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A PERSPECTIVE ON HUMANS ON MARS, THE NASA PSYCHE MISSION, AND THE PURSUIT OF SPACE EXPLORATION

An Interview with Dr. Lindy Elkins-Tanton

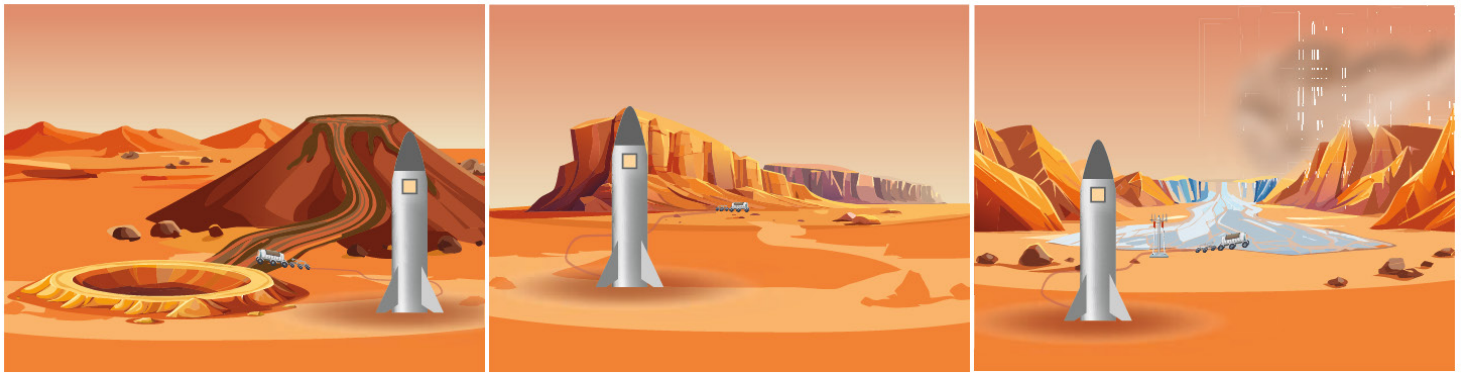
By: Deacon Carreon and Pari Sachdev

Dr. Lindy Elkins-Tanton is the Director of the Berkeley Space Sciences Laboratory (SSL) and a Professor of Earth & Planetary Sciences. She is also the main lead of the NASA Psyche mission, which launched in 2023 and is on its way to the metal-rich asteroid of the same name. Dr. Elkins-Tanton attended Massachusetts Institute of Technology where she received her BS, MS, and PhD. She has worked at Brown University, MIT, Carnegie Institution for Science, and Arizona State University before arriving at Berkeley to lead the SSL in July 2025. Dr. Lindy is also on the committee for A Science Strategy For the Human Exploration of Mars, which is dedicated to uncovering the challenges of crewed missions to Mars, and how to approach these challenges.



BSJ: First we wanted to ask, what would definitive evidence of past life or present life on Mars look like, and how should human explorers approach that question differently than past robotic missions have?

LE: This question of life is certainly one of the biggest questions that humans have and have ever had. Are we alone in the universe? How would we recognize life? I think the first way to answer this question is to say we have to temper expectations for Mars. We know there is not technologically advanced intelligent life on Mars. I don't think that we're going to go up there and find creatures walking around. The most likely thing that we would find, if there's extant life on Mars, would be microbial life living underground. The question is what can we do up there with humans that we couldn't do with robots, and how does this differ? One of the things that we're recommending in this report, A Science Strategy for the Human Exploration of Mars, is a lot of work on deep drilling technologies, because humankind does not currently have the capability to drill to the depths that we would need to see on Mars. It's incredibly hard to drill on other planets, but it will be easier with people there. Our hands are still the best robotic actuators that we have out there, and the ability to make decisions and change direction quickly. What would happen if anything that is found looks likely or interesting? It could be we're talking about fossils, or we're talking about molecules, or maybe we're talking about little shapes or forms that people wonder, could it be a microbe that's in a kind of hibernation, possibly? So many questions! How do we keep the astronauts safe from this? How do we keep this possible life safe from the astronauts and their microbiome? How would we bring it back to Earth, and the Earth Labs being available to look at it? If it's not walking around and talking to us, the decision of whether or not it's life is going to be probably a decade of investigations and measurements in multiple labs around the world and the scientific process of "this is my evidence" and "I refute your evidence, this is my evidence. Let's talk it out and see if we can figure out a step closer to the truth." I don't think there's going to be the giant announcement of discovery for sure, but what we hope for is a bunch of exciting teasers on the path to knowing the real final answer.



30 SOLS
IGNEOUS AND IMPACT MELT GEOLOGY

30 SOLS
SEDIMENTARY ROCKS

30 SOLS
GLACIER IN DUST STORM FORMING REGION

Figure 1. Possible regions of exploration for different scientific objectives for a crewed Mars expedition.

"Our hands are still the best robotic actuators that we have out there, and the ability to make decisions and change direction quickly."

The whole point of this is to inspire everyone on earth and to make people feel involved in a common human future. I really do mean this from the bottom of my heart. It sounds maybe a little bit ultra philosophical, but I do believe that when we all look out and think of a giant adventure for us to do together, it reminds us of our commonality and stops some of the finger pointing and "you're different than me" kind of conversations, because really, we're so much more similar than different.

BSJ: If astronauts want to explore regions that are most likely to harbor life, how do we ensure planetary protection and what challenges might we encounter?

LE: This is a really big, thorny issue that our report tackles. The way the National Academies reports work is there's a formal structure within them called a recommendation. These are things that we really want the customer, whoever it is, to do or to think about doing. This report to NASA has four recommendations only. Some reports have as many as 20, but our number one recommendation is to continue to work closely with international efforts on planetary protection to get these guidelines in a situation where we can do the science investigations we want: go into areas that potentially could harbor extinct or extant life, which might or might not be protected right now, and then to make sure that both the samples can be kept clean and pristine and usable, and of course, that the astronauts are kept safe. As you mentioned, there are many different sides to this. And what we've mainly been doing as we send robots, which are our robotic precursors, is we sterilize them before they go, to try to make sure that there's not a grain of Earth life going with them. It's our best effort. But when you send humans, you send their entire microbiome as well. It is not a sterile endeavor. We have to think about safety in both directions for the sample and the astronaut, and, of course, for Earth. That's where a lot more international work together in coming years is needed.

BSJ: Building on your mention of human expeditions, what are some specific scientific advantages of these human expeditions to Mars compared to robotic missions?

LE: This is a big question, like, why would we even take the risk of sending humans when we can send robots to do everything we need? No matter how optimistic you are, you know that robots don't do everything that we teach them. So there's two things. One is humans want to see a human exploring. I just think it's kind of in our reptile brain, we just want to see what's over that hill. We want a person to look and see what's over that hill. There's the huge inspiration and human aspect of sending people. But everything that humans do in space, everything we've ever done in space, and everything we will do in the future is a team between a human and an agent. An agent is something on the spectrum from pre-programmed machine learning, generative AI, up through even autonomous robots, anything in that spectrum of tech agency is going to be there with the human. One of the things that humans can really uniquely do is discern with our eyes what is on the ground and what we're looking at. It's been shown through lots of studies that even doing remote sensing, where you have a robot on the ground sending back image data to a person somewhere else, really limits humans' capability to discern the angle of the light. That's one thing, and then rapid decision making is going to be very important. We need to have discovery-driven rapid reassessment of plans, and we need people on the ground to do that: to use their hands and human capabilities to drive discovery. Imagine we've got a great drill rig and something goes wrong. You can have a certain amount of robot repair, but there's some things that just would need a person to diagnose and figure out what next to do with the robot repair.

BSJ: How would astronauts deal with the possible health effects of Martian dust and the ensuing radiation levels?

LE: This dust on Mars is a worry since some of it contains chemicals that are dangerous, like perchlorates. It's very different than the dust on the moon. I just want to disabuse people of the idea that once we get astronauts back on the moon and we can deal with that dust, that we'll know what to do on Mars. The dust is made of entirely different materials, and it has different levels of sharpness and different chemical constituents. It's a different story. The best way to take care of dust from the outset is to try to block it with filtration and try to protect seals and this kind of thing. There's a lot more work to be done there, but the place where there's a lot of work to be done is in radiation. That I think, in my opinion, is the biggest barrier that we've got to human spaceflight. There are really two sources of important radiation. One is what comes off the sun, which is mostly protons and electrons, and actually you can shield from that pretty effectively, even things like coronal mass ejections and flares. The more dangerous thing are the X rays that come from those, from the sun also can be shielded from a little bit more easily than the other kind of radiation, which is galactic cosmic rays. And these are individual particles that are sent at very, very high energy from even other galaxies, some from the black hole in the middle of our galaxy, some from other galaxies. And they're not just protons and electrons. Some are as heavy as the nucleus of an iron atom and they come in at high energy, sometimes a million times higher than the highest energy we can create in the Large Hadron Collider. Shielding from them is almost impossible. The really high energy ones, someone said to me that it's the equivalent of holding a bowling ball in your hand and dropping it directly on your foot. That's the amount of energy a single particle is bringing into your body, and that's where people are doing a tremendous amount of work right now: How else can we shield astronauts on their travels and what would the ensuing health concerns be?

BSJ: It's really crucial that we are able to work to protect and know the threats already beforehand. How can we build our own construction materials on Mars, instead of having to rely on expensive cargo supply missions from Earth?

LE: Bringing the bulk materials for settlement either on Mars or on the moon is very difficult, because we have to get these supplies out of our gravity well, and there have been a lot of plans over time, of ways that you could use your lander or some rocket stage, to actually create a habitation. So that's a starting point. But I think they're actually already a lot of companies working on 3D printing with regolith on the Moon and Mars. Cementing together, either by printing regolith, or by fusing it with heat or using mirrors to fuse it, is going to be one of the big ways to build habitations and also to go into lava tubes, natural caves, and then pave over the top with extra layers of the regolith to protect from radiation. Those are some of the plans.

BSJ: What is the relationship between NASA and the public that strengthens our efforts to explore space? How can we increase our public engagement with NASA so we can fuel future space expeditions, both robotic and crewed?

LE: It's incredible how many careers NASA has inspired, not just into space, but into any kind of inquiry about our natural world and the world around us.

It's almost like NASA stands for the human sense of curiosity and exploration in all fields. That's something that's hard to quantify, and it's sometimes hard to translate that into direct support for this governmental agency.

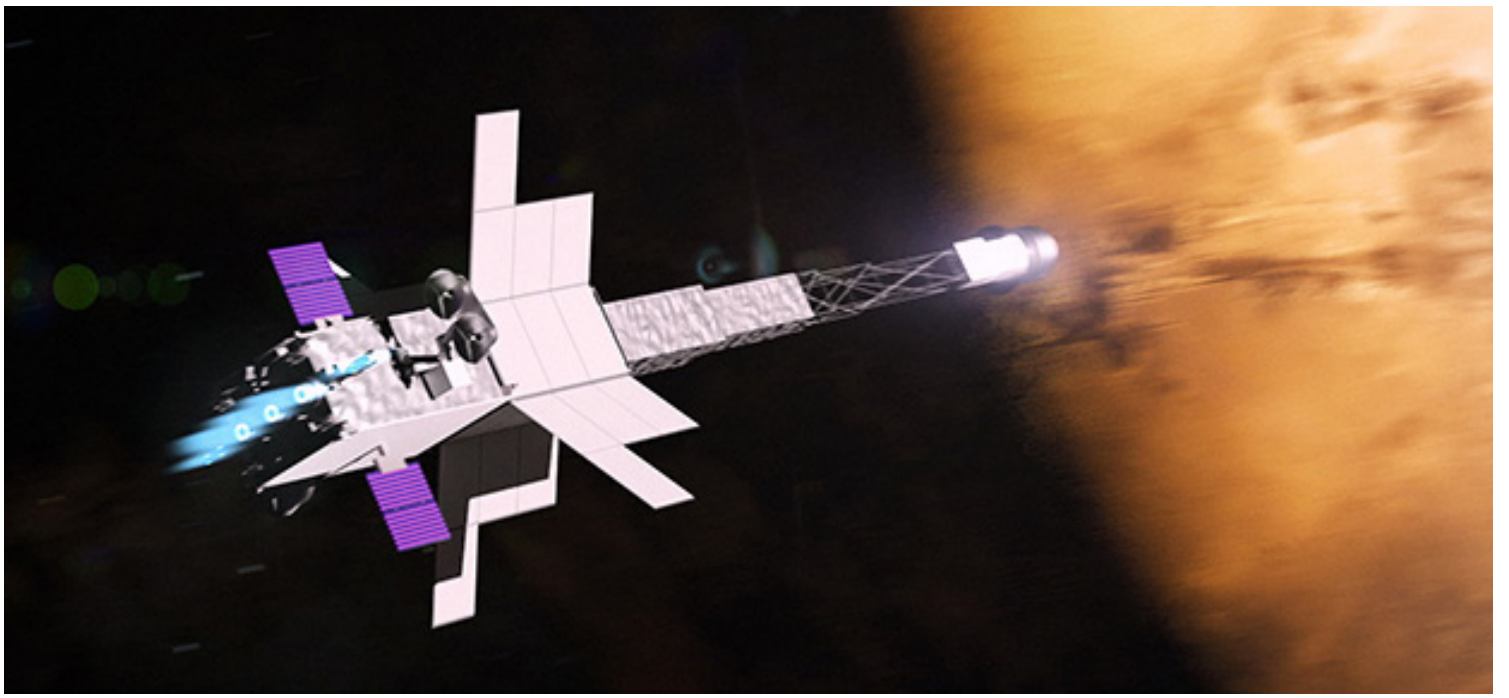


Figure 2. Concept of the Space Reactor-1 Freedom, a nuclear-powered spacecraft that can reduce travel time to Mars and increase payload capabilities.

I will say that traditionally, NASA has been the top agency that's been supported by both sides of the aisle. It's something that people just love. Think about the source of inspiration of just photographs from space telescopes, from the sense of unity and aspiration that sending astronauts into space causes. And I really hope that these things don't get swamped in the communications, news, and social media networks out there. Getting a single signal through can be difficult, but I do think that the progress with Artemis is very uniting and exciting for the nation and I hope that that will continue.

BSJ: Switching gears to the NASA Psyche mission, which is still on its way to Psyche, if Psyche turns out to be more geologically complex or less metal rich than current models predict, how does that influence our theories about planetary core formation?

LE: We have the NASA Psyche mission that I've been working on since 2011, and we competed for three years until we were selected for flight in 2017 against 27 other proposals, and then launched it in 2023. So it's been in flight for more than two years, but we have more than two more years to go before we get to the asteroid. We think our best guess for this asteroid is it's very rich in metal, and it's probably the core of what was originally called a planetesimal, a little tiny planet, one of the building blocks of the big planets, and now it's stranded out in the asteroid belt, and so we really don't know what it is. We have no photos of it. We'll be taking the first pictures. We'll all be looking at them together, because we've got it. So our pipeline puts our images on the internet for the whole world to see for free within 30 minutes of our receipt. So everyone's going to see it once. I think that because we really don't know what it is or what it's going to look like, probably what we're going to learn when we get there, we hope to be able to determine exactly what it is: is it the part of a core, or is it some other way that metal got enriched, and what is the other material that's there besides the metal? I don't know for sure that it would alter how we think about how cores were formed, but I think it would alter how we understand how material, in general, came together to form planets.

It's amazing how little we understand about how you actually build a habitable planet like the Earth, and Psyche will be a missing part of that puzzle.

BSJ: We acknowledge that humans have heavy ambitions to mine asteroids in the future. What could be the fate of Psyche and how can we protect it so it's not altered from its original form?

LE: Oh, I love that. I like the idea of protecting planetary bodies. I think that we do need to. I'm hopeful for the use of space resources, because, frankly, there's no other home that would take the place of the Earth. There's something my friend Steven Ruff said to me once, something that stuck with me, which is, there's literally nothing that humans could do to planet Earth that will make it less habitable than Mars. Keep in mind, we've got to protect our planet. I love the idea of using space resources, but I think that using them judiciously. Let's look at some asteroids that are near Earth, asteroids that have a high metal content that we could bring metal back from. The Psyche asteroid might be the biggest metal rich one, but it's way too far away to make its use practical for humankind, even in coming centuries. It's too far away until we have an economy in space until we become The Expanse. I think that Psyche is safe.

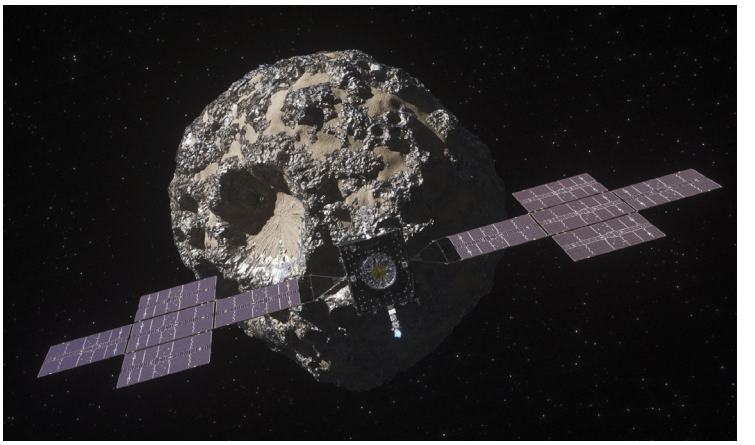


Figure 3. Artist's depiction of the Psyche spacecraft arriving at Psyche.

BSJ: As the spacecraft approaches Psyche in 2029, what are the biggest scientific unknowns that you personally are most eager to see results?

LE: The thing that I love most is that we've never seen this object with a photograph, and we do not know what it is at this point in human evolution. There are very few aspects of the Earth or the solar system that we haven't visited, looked at and have pictures of. We're spoiled. We're used to Googling it and getting a picture of whatever it is you're interested in. Here's something that's impossible. It's a whole new class of objects. To me, that's the most exciting thing.

We have ideas about what it might be, but the very best outcome is we're totally wrong and it's something that's a surprise. My biggest nightmare is that it's boring.

BSJ: In A Science Strategy for the Human Exploration of Mars, the mission uses ion propulsion and a highly integrated science team structure. How did innovation in spacecraft design and team organization contribute to making Psyche possible?

LE: What we tried very hard with the spacecraft was to use what's called Heritage Hardware, stuff that's "gone" before, so it lessens our risk and lessens our cost. So the Hall Effect thrusters that are on the Psyche spacecraft are the

"We have ideas about what it might be, but the very best outcome is we're totally wrong and it's something that's a surprise. My biggest nightmare is that it's boring."

standard ones that the company Maxar uses for its propulsion system in its spacecraft. We bought their simplest off-the-shelf spacecraft, just the chassis, like the structure and the power system, and then Jet Propulsion Laboratory (JPL) integrated the science instruments and the avionics and the software and all the rest of it and so there wasn't really an innovation in that area, other than bringing JPL and Maxar together; they never worked before. But the team structure is a different thing. I have a lot of very strong opinions about teams and how to help the team both reach its own success for the project, but also the success of each individual person on the team. And I would say that's almost our mantra.

What we really want is for every person on the team to have their voice heard, and especially for their ability to bring forward problems that they see, and have those problems greeted with enthusiasm, because the fundamental job of a project team is to locate and solve problems.

The only way you locate the problems is if the people who are authentically doing the work, the person typing the line of code or soldering the wire can speak up when there's a problem, and because those people are often not in the upper ranks of the leadership structure, the leadership has to understand that those are the horses to listen to. I will just say, shameless plug, in April 2026 my new book, called *Mission Ready: How to Build Teams That Perform Under Pressure*, will be published by the Hachette Book Group. It's dedicated to the Psyche team, and it's about that topic: How can we optimize teamwork, both for the individual and for the project?

BSJ: Can you elaborate more on the emphasis of science-driven campaigns over just engineering or architecture? How do we ensure the proper balance to prevent misunderstandings over the priorities of the mission?

LE: In a simplistic sense, it's always either the science that is driving us to do a mission or a nationalistic goal, like we would like our astronauts to reach "X" target before "Y" other country reaches that target, you know, some nationalistic goal. Then it's the engineering that enables that to happen. What happens a lot of times with missions is the engineering leads the charge for the planning, development, and build. As soon as the mission is on its way, of course, engineers are still there. They're operating and they're fixing. But it turns to science, which was the reason that it was built in the first place, or it turns to the goal of the country. I think the place where we can all do more, all of us who are in any kind of STEM field, is to integrate those scientists, engineers, and frankly, every other aspect that you need on a team. We think of it as scientists and engineers, but there's budgeters and schedulers, and there are people who make art, and then there are the people who do social media, conduct outreach, and write. All these people are there because they're necessary for their expertise. In my experience, if you get them all together and have them talk a lot right from the beginning, it prevents many misunderstandings. There's a traditional idea in spaceflight that you want to keep the scientists and the engineers separate, because the scientists do not understand the incredibly strict constraints of engineering, and they keep asking for things that are impossible. The joke is, the scientists say over and over again, "Why can't you do this?" "But wait now, I need that." "I want to change it to this other thing." "Here's a better idea." And the engineers are like, "Be quiet, doing the one thing." "That's all I can do." "You have no idea how hard this is." "We are going to succeed on plan one." "Just don't give me plan two and plan three." If you just print, that's kind of a cartoon of it. But if you just prevent that misunderstanding and have people talking all the time from the beginning, then you end up with a sense of success for everybody.

BSJ: For our very last question, what is one thing you would tell a younger version of yourself at the beginning of your research journey?

LE: All right, so this year I turned 60, which feels like a really big benchmark to me. But I feel like even in these couple of years, I've been learning so much, and actually feel like I'm becoming a better person, like more evolved, more in control of myself, and calmer. I think about all those lessons and imagine how "uncalm" I was in different iterations of my younger self. So I would just tell my younger self something reassuring, like I think that the key to life is showing up and putting one foot in front of the other. I think everybody at a super competitive, amazing place full of geniuses like Berkeley or MIT, where I did my undergrad, feels like if they don't get an A+, it means they aren't actually good enough. Not true. I think that what makes a person good enough is that they're willing to keep showing up and trying harder and learning, and just giving themselves that reassurance that if you have something that you're really interested in, you don't have to have a dream, you do not have to have a 20-year plan. But if there's a thing you're after today that you're passionate about, and you feel discouraged from doing it for some reason, keep going toward it. Who is anybody else to say that you're not the right person to do it? That's what I would want to say to myself. Just keep going.

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