jeff Koons in Hawaii, it's 74 meters across. It's a lot of individual very thin glass telescopes working in the infrared phased up, to be able to survey the sky, looking for those heat signatures of advanced technologies and as Jeff says, if we build it, and we don't see the heat signatures, doesn't matter what you think they might be doing technologically, that's the second law of thermodynamics. And that's a significant no.

But we're not there yet. We're still thinking about ways to have positive outcomes. And I work on this and I talked to as many people as I can, because I'm trying to change your perspective, trying to make you think bigger. You think about SETI, it's like holding up a mirror to the whole planet. And the message when you think about all of us, when compared to some of them, is that we're all the same. And this science, if it never detects a signal, at least if it can propagate this message that can help to trivialize the differences among humans, I think it will be extraordinarily profound. And so, I leave you with this last vision, vision of the 21st century, which Craig Venter and Daniel Cohen have famously called the century of biology, but I think the really exciting thing about the 21st century and it's in the future of the students at this university, it's the center, it's the century of biology, on earth and beyond. So I'll leave the last word to Caleb Scharf, who last year said, "On a finite world, a cosmic perspective isn't a luxury. It's a necessity. So change your perspective." Thank you.

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Q&A SESSION

Jill Tarter: Okay, I think I've left enough time for questions. And there are some microphones on this side and that side. And so I came in here knowing what I was going to say. So I'm really interested to hear whether you have any questions. And I really like to try and answer them.

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Participant 1: I was just wondering what your take on von Neumann probes are. I know that Sagan has his famous response that the replication rate was underestimated, and that we should have seen the galaxy eaten up by now by self-replicating probes, but that's not necessarily, that doesn't necessarily have to be the case. There can be self-limiting programs. So do you think that the absence of evidence of self-replicating probes is indication of some solution to the Fermi Paradox?

Jill Tarter: Okay, so the question was, what do I think about the idea of self-replicating probes. Small AI, small intelligent machines that would go out, find some new real estate, use it to replicate themselves, in fact, maybe use up all of the real estate replicating just themselves, and yet, they're not here. I mean, we're not grey goo, right. We're us. And that's part of a bigger conundrum called the Fermi Paradox. Fermi paradox says, you know, if ever in this galaxy, there was ever a technological civilization, anywhere, any when, then obviously, the technology would have advanced that they would have developed the capability to travel between the stars, or launch self-replicating probes to travel between the stars, they would have done that and then whatever you're a model for, how they get from here to there and how long they went, wait before they go out and colonize other locations, whatever your model, the numbers say that the galaxies get completely populated in a time that's short compared to the 10-billion-year history of the galaxy, and then they say, the Fermi Paradox says, but they're not here. That means that there can never have been, anywhere, anytime in this galaxy, a technological civilization before us. We have to be the first. That's pretty profound, you know, it doesn't hold up. We cannot say they are not here. We have so poorly explored even our cosmic back doorstep, our immediate solar system can't rule out small, smart machines.

Now I'm not saying that they're abducting analysts on the streets of New York for salacious medical experiments. That's, that's not what I'm talking about. But what I'm talking about is having sampled one glass out of the ocean of electromagnetic signal space, having looked around us, and yes, we've looked at the special gravitational equilibria points, the Lagrange Points. We've looked for reflected things, we've actually looked with radar at a couple of them. And we probably would have seen big bright Battlestar Galactica, but not little dark stuff. So it isn't out of the question, but they are here, in some form, that we haven't yet detected. So, I'm not real impressed by the Fermi paradox. I think that the answer is we know, we've hardly begun to look. So, let's get on with the looking.

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(1:07:32) Participant 2: You kind of talked about, a little bit what I'm going to ask, but I was just curious, so, from what we do know, what, what evidence leads you, I mean, there's tons of evidence, but what specifically is the most mind-blowing fact for you, that leads you to believe that, that there is extraterrestrial life, like I heard something about finding water on another planet, things like that. Is there anything in particular that, that you saw that, that, that was mind blowing for you?

Jill Tarter: So, what leads, you asked, what leads me to believe, what evidence is there that there could be, that there's life out there? First, let me correct you. I don't believe that. I don't know that. I am asking a question to which I do not know the answer. And so whatever I believe makes no difference at all to what's out there. There is an answer, believe what I want. There's an answer. And I'm intrigued to try and find it and what I can say is that over a career, that's now lasted a long time, there have been two real game changers and I talked about both of them, exoplanets, and extremophiles, right, it makes the cosmos look potentially more bio friendly, then it did when I started, and it could have gone the other way. Could have been no star has planets. Well, almost every star is going to have planets. And 20% of them are going to have earth-sized planets in the habitable zone or so the current statistics say, I couldn't, it could have turned out differently. It could have turned out that my teachers were correct and that sunlight is the energy for all life on Earth. No sun, no life, not right. There's more bio, bio matter under your feet than above the surface of the planet. There's lots of life where there's no sun. There are other energy sources. Again, it could have turned out that my teachers were right. But extremophiles have tried to open our eyes. And I think we should listen to that message and go see what's out there. But I don't believe anything. I don't know the answer to the question. And as I said, it didn't matter if I believed it or not, it wouldn't change what the answer is.

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(1:10:24) Participant 3: You seemed to mention that in our search for extraterrestrial intelligence that we've kind of gathered so much information that we have a hard time processing all of it. And I'm wondering, as we've kind of entered, you know, the age of big data, and we have companies that are doing data mining, has that had any effect on our ability to process this information?

Jill Tarter: So the question is, we've collected a whole lot of data and it's a bit much to process at one go. And so has data mining and the whole new field of big data influenced, and absolutely the answer is, and SETI@home was the first cut of that, right? Taking these big data sets, cutting them up into small pieces, sending them out in a distributed computing fashion. So that was step one. Thinking about data mining for patterns in different ways. Looking for things that are there that you don't necessarily know are there. All of us are trying to learn, you know, and it's like pedaling really very fast to keep up about machine learning and deep learning and trying to apply those kinds of algorithms to our data. I still am working in a way that says that with respect to SETI, our biggest challenge may be not detecting signals, but discriminating their technology from ours. There are a lot of satellites up there. They're, they're very noisy, right. And so I think there's real benefit to detecting a signal in real time and once you've found it, immediately following up to do tests to discriminate our technology from something else. We may be able to get away from that by simultaneous observations and recorded data. There may be enough information from doing the same observation from two different locations, that when we do the data mining and we find signals and we're not at the telescope anymore, and we can't look back at that place in the sky, there may be enough information that we can apply these big data techniques and still be able to discriminate against our own technologies. So yes, more data, more technologies, more tricks. Everybody will win. Yes. Well, I'm going to have dinner with Don Brownlee after this. And I want him to buy me a glass of wine. So, I can't be too impolite. Now, rare earth is and it's a really good attempt to organize what we think we know. I find it not compelling, because having an example of only one, one example of large, complex animal life, I think we really don't know what is necessary and what is contingent in the story of what got us here.

As a physicist, you'd like to be able to figure out what the branching ratios are for any experiment and figure out this percentage of the time it goes this way, that percentage of the time it goes some other way. So they've actually drawn our attention to bottlenecks. It's pretty clear in the data that the total evolutionary history there've been bottlenecks. But the fact that it came out this way, and therefore you say, oh, it's so improbable, you have to have all of these conditions to make it work. I'm not yet buying, because it could have gone some other way, and yet have the functionally equivalent outcome. So Don, can I still have a glass of wine? Thank you. A wise man. Yeah.

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(1:14:59) Participant 4: If we were to discover some kind of extraterrestrial life and if they were hostile, do you think we'd be able to survive?

Jill Tarter: Okay. So, don't laugh, we're having a big debate in our community about this. So the question is, if we were to, if we were able to discover some extraterrestrial life and they turn out to be hostile, could we survive? So, let's break that down. If I discovered them with a radio or an optical telescope, that passive activity doesn't let them know I've discovered them. So there's another step, right, their technology has to be sufficiently advanced, so that should they understand that I've discovered them, they can zap us from a large distance, or they have to have the technology which allows them to travel over interstellar distances to get here to do us in. In the latter case, we don't have that technology. It sounds like their rules are going to apply. In the former case, where we detect them but somehow tipped them off that I've detected them and they know we're here and then they're going to zap us from afar, they could have done that anytime in the last 2.4 billion years. Right. Now, there's this argument, where's Vicki? There's this argument about bio signatures. But we have profoundly, profoundly changed the chemistry of our atmosphere, that is, we, life since cyanobacteria figured out how to, how to produce oxygen with photosynthesis. Now, it's not enough to produce, to just see oxygen, but an advanced technology who could understand the environment of our planet and watch it change over time, would have known that life was here, a long, long time ago. I think if they were so inclined to eliminate our plague, they might have done so already. So again, I don't know the answer. I absolutely don't know the answer.

And people argue we shouldn't transmit, oh, Stephen Hawking a couple of years ago got a lot of, a lot of play. Because on his TV show, he said, you know, didn't work out too well for the natives when Columbus showed up. Maybe we shouldn't be, you know, making our presence known. It's, it may not be the right analogy, or at least it requires them to be here physically. Other people, Steven Pinker, published two years ago, 900-page fabulous book with all kinds of data, showing that we are kinder and gentler than we've ever been. And maybe you can't get to be an old technology, unless you figure that piece out, stop killing one another and stop messing up your planet. Maybe an old technology is something that we don't have to fear.

Or maybe, you know, it's the aggressive sons of bitches that managed to survive. I don't know the answer to that. I don't know the answer to that. I think we have to look to our own survival and not be our first and worst own enemies. Yes. Question. Very astute question. When Kepler sees a star blink, how do we know that it's a planet? Couldn't it be an asteroid or something else and that is an enormously important question. Because yes, it could be. For example, do you know what sunspots are? Our sun has these eruptions on its surface and having to do with the magnetic fields of the star, and they make dark spots. And if you have, if you project, don't look at it, you don't look at it with your naked eye, but if you project the image of the sun on a piece of paper, you can see some dark splotches, right, the sun has zits.

As the sun turns, the number of those dark spots changes and it changes over time. So suppose we're looking at a distant star and it's got a huge big sunspot, right, and it's on the backside of the star. But now we keep staring at that star and the sunspot rotates into view. Suddenly, there's a dark area on the disk of the sun, of the star, it doesn't have quite as much light. So this star would appear to blink. And if that sunspot lasts for a long time, okay, the next time it rotates around, it'll be dimmer again. That's what happens with the planet which has an orbital period. We see it pass in front of the star, the light goes down, it comes back around, right, the light goes down. And we think, oh, that's a period, maybe. So we wait for the third time. Yes. But in fact, there could be artifacts on the star itself, which confuse us. It's usually the fact that we can rule out star spots as a, as an explanation, because the stars rotate much quicker than the planet goes around. So the periods that we would get out of something like star spots would be very short, it would be very hard to explain a planet that went that fast. And, but there are other effects. This is a very hard job to do.

First of all, we need to be measuring the light from a particular star, one star out of 170,000 others to one part or a few parts in a million precision. And then lots of things can add noise. So that's why the Kepler spacecraft says we have an exoplanet candidate. Not we detected an exoplanet. First thing is we have a candidate and then you can look sometimes with ground-based telescopes at the star in different ways and detect the planet with other characteristics. Or if there are multiple planets in the system, they'll actually interact with one another and where you would expect, period, period, period, and over here, period, period, period, because there are multiple planets, their interaction can make the planet show up a little bit sooner or a little bit later.

And these, what we call transit timing variations when you have multiple planets in the system, actually, they can't be mimicked by sunspots, or anything else we can think of. So we can, we can decide that. Yeah, those are really planets that way, but maybe 10% of those Kepler candidates are actually going to be something that's fooling us. Oh, I see. Kepler Gen Four in your future. Okay, question over here.

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(1:23:30) Participant 5: This is a question relating to like, UFOs, unidentified flying objects.

Jill Tarter: I've seen one.

Participant 5: Oh, so I was going to ask if, do you believe that it's very likely that we have seen a legitimate UFO, but that we've just like, perceived it as something else due to the fact that we just commonly believe that they don't exist?

Jill Tarter: I think, the question is, do I believe that we've seen legitimate UFOs and that we ignore them because we don't think they exist? Actually, absolutely not. We have many sightings of legitimate UFOs. But what does UFO stand for? Unidentified flying object, it doesn't mean that they have anything whatsoever to do with extraterrestrial spacecraft. That's the missing link. And I said I've seen a UFO. And let me tell you, it was an amazing experience. My husband and I have a small plane, we're flying back to San Francisco from our observatory in Northern California. It's dark, it’s late. We're under positive control, that is, we're talking to the tower. And suddenly at our two o'clock position, we see a bright light. Well, now, normally you think, well, that's the headlight of an airplane. But why didn't the tower tell us that we had traffic, because that's what the tower is supposed to do. So we call up the tower and they say, we say, oh, hey, can you tell us what’s on our two o'clock position? “We have nothing on the radar at your two o'clock position.” No kidding.

My husband is an astronomer as well. Looking at him, looking at me. We’re saying, nah. Nah. Well, I mean this, this anxious period went on for a little bit, long enough so that the clouds that we didn't realize were there, parted a little more and allowed some more of the moon to shine through a hole, so that one was a UFO for a while, but then became an identified flying objects. And, and I'm serious, what is missing is any data that indicates that phenomena that we observe is explained by flying saucers or some extraterrestrial spacecraft. We give you another example because I'm, this is a hobbyhorse for me. Okay. High altitude pilots for a very long time, and these are credible witnesses, were recording, reporting flashes of light above the tops of very high Anvil thunderclouds. You know the anvil shape? They were seeing flashes of them. People were thinking it was spacecraft, flying saucers. It was that time, it was really ripe. We couldn't prove what they were until we finally had a cadre of down-pointing Earth observing satellites.

And then what we found is that lightning from a thundercloud travels not only down to the ground but ups and we now call these things sprites and elves. It was a whole new area of physics to explore. So, they were legitimate. Those sightings were physics. They were real. No flying saucers. So, I actually believe that there are probably things that we are seeing that has to do with physics that we don't yet understand. But there is neither evidence to show that I'm right in that belief that it's unknown physics, nor is there evidence to show that the exaggerated claims of extraterrestrial visitation is correct. We need data. We need evidence. Other than that, we can't do anything. Yes, over here.

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So, Stan Freidman, makes, is a big UFO proponent and he makes some nasty comments about SETI and the question was what do, Congressmen make even stupider statements. Sorry. So and so what does SETI do about investigating extraterrestrial technological civilizations who have visited Earth previously, as opposed to looking in the electromagnetic spectrum. I'm on the board of what used to be called PSYOP, it's, it's now the Committee for Scientific Investigation, CSI. We look at data. We examine, I do, my colleagues do, on the board, we examine data that people bring to us and we say is it credible? What's the evidence? To date, nothing has passed the overwhelming requirement or scientifically valid, verifiable data. I'll tell you one of my favorites that I wasn't involved in, but a colleague of mine was.

The rock star in the Berkeley, the Bay Area, and so TV crew was interviewing this rock star and Alcatraz Island was in the background, really scenic. Suddenly, there's a dot over Alcatraz, then the dots way over on the other side of the field, that it's there. And then it's there. And you know, watching this footage, you'd see that, and Mr. Friedman would have many extravagant things to say about that, because he makes his living giving those talks. Well, what was it? When the film was analyzed by experts, not so-called experts, but actually, people who were experts in the field, in the field. It was found to be a fly on the surface of the TV camera lens, just hopping, you know, doing its fly thing. But when you project that out and say that's at the distance of Alcatraz, that's at the distance of the San Francisco Golden Gate Bridge, and it went from there to there.

Right, that's the, it's, you know, I'm being not very nice, but it, witnesses are so hard in this field. Hard to look at something particularly at night without any referentials and decide how far something is, is it something that's very large and very far away from you, or something that's much smaller and closer. And so, eye witnesses have a very difficult time with this and recorded information hasn't yet stood up to the test. If you've got some, I'll give you my email and send it to me and we'll take a look at it. That's all I can say. That's all any scientist can say. I'm not here, and it isn't my job to prove your story wrong. It is your job to provide data and evidence that prove your story, right. Over here.

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(1:32:11) Participant 7: I can ask you questions all night, but I'll ask two. One is the Van Allen belt. The Van Allen belt, scientists say, or NASA actually admits on their website, that highly energetic particles find it impenetrable, almost impenetrable. So, my question is, can this be interfering with any type of incoming signals that an ancient extraterrestrial civilization may have broadcasted into the universe? Is it hard for us to, to receive with our equipment today?

Jill Tarter: Okay, so you made the statement that NASA's website says the Van Allen belt is impenetrable by —

Participant 7: Actually it was almost impenetrable, almost.

Jill Tarter: And then could this Van Allen belt, this radiation, be interfering with signals from an extraterrestrial technology? Well, first of all, we launch spacecraft through those belts all the time. And we have to protect the spacecraft. It is not a trivial thing. Right? That is a risk for anything passing through them. But it's, I would not say it's almost impenetrable. I would say it's demonstrable, that we've penetrated it many times. But not without caution and taking caution. With respect to could it be interfering with signals? I suspect it could. Particularly very low frequency radiation. But the ionosphere, that general ionosphere does that anyway, when you get to real low frequencies, so yes, but it okay, let me just say yes, that might be a possibility.

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Participant 7: Question two: Say ancient extraterrestrial civilization that was evolved, more evolved than us by, say, a million years were able to now be an interdimensional kind of civilization and have technology that's interdimensional. Wouldn't our equipment be almost futile if not entirely futile to detect anything?

Jill Tarter: So suppose there's an advanced technology with the ability to be interdimensional and create signals that are interdimensional, wouldn't what we're doing now be futile? I got to say, that's just like zeta rays. If that's what we're doing, we don't know enough physics and technology yet to do it. We got to stay around long enough to get smarter and then maybe we could detect that, if it's a possibility. So I guess you get the last question. Okay, well, let's start with you.

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(1:35:27) Participant 8: This is probably a question you can't realistically hope to answer, but I figured it was worth asking.

Jill Tarter: Why is it they're always this tall when they ask the real thing? I'll try.

Participant 8: But what are the odds of you finding some sign of any form of life anywherem that's not us in my lifetime?

Jill Tarter: Okay. I think that's my answer. The 21st century is your century. And I honestly believe that it is going to be the century of biology on earth and beyond. But I'm not going to find it. It's going to be your job. You have a question? Okay. Then I think we probably, it's eight o'clock, we need to wrap it up. But the question is have I looked into the notion that human consciousness survives, I assume you mean survives death, and is among the stars. That is a, that is a theme, a mythology, a belief that is prevalent in many different traditions, in many different places. But we're talking about belief. I'm talking about science. So, I don't know how to make a scientific study of that. I've seen no data that indicates that that's the case.

And my whole career, in addition to trying not to have a wow signal by doing my signal processing in real time, my whole career has been to try and change the situation with respect to SETI, which was for millennia, we ask the priests and the philosophers and anybody we can thought was wise, what should we believe? Is there life beyond Earth? Is there not? The answers came back in, in the form of many different belief systems, many different answers. But what hooked me as a graduate student in the middle of the 20th, or the three-quarters of the way through the 20th century, not that old, was the fact that with radio telescopes, and then more recently with optical telescopes, suddenly scientists and engineers had some tools with which to do an experiment or observation, to try and answer that question. So I've been enthralled with the possibility that we, we can actually change the verb to believe to the verb to explore, to see what is and if that's what is, eventually some exploration will in fact, discover. So, belief is not where we're about. It's, let's go out there and explore and find out what it's all about. Thank you.

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