Getting Curious with Jonathan Van Ness & Christina Hernández and Dr. Terik Daly

JVN [00:00:00] Welcome back to Getting Curious. I'm Jonathan Van Ness and every week I get to sit down for a gorgeous conversation with a brilliant expert—or like this week, *two* brilliant experts— to learn all about something that makes me curious. On today's episode, I'm joined by asteroid experts, Christina Hernández and Terik Daly. One note before we get started, we recorded this episode in advance and since then, there's been an update. You'll hear Christina talk about a mission called Psyche. When we spoke, it was scheduled to launch in 2022. We've now heard that the launch date is drumroll… up in the air. You can stay tuned to NASA for more information and updates. Without further ado, here's our episode with Christina Hernández and Terik Daly, where I ask them: Can asteroids going to rock our world? And if they can, should I be scared?

Welcome to Getting Curious. This is Jonathan Van Ness. This is such a good episode. We have updates on a previous episode, but we're also going into a gorgeous new world that I've been terrified of ever since I saw Don't Look Up. We are getting into asteroids. So welcome to the show. Christina Hernández, who is an engineer at NASA's Jet Propulsion Laboratory. She joined us on Getting Curious last year to talk about NASA's Mars Perseverance mission, which was, like, "Oh my God, I still think about that episode, learned so much." She's now back to share her work on NASA's Psyche mission. And then we have a new guest who, even though you all can't see, both of our guests are wearing just, like, amazing glasses today, I just have to say it, really framing everyone's faces amazing. Good job, both of you. But welcome to the show. Dr. Terik Daly, who is a planetary scientist at the Johns Hopkins University Applied Physics Laboratory. Hoo! That's a gorgeous place. And he's working on the Double Asteroid Redirection Test a.k.a DART mission for NASA. Wow. So basically, you both are kind of like more major versions of Jennifer Lawrence's character, who was kind of, like, a lowly asteroid scientist at that lab in Don't Look Up. Y'all are, like, the managers who had totally listen to her finding that asteroid, you know, so it'd be, you know, totally different. But we first of all, how are both of you?

CHRISTINA HERNÁNDEZ [00:02:13] Amazing.

TERIK DALY [00:02:15] Yeah, I'm just like, super excited. It's a great day, and it's always fun to talk about asteroids.

JVN [00:02:18] Oh, my God. I'm glad and comforted that that's how you think of it. And then just really quick before we dive into all things asteroids, which we're all really excited to learn about, Christina, what happened over there on Mars? How did it go? Literally living on Martian time for, like, 25 or six hour days or whatever. What happened?

CHRISTINA HERNÁNDEZ [00:02:36] So it was insane. So the last time we talked, we were in the lead up to landing. And so I was super nervous, you know, trying to get all my ducks in a row, making sure that our science instruments were going to be able to do their thing once they were on Mars. Well, now we are on Sol 468. And what that means is we've had over a year and a half of science, helicopter flights. We collected eight samples that one day we're going to bring back and thank the Lord, the instruments are working! So we did our job and now the scientists are getting this great data to try and understand what's happening over at Jezero Crater and the River Delta. I'm just so excited for this mission and the continued science that it's doing.

JVN [00:03:23] So did we, like, find the water or, like, aliens or something. What's going on? What's the tea, tell us everything.

CHRISTINA HERNÁNDEZ [00:03:28] So remember, we knew there was water on Mars, right? So we landed on the river delta because it was a habitable place. And so what we're doing is we're looking for all these promising snapshots that our instruments are collecting, getting those core samples so we can bring them back to Earth and really understand if there might be evidence of past ancient microbial life on Mars.

JVN [00:03:52] The past ancient microbial life! Oh, my God. But so we don't know yet.

CHRISTINA HERNÁNDEZ [00:03:57] We don't know yet.

JVN [00:03:58] Is there anything really fierce that we do know that we didn't know last time. Like, is there just, like, a particularly cute tidbit that our podcast listeners will just, like, live for. Is there just, like, a cute little tiddy bit of something?

CHRISTINA HERNÁNDEZ [00:04:09] So one of the things that I learned is that we were actually able for the first time to really understand whether rocks were sedimentary, igneous, actually classify the type of rock where we landed. And that was all because of our instruments Sherlock and Pixel, which are, like, our detectives that use chemistry to figure out what a rock or sample is made up of. So that was really cool to me.

JVN [00:04:34] What are the rocks again?! It's, like, igneous, sediment.

TERIK DALY [00:04:39] Metamorphic!

JVN [00:04:40] Yes, metamorphic! Come in for the—yes, 800 Double Jeopardy points for Terik. Okay, so, and so, what was it?

CHRISTINA HERNÁNDEZ [00:04:46] So I believe they, they found sedimentary rocks.

JVN [00:04:49] Makes sense! River, delta.

CHRISTINA HERNÁNDEZ [00:04:52] Exactly. So that was really cool. But I think the star of the show, and I mean, I'm all about the science instruments, but that helicopter frickin' worked! And it's flown over and over again. And now it's, like, our little buddy scouting and trying to find the next place for the rover to go. So it's pretty game changing.

JVN [00:05:13] Wow. Okay. I'm obsessed. That's major. Slow claps, you did it! Wait, do you get to sleep on normal time now or do you still have to be a martian time?

CHRISTINA HERNÁNDEZ [00:05:23] No. So we're no longer on Mars time, I am on Earth hours 100% now, and it's great.

JVN [00:05:29] Okay. I'm obsessed with everything. Okay, Terik, honey, you will not be neglected any longer. We just had to catch up just a smidge.

TERIK DALY [00:05:37] Can I just add one Mars tidbit that I found super cool?

JVN [00:05:40] Yes.

TERIK DALY [00:05:41] So also they've sampled, right? So the Perseverance Rover, like, now has parts of rocks inside of it. Super exciting as someone that doesn't do Mars but is fascinated in the solar system, we've all been dreaming about that for, like, decades of bringing back samples from Mars. And this is that first critical step of getting them out of the ground onto the rover.

JVN [00:05:58] So are they just going to, like, send a rocket back to just, like, scoop that up and come back?

CHRISTINA HERNÁNDEZ [00:06:04] So that's the big question. We are now in the process of actually designing the Mars sample return campaign, and it's a joint effort between NASA and ESA and institutions across the US and the world.

JVN [00:06:16] Who's ESA?

CHRISTINA HERNÁNDEZ [00:06:17] European Space Agency. So it's our homies over in Europe. And basically we're trying to figure out, "Okay, we're going to go to Mars, we're going to have potentially a lander." And we're still trying to figure out what's the method that we're going to collect samples. Is it going to be a rover? Is it going to be helicopters? I mean, the possibilities are endless. And we're just trying to figure out what's the best way so that we can bring those samples back.

JVN [00:06:44] Dang. So then this is the second hard-hitting question. Did you both see Don't Look Up?

CHRISTINA HERNÁNDEZ [00:06:52] Yes.

TERIK DALY [00:06:53] I have not seen Don't Look Up. It is too close to reality for me.

JVN [00:06:56] Oh, fuck, Terik! Okay, it was, like… ummm…. uhhhh… okay. That's not totally what I wanted to hear you say, it's fine. Did you happen to see, like, the end on, like, TikTok or something?

TERIK DALY [00:07:10] No, so I have not seen what it looks like at the end because I've, like, firewalled myself off from Don't Look Up.

JVN [00:07:17] Okay, well obviously I need to do a Gay of Thrones-style recap. That's what it is! I need to do, like, I'm going to do a one-minute Gay Of Thrones-style recap. Cause I just need, I need you both to tell everyone about how realistic this is. Okay, ready? I'm going to start the clock. So basically, they find the asteroid and they were going to blow it out of the sky and they, like, all unified together to go do that with, like, all of these spaceships, and they were going to, like, send, like, nukes at it or something or, like, bombs or something. They were going to do something to deflect it. But then they found out that the asteroid was made of the same metal that they used to make cell phones. And, like, if they could figure out a way to, like, blow it up into smaller chunks and then, like, blow it up over, like, some rural area or, like, some remote area, then they could go get the chunks of metal and, like, have, like, cell phones forever and, like, stop mining or something. So then as they're about to go blow up the things, they decided not to blow it up. And then of course, when they went to go to the mission to blow up in another chunks, which, you know, all of the people said you could totally do it, it was totally going to work, it failed. And then it was too late to do the original mission, and then they just were gonna be incinerated. And that's what happened. And so that's what happened. And it was made of metal. That was it.

CHRISTINA HERNÁNDEZ [00:08:21] Yeah, it was a very sad movie.

JVN [00:08:25] And then they all just, like, die at the end, and it's really sad. Like, they're, like, the fireball, and they're all just, like, having dinner, and then they all die, and it's like, so sad.

CHRISTINA HERNÁNDEZ [00:08:32] But I will say this. I was totally in tears at the end of the movie, but it also made me feel more motivated as to why we explore space, right? That's why we need to understand the world around us. That's why we need to promote science communication, because people need to understand, when scientists give recommendations, it's often based on data, right? They, they have a reasoning and we need to be able to, you know, listen.

JVN [00:08:58] I think I need to go more of, like, an Armageddon approach before I go into, like, an overall approach because, like, this is just, I'm gonna assuage my fears first, cause you

know how they say on a plane, you got to take care of yourself first. So I'm just going to, that's what I am going to do right now. So, how big would it have to be to, like, fuck up a whole continent or, like, a whole hemisphere. How big is, like, a hemisphere-fucking asteroid.

TERIK DALY [00:09:18] Okay, that's going to be something that's about, a kilometer or so in size. If you have something that's, a kilometer in size, you're going to get probably, like, a ten kilometer crater and you, like, could trigger the possible collapse of civilization. If it hits in the ocean, you're going to have tsunamis, you're going to change the climate. It's going to be a bad day. If you're talking about, like, a dinosaur level, like, extinction event, you're talking about something that's even larger than that. We think the dinosaur-killing asteroid was, like, Mount Everest kind of size.

JVN [00:09:44] Damn, really?

TERIK DALY [00:09:46] Really, really.

JVN [00:09:47] Wouldn't that, like, knock us off our orbit or is orbit so strong that, like, it doesn't knock you off our orbit if something that big runs into you.

TERIK DALY [00:09:54] So the Earth is, like, huge. Okay, like, the biggest asteroid was actually a dwarf planet. It's called Ceres, and it's, like, the size of Texas. So even, like, the biggest objects in the asteroid belt are really small compared to the Earth, so it doesn't really change our orbit.

JVN [00:10:08] Ah, okay, fierce, so, but then, the dinosaur one was even bigger than a kilometer?

TERIK DALY [00:10:13] Yeah, like, 6 to 7 kilometers across.

CHRISTINA HERNÁNDEZ [00:10:16] Wow.

JVN [00:10:17] And that was the Yucatán Peninsula, right?

TERIK DALY [00:10:19] Yep. We call that crater Chicxulub.

JVN [00:10:21] Yes. Because when hubz and I went there for this vacation last year and then we were like going swimming in the underground caves. And the fierce tour guide told us that those caves were created by these huge chunks of liquid hot magma that got, like, spit out from the asteroid and then, like, plunged through because there's, like, these holes, and then you just look down and there's all these, like, underwater river caves. And she said those were, like, literally from all, like, the fallout of the asteroid chunks.

TERIK DALY [00:10:45] Yeah the cenotes that are down there?

JVN [00:10:46] Yeah!

TERIK DALY [00:10:47] Yeah, exactly. So there are, they are related, you can actually kind of trace them out geographically and kind of see the structure and how that relates to the crater most. The crater is actually underwater at this point in under sediment, but you can map out sort of the perimeter based on the snow days.

JVN [00:11:00] Wow, that is so cool. Okay. So that was the dinosaur one. Has there been, like, another really big one that fucked up everything?

TERIK DALY [00:11:10] Well, I think it depends about what you mean by, like, "everything." Okay, so, like, back 50,000 years ago, there was an asteroid that was about 50 meters across—so think about, like, Olympic swimming pool size, made of metal—that went and impacted in what is now near Flagstaff, Arizona. Ten kilometers from the impact point, you're just incinerated. Twenty four kilometers from that, if you're a large animal, you're, like, wounded or killed. So that's, like, you know, large animal is a nice name for a person. And then even out beyond that, you've got hurricane force winds. And that's just something the size of a swimming pool, Olympic-sized swimming pool. So asteroids, they come in real fast, many miles a second. And even when you're small at that size, you have a lot of energy. And so you can do a lot of damage. The most recent example, actually, of one that caused damage was back in 2013, an asteroid about 20 meters across or so exploded over Chelyabinsk, Russia.

JVN [00:12:05] I remember that!

TERIK DALY [00:12:06] Yeah. And so there's actually on YouTube, like, amazing dashcam footage of it because the Russians, I guess they all have dash cams, but that sent about 1600 people give or take to the hospital and caused, oh, something on the order of tens of millions of dollars in damage.

JVN [00:12:22] But no one died?

TERIK DALY [00:12:23] No one died. No. And that actually exploded in the atmosphere, sent out a shockwave, which then broke windows. So most of that damage was from actually broken windows cutting people. It didn't actually hit the ground. It was too small.

JVN [00:12:35] Wow. Okay, Christina. Um… are we…

CHRISTINA HERNÁNDEZ [00:12:40] I'm, like, terrified now.

JVN [00:12:42] Yeah, are we okay?! Like… yeah. Okay, so we are. Everyone's fine so far. Now that I've really gone in with the worst, you know, I like to go on with the worst first and then, you know, we work back from there. So, you know, Jennifer Lawrence and all of those fierce

scientists, the scientists are doing their things. You know, which, honestly, when I talk to you guys, I wish you could see these like scientists on Zoom. I feel so comforted around the presence of scientists. You guys are so capable. I feel so good. Really, you know, it feels better knowing these guys are there. So if J.law looks up IRL, J.law looks up and says, like, "There's one hurtling towards us," would we be totally fucked? And then if so, like, could we tell where it was going to hit so we could all take a plane, like, elsewhere? How do we predict where it's gonna hit?

CHRISTINA HERNÁNDEZ [00:13:31] We track asteroids. We're constantly monitoring them. And because we know orbital mechanics, we can actually figure out where they could land or impact, right.

TERIK DALY [00:13:42] Yes. So at the Jet Propulsion Laboratory where Christina works, there's actually a center for near-Earth object studies. And their main job is to actually monitor the orbits of asteroids that come near Earth and compute the probability that one of them might impact Earth. Right now, we don't know of any that will. If you first discover something, the main limitation is data. So asteroids are moving through the sky and you need to see that movement in order to be able to fit an orbit to it. So, like, when you first find it, you may not have very good information, but then as you observe it again and again and again, you build up a really good orbit. In March of this year, actually, that same center for near-Earth object studies predicted that a small asteroid would impact and blow up in the atmosphere near Greenland. And in fact, it did, harmlessly. It was only it was, like, you know, six feet across, a small asteroid. But with enough observations, yeah, JPL's Center for near-Earth Object Studies can predict really well where it would hit. The challenge is sometimes we don't have enough data to really make those predictions when we first find an asteroid.

JVN [00:14:39] Christina, do you remember in Don't Look Up how long it took for the asteroid to impact from when they first find it in the movie. Don't they have, like, a year or, like, a year and a half or something?

CHRISTINA HERNÁNDEZ [00:14:47] Yeah. And they had an estimate, right? And it's kind of like what Terik's saying, it's like, you're limited by the data that you have available in your understanding of asteroid formation and asteroid paths. Now, what was interesting, though, in the movie, that data started to get updated. So if you remember, the timeline kept moving up in the movie because as the asteroid was getting closer to Earth, they were getting more data because it was easier to observe. That's what's great about having, you know, centers and scientists who are constantly "looking" up and trying to track these objects over time because that's how we can, you know, monitor, "Did anything change in the sky between, you know, last week, last month, and today?"

JVN [00:15:31] Now, do we have any spots, like, when you're driving in your car and you turn around, you can't see? You know, it's like, "I didn't see. Sorry!"

TERIK DALY [00:15:37] So NASA and international partners. They are scanning the skies every night to find asteroids. And I actually just looked today, and the most recent asteroid that comes near Earth was discovered yesterday. That was asteroid number 2918. So that was the 2918th asteroid found near Earth. And it was just found yesterday. But one of the challenges is looking on Earth, right? We have to look at the night sky. And so if there's something coming up from the dayside, we can't see it. So what we really need is a telescope in space, because in space you're not limited by the day-night stuff for where you can see.

JVN [00:16:11] You're not?!

TERIK DALY [00:16:12] So…

JVN [00:16:14] Doesn't the sun fucking shine in the goddamn universe? I swear to God. This is the part about astronomy that gives me a nervous breakdown. All this stuff about, like, I just. Okay, it's fine, calm down. This is not about, you know, understanding it. Tell us about why. Oh, because I guess just in space, it's, like, in that movie Gravity. And, like, all the space movies that you get through the atmosphere, everything just turns into, like, night sky.

TERIK DALY [00:16:40] On Earth, like, the only direction we can look is away from the sun. But if you're in space, you could look out like the twilight line, basically. So you could avoid looking at the sun and see more of the dark sky. So there's actually, NASA's working on a concept called the NEO Surveyor, which would be a telescope to go in space. And that's its only job is to look for asteroids that would come near the Earth. And the goal is that within five years or so, it would find about two thirds of the asteroids large enough to cause regional devastation, which would really, like, help us feel better, right? Because right now we don't know of any asteroids coming with a name on it, but we also know we don't know where most of the asteroids are that are large enough to give us heartburn. So if we find them, we can sleep better at night.

JVN [00:17:20] Well, fuck me. Why do we got to wait five years?

TERIK DALY [00:17:24] Well, asteroids are hard to find! They're small, right, compared to, like, planets and stars. They're dim and so they're hard to see. You have to be able to have a really good telescope to find them.

JVN [00:17:34] Kind of makes you wish there was some friendly alien somewhere so we could get some other fierce data from some, like, other perspective.

CHRISTINA HERNÁNDEZ [00:17:39] That would be nice.

JVN [00:17:41] Right? So there's, like, regional devastation and there's, like, civilization collapse. What other cute indicators do you have to define how fucked we are in terms of asteroid impact?

TERIK DALY [00:17:57] Okay, let's start, like, at the other end and be like, you know, "small enough we don't care." Okay. Something that's, like, the size of my Toyota Corolla is in the atmosphere. It's going to burn up. No one cares. Something that's the size of, say, like, school bus or a couple of school busses. Like, now we're talking something that might explode in the atmosphere and release a shockwave that might cause, like, broken glass and things like that over like, you know a city kind of sized area. So if it happens over, like, you know, Siberia and no one's there, we probably don't care. If it happens over L.A., we worry.

JVN [00:18:29] Okay, so that's scary. We don't want that to happen over a major urban area.

TERIK DALY [00:18:33] Yeah we don't. Right. And then, like, 50 meters is the kind of thing that could cause, like, over a metropolitan area. Like, if you, you know, took that one I talked about in Arizona and, like, set the damage sort of over DC, like, you lose all of DC in that fireball and parts of the surrounding areas. So really, like, 140 meters or so across, so think, like, Giza Pyramid, that's where I worry about, like, regional devastation.

JVN [00:18:59] So there's, like, "nothing," "city fucked-up-ness," then there's, like, "regional." And then there's, like, "civilization collapse."

TERIK DALY [00:19:06] Yeah. Those are some good buckets to put things in. Mhhm

JVN [00:19:09] Okay, got it. And then what is that? Okay. Okay. Okay. Okay. Okay. Okay. Okay. Just one more Armageddon question. So I heard you say earlier with the Olympic-sized swimming pool. High winds. Fireball. If it happened near the ocean, is there maybe a tsunami from that one? Is there, like, big waves from that one?

TERIK DALY [00:19:30] If it hits the ocean. So asteroids can be made of different things. So some are, like, made of metal. Okay. And those are really strong. So they can get through the atmosphere better than something that's weaker. So think of, like, a pile of gravel, like that's not really strong. So those gravelly kinds of asteroids might burn up in the atmosphere, explode in the atmosphere, whereas a metal one might make it to the ground at that size. And if it gets to the ground, then yeah, if it's in the ocean, you might get a bit of a tsunami.

JVN [00:19:58] Then, like, if you're in the crater, you're definitely fucked. And then if it's the civilization one collapse, the reason that that collapses is because it sends up such a dust fireball that doesn't it, like, cool the Earth or something because the sun can't get through.

TERIK DALY [00:20:11] Yeah, it changes the climate. So it's, it's blocking out the sun. It's also changing the composition of the atmosphere. You can get, like, acid rain and things like that. It's just, it really changes the global ecosystem.

JVN [00:20:22] And for how long? Like, how long after the Yucatán Peninsula dinosaur one did it take for it to go normal probably.

TERIK DALY [00:20:29] There's, like, "bacteria grows here" normal and there's like, you know.…

JVN [00:20:32] Cute normal, like, furry mammals. I want to kiss your nose. Maybe there's, like, some cute Neanderthals and, like, some, you know, I don't know, evolution's happening and there's waterfalls, there's Land Before Time. Oh, wait Land Before Time! No!

TERIK DALY [00:20:46] Wrong way, wrong way! [CROSSTALK] I would need to look that up for you. And the reason why is that actually, a few years ago, they took a boat and they drilled samples through the Chicxulub crater. And so they actually measured, like, when did life start to come back? But I don't have those numbers off the top of my head.

JVN [00:21:05] Wow. Christina, remember how in Don't Look Up that asteroid was made of metal?

CHRISTINA HERNÁNDEZ [00:21:09] It was!

JVN [00:21:12] Noooo!

CHRISTINA HERNÁNDEZ [00:21:14] But I do feel comforted that folks like Terik are on this.

JVN [00:21:18] Yeah. And we would also, like, never let them go get the metal for the laptops and, like, the Tesla cars. Right. Or we totally would. So you both are working on asteroid-related missions right now. So, like, what are your missions' mission statements?

CHRISTINA HERNÁNDEZ [00:21:32] I'm working on Psyche and to be honest, I kind of joined this mission because the tagline is "Journey to a Metal World," and I love heavy metal. So for the first time, right, we're going to an asteroid that's not made up of, you know, rock and ice, but we actually think it's made up of metal. Right. So it's one of those metallic asteroids that Terik was talking about. And what we think is really interesting is that that could be the remnants of a planetary core. So planets like Mercury, Venus, Earth and Mars, they have metallic cores in the inside. And if we think that this asteroid could be a remnant, we might be able to understand a little bit more about our solar system, how planets like the Earth formed. You know, what happened to this asteroid? Was it a planet or did it form some other way? And so the objectives of Psyche are really to characterize, so understand the asteroid as we approach it, understand the topography, what's the shape of it, you know, that might tell us how it was created and understand the gravitational field, right? Any piece of mass in space has a gravity field. And so how is it moving? How is it wobbling? And then most importantly, confirm that it's made of metal.

JVN [00:22:48] Ohmigod, queen. I'm just a little stressed because if it's the metal, isn't that going to fuck up your instruments?

CHRISTINA HERNÁNDEZ [00:22:56] No, actually! So Psyche is in the asteroid belt. So it is not an asteroid that is what we call a near-Earth object, right? The ones that are impactors. So Psyche is actually, you know, just chillin between Mars and Jupiter and we're going to go and study it. And we built our science instruments, you know, like, we did on Mars 2020 and our other missions to understand that asteroid. So we have a magnetometer that's going to understand the, the magnetic field. Right. It's made out of metal. You know, maybe there's something interesting there. We have a camera because everybody loves, you know, cute pictures of asteroids and it has different filters. So we'll be able to understand what that asteroid looks like, you know, from different perspectives. And we have a gamma ray spectrometer. So that's, you know, this cool gizmo that's going to help us understand the elements. You know, what is this asteroid made out of? And additionally, we have a tech demo. It's not really part of the asteroid science itself, but it's studying laser optical comms. So what that means is instead of sending data from the Earth to our Psyche spacecraft, we're going to be using lasers for sending the data back and forth. So that's kind of cool.

JVN [00:24:15] So basically with Psyche, the plan is to, like, build this gorgeous craft. It's going to fly to the asteroid belt, land on the asteroid, learn about it, and then tell us all about asteroids.

CHRISTINA HERNÁNDEZ [00:24:26] So it's actually going to orbit it. So we are building a spacecraft with one of our partners here in California, Maxar Technologies, and it's actually a solar electric propulsion spacecraft. So it uses little electrons and charged particles instead of fuel to get from Earth to the asteroid. And so once it's at the asteroid, we're going to have these beautiful orbits at different distances so we can use our instruments to observe the asteroid.

JVN [00:24:55] Oh, my gosh that is so cool. Okay, wait. So, Terik, tell me about your gorgeous mission and its mission statement.

TERIK DALY [00:25:01] DART is the Double Asteroid Redirection Test, and it is NASA's first planetary defense test mission. So planetary defense refers to all the things we do to understand and then lessen the hazard posed to Earth by asteroids and comets. And the test part refers to testing a technology to potentially prevent an asteroid from hitting the Earth. So as I said, right now, we don't know any asteroids that are going to hit the Earth, but we know we don't know where all of them are. And so we want to be ready to do something about it if one day we find one that is coming towards us. So what we're actually doing, we've built a spacecraft, we've launched the spacecraft in November, and it is right now cruising, and on September 26th, it is going to purposely slam itself into an asteroid, actually the moon of an asteroid, and then change that asteroid's orbit. So what that means is that that asteroid will be in a different place at a particular time than it used to be. And we'll measure the change in

that asteroid's orbit using telescopes on the ground. And by doing so, we'll see how effective our spacecraft was at shoving that asteroid and changing its orbit. Then, we'll take that information and use it to help us plan future missions so that if the time comes when we do need to give an asteroid a shove, we are ready to do it. I mean, think about it, like, you know, if you're driving in your car, you don't test your airbag when you're in a car crash. Right. You test it beforehand. This is like the "let's test the technology before we need it so that if we do need it, we're good to go."

JVN [00:26:31] Two follow-ups to that. Comets! Aha! Great, we didn't really talk about those, so, what the fuck? You know, excuse my French but, like, what are those? Do we need to also be existentially worried about comets as well?

TERIK DALY [00:26:48] Yeah. So asteroids are most, like, rocky and metal with maybe a little bit of ice and stuff and then comets are more icy. Okay. They're, like, formed way out, outer solar system. Think like Pluto and beyond. The ones that are really far away, like, by Pluto and so forth, they're really hard to predict, we call them long period comets. And they come in fast, it'd be hard to do something about. But the good news is that most of the objects we know of are asteroids, that's the threat that we understand, that's a threat we can do something about. So that's what we're focusing on. Comets exist, yes, but they're not the threat we're most concerned about right now.

JVN [00:27:21] Is it because they're really icy so they might burn up so much on entry?

TERIK DALY [00:27:25] Think about, like, driving in the car, like, bugs on the windshield, right? Like, if there aren't a lot of fireflies out there, you're just not going to get fireflies on your windshield. So you don't worry about cleaning them out, right? So it's kind of like that. Like, we have a sense of what kind of the population is out there of asteroids and comets. We understand that asteroids are the ones that are going to be most of our problem. So that's what we focus on because that's the most probable situation.

JVN [00:27:47] Okay. And then also, the DART mission, when did that, like, start?

TERIK DALY [00:27:52] The concepts for the DART mission go back a ways. So in 2010 there was actually a report out of the National Academies that said, "We should test this technology called Kinetic Impact." And then five-ish, maybe seven-ish years after that, the DART mission sort of came to be NASA eventually decided to fund it. They "confirmed the mission" is the phrase, and then it went into development and as I said, it launched last November. So it's been a period of, you know, many years getting it developed. And I'm sure Christina can talk, too, like, the development timeline for any space mission often comes down to engineering constraints, right?

CHRISTINA HERNÁNDEZ [00:28:26] Absolutely. As you're building this vehicle for going to the outer solar system or middle solar system, you need to make sure that it's going to work.

Right. We do a lot of testing and I'm sure, Terik, with that new test and the mechanism of kinetic impact and wanting to make sure we understood it, you had to do different types of testing and you also had to make sure that you hit your target, right? So scientists and engineers work together to build it and that just takes time.

JVN [00:28:52] Fascinating. So with both of your missions. Can you tell me about what your respective roles are in these missions? So, Christina, let's start with you. What do you do in yours. Let me guess! Engineer!

CHRISTINA HERNÁNDEZ [00:29:04] Yes, I am an engineer. And then usually there's, like, five or six adjectives attached to that, right? So by trade, right, or by, you know, title, I am the Flight System Behaviors Lead and the Flight System V&V Lead. So verification and validation, all of that to say what I'm in charge of is making sure that the Psyche spacecraft is built correctly. Right. Like, we didn't connect something incorrectly or something doesn't break. But more importantly, my job is to make sure that this spacecraft is going to work once we get over to Psyche. So I help a team of engineers, right? It's never just one person. And we do testing with software, with hardware, and we're putting it together right now. We're over in Florida and we're doing our final test to make sure that we are ready for launch.

JVN [00:29:56] I feel like I used to drive home from work after doing hair, like, cry because they'd be like, "I'm never going to learn how to do these haircuts the really way that I want to." But you guys have, like, so much pressure. So thanks for doing that work. Anyway, just, you know, had to say it, like, love you Christina, you're the best. So then you Terik, you are a ___ in your mission.

TERIK DALY [00:30:16] Yes. So I have the title the Deputy Instrument Scientist for the camera that's on DART, the camera's name is a DRACO. It's an acronym, but it's called DRACO. So that means that my job is to work with the engineers—because as Christina said, it's all collaborative—to make sure that that camera does everything that it needs to to make us hit the asteroid, and then also to ensure that the images that camera takes are delivered to the public and archived permanently so anybody can access them anywhere. The moment the spacecraft crashes into the asteroid, the camera stops working, right? That's by design, because the spacecraft goes at, like, 15,000 miles an hour. It goes boom. Then I put on a new hat and that hat is to actually use the images from that camera to figure out how big the asteroid was. Because in order to figure out how effective our shove was, we need to know how much the asteroid weighs, so we do that based on the size and an estimate of the density. So, like, the first 30 days after impact, I'll be frantically on my computer with some colleagues working to figure out how big that asteroid was.

JVN [00:31:20] And then when's impact going to be again?

TERIK DALY [00:31:23] 7:14 p.m. Eastern Daylight Time on September 26th.

JVN [00:31:26] September 26…Oh, my God. I'm going to be in fucking Australia. What time is that in Australia? Is it going to be televised? Could we see that camera recording somewhere, darling?

TERIK DALY [00:31:38] NASA is still figuring out the details of what's going to be shown. But yes, something will be shown. There'll be details available on the NASA website.

JVN [00:31:48] Just a little bit more follow up on asteroids. How do they get made?

CHRISTINA HERNÁNDEZ [00:31:52] I can try and take a stab. And this is an engineer's perspective or "space geek's perspective" science. But from my understanding and Terik, correct me if I'm wrong. Asteroids were formed when the solar system was forming. Right. It was chaotic. There was impacts and the asteroids are remnants of all of that. And so they're roughly about what is it, like, 4.6 billion years old?

TERIK DALY [00:32:16] 4.6 billion, yeah.

CHRISTINA HERNÁNDEZ [00:32:18] 4.6 billion. Yeah, so they've been out there and, you know, because of orbital mechanics and gravitational pulls from the sun and the planets. I believe a majority of our asteroids are actually between Mars and Jupiter, right, Terik?

TERIK DALY [00:32:30] That's yeah, that's where one of the big populations is. There are some other asteroids that are out sort of following along and leading ahead of Jupiter's orbit that might have kind of a similar number. But for sure, the main asteroid belt between Mars and Jupiter is where a lot of the asteroids live.

JVN [00:32:45] So you have the asteroid belt. Like I remember that. And like learning about the solar system, I made, like, a really great solar system with supplies from Benjamin Franklin, which is this, like, local craft store in the middle of America and I made, like, I remember making the asteroid belt. Mine was out of M&Ms, and it was really good.

CHRISTINA HERNÁNDEZ [00:33:01] Nice!

JVN [00:33:02] Yeah, it was a really good asteroid belt. So there's that main one because it's like. Because it's like. The first planet's Ven–, [CROSSTALK] Jupit–, Mercury. And then Venus. And then us.

TERIK DALY [00:33:20] Yup.

JVN [00:33:21] Venus. Mercury. No Mercury, Venus, us, Mars, asteroid belt, Jupiter, Saturn. Right?

TERIK DALY [00:33:30] Yup!

JVN [00:33:31] Uranus, Pluto!

TERIK DALY [00:33:32] Neptune. And then– [CROSSTALK]

JVN [00:33:34] Fuck! That Neptune. It's always fucking me up. I'm okay. So I feel like I was, like, that meme where you're, like, stepping on the rocks in the lake, and then you almost make it to the end, but then you, like, fall on the very last rock before you leave. So rude. So, wait, where was the other belt, Terik?

TERIK DALY [00:33:51] So Jupiter is, like, orbiting the sun. And then there's the population of asteroids that, like, go ahead of Jupiter in its orbit. And one that goes behind Jupiter, we call those Trojans. They, they live at, like, particular points in space where gravity balances out in an interesting way to make them stable. We've never visited them. But NASA recently launched a mission called Lucy that's going to go and actually visit some of these Trojan asteroids, which will be really, really cool to see.

JVN [00:34:18] So that thing will have to, like, navigate the first asteroid belt to, like, not get hit by an asteroid there. Right? To get through all that and then get all the way over there, right?

TERIK DALY [00:34:27] So if you're thinking in your mind, like, you know, Star Wars asteroid belt, like, where, you know, so the asteroid, but mostly empty space. So it's like space is just too big and asteroids are small. So, yes, there are like, you know, we know about the million asteroids, but you have to work really hard to actually go find your asteroid. I mean, I don't know what it is like for Psyche, but maybe you can speak to that, how hard it is to get to Psyche specifically, Christina.

CHRISTINA HERNÁNDEZ [00:34:50] Yeah. So after Earth, we'll go to Mars. We'll do a flyby of Mars. Right? We're gonna use the gravity of Mars to kind of give us, like, a boost, kind of like when you're playing Mario Kart and you get that little mushroom. Get your little boost, so you can get to the Psyche faster. But Terik's right, right? You know, there's a lot of space, right, in outer space. And we do analysis to kind of protect our spacecraft in case there's little pieces of rocks and ice that hit our spacecraft. As we're in space a long time, the probability of getting hit with something little and small is pretty high.

JVN [00:35:21] Bringing it back to regional and civilization collapse/devastation. It's not *these* asteroids that we're worried about because aren't they in, like, a fixed orbit? Or does ours cross with theirs? Or is there, like, a rogue asteroid that we haven't seen before from some other planet that got knocked off its orbit? Now it's hurtling towards us.

CHRISTINA HERNÁNDEZ [00:35:38] Yes, so Psyche is in the asteroid belt, but I'll let Terik talk about those near-Earth objects.

TERIK DALY [00:35:43] Yeah, so the near-Earth asteroids, the ones that come close enough to Earth we worry about them—, those are different from the main asteroid belt. We think that over time, asteroids leave the main asteroid belt due to gravitational interactions and solar forces and things like that. And then they move into orbits that can bring them near the Earth. The larger asteroids are the ones that are easier to find because they're brighter in the sky. There are exactly four asteroids that are large enough to be, like, dinosaur killers that come near Earth. And we know where all four of those are. We know they're not coming to us. And we've found 95% of the asteroids that are a kilometer. It's, like, you know, continental devastation-size. We know where 95% of them are. So we're not really worried about those. The place where we're still vulnerable is that sort of regional devastation range, we've found maybe, like, 40% of those. So we know we have room to find more things there. Once you've found all the asteroids you think are out there, and if it turns out none are coming our way, like, we can all just sleep better at night. Right? The earlier you can find them, if there is one coming towards us, the more options you have to change its orbit or to move it out of the way or to evacuate people. So finding them early is really the name of the game because it gives us options in how to respond.

JVN [00:36:51] Wow. I am triggered/intrigued. Okay, so we talk a lot about, like, the history of science and just, like, you know, history things on Getting Curious, which we love, very into history. What's the history of studying asteroids?

TERIK DALY [00:37:05] So back in the 1700s, late 1700s, astronomers thought there was, like, a missing link between Mars and Jupiter. And so there was this group of astronomers that, like, banded together. They called themselves the "Celestial Police" to look for that planet. So in 1801, an Italian astronomer found a body that was in that region called Ceres, which folks thought was "the missing planet." But then they found more and more and they realized that there wasn't a planet there. There were a bunch of asteroids. So that's sort of, like, the very early time, late 1700s and early 1800s. Nowadays, you know, NASA is searching and international partners every night are searching the sky for asteroids and they're finding them. Like I said, the most recent near-Earth asteroid was found yesterday. And there's actually, so there's a space-based telescope called Neo Surveyor that NASA's working on. But there's also a very large ground based telescopes called the Vera Rubin Observatory that'll come online soon. And once both of those are in place, we will have a much better understanding of what the asteroids are that are out there and whether any of them pose a threat to Earth.

JVN [00:38:12] Interest. Okay, wait, Christina, Psyche mission. So you had to do Mars and Psyche simultaneously?

CHRISTINA HERNÁNDEZ [00:38:19] I did!

JVN [00:38:20] They have you multitasking out here. Was that hard?

CHRISTINA HERNÁNDEZ [00:38:23] Gotta work. Got to get paid.

JVN [00:38:26] Was that, like, really was that hard, like, switch? Because, I mean, you're engineering such different things that I guess is it or is it just like deep space is deep space. So it's kind of like you and you got to make sure that everything works right, so…

CHRISTINA HERNÁNDEZ [00:38:38] It's very different, right? So and you can even think about it. They were at different phases, right? We were at Mars, right? We were, you know, chugging away at Mars, on Mars time. But Psyche was still in the process of putting all of its boxes together to test it, to build the spacecraft. So it was definitely tough at first, right. But, you know, with some good music, some coffee. You know, you can get through anything. And so now, you know, I'm just 100% on Psyche and it's much easier, right, because you're, you're in one place of the solar system instead of context switching.

JVN [00:39:13] So what's the technology that you're using to find out, like, what the metal is there, right?

CHRISTINA HERNÁNDEZ [00:39:20] Yes, and that's where my love for science instruments come in. So even though I'm on the flight system, you know, I'm helping on the, "the bus" that's going to get us to Psyche. Our payload team is working on some really cool instruments. So as I mentioned, right, we have a magnetometer. And so that is a really cool instrument that basically helps detect a magnetic field and that helps us understand if something's magnetic or how strong the magnetic field is, what it could be made of. In addition, we have a camera, right? Because what I've really come to appreciate through Mars exploration is it's all about the photo, right? Because the photo is evidence that we as humans understand visually, and it helps us see things in different perspectives as you put on filters, right? Kind of, like, you know, our Snapchat filters. Sorry, there's a kitten in the background!

JVN [00:40:11] No she's so cute, I love that cat. For one second I thought you guys, you can't see it, listeners, but Christina's cat is playing so cutely over her shoulder. But I thought that, like, there was like a random loose snake that, like, somehow broke in your house but it's really just like a feather. But I was like, "Oh my God, Christina, there's a snake!" But it's really just like a cat toy. Everything's fine.

CHRISTINA HERNÁNDEZ [00:40:26] Yeah, in addition to being an engineer, I also foster kittens and cats also. That's, like, my part time job.

JVN [00:40:31] Oh my gosh! Do you follow the Kitten Lady?

CHRISTINA HERNÁNDEZ [00:40:35] Oh, my gosh. I love Hannah Shaw. We can talk about it later. She's amazing.

JVN [00:40:38] I love her! I'm obsessed with her! Not to, like, namedrop, but she has been on Getting Curious. I'm just saying!

CHRISTINA HERNÁNDEZ [00:40:45] I saw that episode and I loved it.

JVN [00:40:46] So good.

CHRISTINA HERNÁNDEZ [00:40:47] Anyways, back to our science instruments. So we talked about the magnetometer. We talked about our multispectral imager. Right, which is our camera. We're going to actually be using the telecommunications system, right? So our antennas do gravity science. So in answering the question of what the asteroid is made up of, right, by understanding its gravitational field, you could understand how big it is from a mass and weight perspective. And also, you know, what's the trajectory of Psyche going to look like over time? And last but not least, you know, my favorite type of science instruments have become spectrometers. So we have a gamma ray and neutron spectrometer. So it's kind of like a two part instrument. And by emitting neutrons and gamma rays, right, the spectrometer actually reads back the energy from Psyche to try and figure out what elements it's made up of. And so, you know, as we learned with Mars, right, we have different types of science instruments that do different types of things. But together, right? They all work together to kind of help answer those fundamental questions about how Psyche came to be, what Psyche is made up of. And most importantly, even though asteroids sound like a really scary thing when it comes to our amazing and loving, like, sci fi movies and Terik's commentary, they also help us understand, you know, how we got here, right? How the solar system came to be. And more importantly, can that teach us anything about other solar systems out in space? So even though it can sound scary, it's also pretty cool and amazing.

JVN [00:42:24] So asteroids could really be our friends. We just have to learn how to work with our friends!

CHRISTINA HERNÁNDEZ [00:48:28] Exactly.

JVN [00:48:29] Okay, wait, so then just really quick. I just have one more asteroid question, well, a few more. Who says that? "One more." I have a couple more, but, so if one misses us but it stays on that same orbit, couldn't it come around, like, again? Is there, like, a consistent problem child of the asteroids?

CHRISTINA HERNÁNDEZ [00:42:49] The sun is kind of the diva, right. And everything kind of goes around the sun, right? And then the smaller objects, like the planets, also have moons and other objects that orbit it because they all have, like, mini gravitational fields. But, you know, as an asteroid passes, it might have a really long orbit, right? What that means is like it might take its revolution, right? It could be hundreds of years before that asteroid comes back around Earth or it could be 50, 20 years. It all depends on the orbital mechanics. And so like

Terik was saying, we have scientists who specialize in tracking. Right. They're asteroid trackers. And they help us understand once the asteroid passes, when's it going to come back?

TERIK DALY [00:43:35] One of the things I think is super important to realize is that, like, our solar system is, like, one of many. So we think there's something like 100,000 million stars in the Milky Way. And that's just, like, one galaxy. And as Christina said, there's like a lot of galaxies. There's probably 100,000 million planetary systems around those stars which could have their own asteroids. Right.

JVN [00:43:58] Oh Jesus!

TERIK DALY [00:43:59] We've seen debris discs around other stars. But those, those ones don't come near us, right, they're on their own stars. So don't don't lose sleep there.

JVN [00:44:04] Should we be looking on telescopes to see about those planets, to see if we can see any gigantic, like, craters on other planets from asteroids?

TERIK DALY [00:44:14] So right now, we do not have the technology to be able to see that. Right. So these things are, like, lightyears away. They're small points of light, you know, that you can kind of look at with giant telescopes. They're just, they're cool, but they're not, like, they don't raise my blood pressure. They're just, like, "Oh, that's cool."

JVN [00:44:30] So then back to DART. Ah! So how are you guys, like, testing that closer to Earth? Like, do you just do, like, little mini baby models or something?

TERIK DALY [00:44:39] Test which aspect?

JVN [00:44:41] Like how to slam that fucker into her?

TERIK DALY [00:44:43] Yeah, yeah, sure. So we, we're using a technology called Smart NAV. The spacecraft is actually guiding itself to hit the asteroid. In the last 4 hours, it is a self-flying spacecraft. It's really smart. So what it does is it takes the image that the camera sees and then it does some math on that image and then tells the spacecraft, "Oh, I need to go this way or I need to go this way." But it's actually kind of, like, mind boggling is so we're hitting the moon of an asteroid. So this little asteroid is called Dimoprhos and it's orbiting a larger asteroid called Didymos about once every 12 hours. We're going to hit that smaller asteroid. The spacecraft can't even see that asteroid until less than an hour before impact. It's not until just a few seconds before impact that we can make out, like, features the size of, like, you know, vending machines on the surface. And despite being able to not see its target until less than an hour before it has to hit it at four miles a second, the spacecraft is still smart enough to fly itself to that point. In fact, you can think of it of, like, imagine this spacecraft is, like, using this smart now technology. It, like, stops maneuvering, like, over the Indy 500 and then it just

keeps going all by itself towards Baltimore and lands inside the baseball stadium. All by itself. No humans involved.

JVN [00:46:07] If it misses, does it have the technology to be, like, "Oh, my God, I missed, like, I need to do another pass."

TERIK DALY [00:46:12] As Christina mentioned, this validation and verification, right, all this testing that gets done to make sure things will work. So on the ground, people have been simulating this in computer models for years. And so, you know, we people understand what the probability is of impact. We are confident that we will hit the asteroid because that's the technology we've been testing of, we've demonstrated that here on the ground. We verified it. We validated it. The one thing we can't control, of course, is the asteroid. We actually we don't know very much about what we're going to hit. No one's ever, like, seen it separate from the big asteroid. And so the biggest unknown is what's that asteroid like? So we make some assumptions. I'm guessing that for Psyche people made some assumptions about the asteroid, too. Make some assumptions. You design to those assumptions. And then the asteroid can sometimes surprise you. So if it ends up throwing us a curveball, then we'll just have to roll with that.

JVN [00:47:02] Do we know if yours is metallic yet, for DART?

TERIK DALY [00:47:04] So we have measured the way, the way that light reflects off the surface of that primary asteroid. And that looks rocky. It's what we call an s-type asteroid, which is made primarily not of metal, but of, like, igneous kind of rocks.

JVN [00:47:20] So how far off course is the goal to push it? And is this asteroid like a regional-size fuckup or, like a, like, a civilization size ending size asteroid?

TERIK DALY [00:47:32] The asteroid we're hitting, Dimorphous, is about 160 meters across. So that's the size that we worry about for regional. [CROSSTALK] Yeah. That's actually part of why we chose that asteroid. It's the right size. We expect that we're going to give it a shove and change its orbital period by something like a few minutes, which is actually enough. We can measure it from the ground using telescopes and then we can look at that change in the orbital period and how much we think the mass of the asteroid was. And then use that to figure out how hard of a push. Imagine a rocket. It goes up, right because it is ejecting material behind it. Okay. So if, when the spacecraft hits the asteroid, not only does it push the asteroid, but it also launches material and that material goes the other way. It's a little bit like a rocket engine. So the overall push from the asteroid is more than just the spacecraft. It's the spacecraft, plus whatever gets thrown off. How much gets run off depends on, like, what the asteroid's properties are like. Is it really hard or is it kind of soft and porous?

JVN [00:48:28] And you just want more of a push, right?

TERIK DALY [00:48:30] Right. And that's part of the test is, like, what does the asteroid do when we slam into it? How much of an extra push?

JVN [00:48:36] Sometimes I think about, like, this is, like, a little morbid, but, like, I think about, like, car accidents. And I always think about, like, how, like, if one person would have just left, like, 5 minutes later or, like, 2 minutes later, like if just if the timing had been like *this* much different, like a collision would have been avoided. So is that kind of the thinking that you just need to, like, push that thing just, like, just off course enough so that it would miss a direct impact or like, just, like, it's still going to hit Earth, but maybe just get it off of that urban area or something?

TERIK DALY [00:49:04] Well, the objective is to make it so it misses the Earth entirely. Right. You're right. That's for the asteroid and the Earth to crash, they have to be in the same place at the same time. So we want to avoid that. So what we do by changing that orbit is we make that asteroid to be in a different place. Now, if we can make that change in the orbit, say, like ten years in advance, there's a lot of time for that asteroid and the Earth to go around the sun and let those positions change. If we find an asteroid, say, six months before impact, we unfortunately don't have a lot of options for deflecting that.

JVN [00:49:38] So if it's six months or less, we're fucked.

TERIK DALY [00:49:42] It depends on the size, right? Like, if it's this sort of, like, Toyota Corolla size, no one cares. If it's, you know, something that's, like, the size of the Pyramid of Giza. Yes, we have a real problem on our hands.

JVN [00:49:53] So why couldn't we just use that same technology that's going to fly that fucker at that thing? Because. Oh, because you've been observing it for like 15 years. So, you know, right where it's going to be. We couldn't just fly a spaceship that's got the picture that could just, with a nuke on it or something, to just blow that fucker up?

TERIK DALY [00:50:06] So if you only have a few months of warning, yes. A nuclear deflection or disruption is really the only viable option. Aside from, like, evacuating the area that might be at risk.

JVN [00:50:18] Oooh, which is very, like, a la Armageddon. Like, isn't that why I know that? Because isn't that what they did in Armageddon? Like, didn't they just, like, go nuke an asteroid or whatever.

TERIK DALY [00:50:26] Yeah. Nuking an asteroid is, like, a popular thing in movies, but they're actually, like, there are treaties, right, that prevent the use of nuclear weapons in space.

JVN [00:50:33] Maybe warheads. Like dyn– dynamite these.

TERIK DALY [00:50:36] Yeah, so there are, like, like, policies. I'm not a policy expert, but, you know, if there's like an international working group that deals with these kinds of questions about asteroid deflection.

JVN [00:50:44] But whatever it is, there's this like in that would be more of the mode if it was like a last minute thing.

TERIK DALY [00:56:49] That's correct.

JVN [00:50:51] So when you hit it would you be pushing it, like, forward on its path, back on its path, or, like, north of its path or, like, south of its path, or does it matter?

TERIK DALY [00:51:02] So in the specific case of DART, the way that we're hitting the asteroid is going to put it on an orbit that is slightly closer to the primary asteroid. But depending which way you hit it, you could either make the orbit move out or the orbit move in.

JVN [00:51:19] So the goal is, is to either push it closer to the main thing or farther. But if it was a coming to Earth thing, it would be ooh, it would be orbiting the sun. So then you would need to push it farther from the sun or closer to the sun.

TERIK DALY [00:51:34] Exactly. Because actually how far you are from the sun determines how long it takes you to go around the sun. And so then you change the orbital period. You're no longer in the same place at the same time.

JVN [00:51:45] So you're going to try to make an impact, like, on, like, the outer middle of the asteroid, to, like, push it towards, like, its main planet?

TERIK DALY [00:51:54 So we're actually trying to hit it dead on in the center.

JVN [00:571:57] But, like, the outside of it, so that it's going to move towards the main planet. So if you wanted to make it go out from the main star, wouldn't you need to hit it on…

TERIK DALY [00:52:05] You would hit it kind of like a rear end to give it some extra kick as opposed to what we're doing on DART, which is, like, a head-on to slow it down a bit.

JVN [00:52:12] Right. Okay. Slow it down. Okay, I think I understand. I'm pretty sure. You guys, this so confusing, but I'm, like, obsessed with it. How big do you think it would need to be to push, like, a civilization ending one closer would that just need to be, like, a way bigger spacecraft if it needed to be stronger?

TERIK DALY [00:52:29] It's a push like a much larger asteroid. Yes, you would need a much larger spacecraft. And, you know, people have done kind of like exercises to practice what people might do. And in a really large, like, dinosaur kind of asteroid, which we don't worry

about because we know where all those are, that kind of situation usually involves the threat of nuclear device and a long warning time. Something more realistic, say, like this sort of, like, 140-ish meter size object. People will sometimes say, "Well, you could launch like two darts at it or something like that to be, like, extra sure that you would move it enough." But it does depend on the size of the asteroid, yes.

JVN [00:53:02] Interest. Okay. Wow. I feel like I've learned so much. I'm obsessed. So for Christina, we talked about this a little bit, but I would love this question for both of you. How has studying asteroids different from your other missions?

CHRISTINA HERNÁNDEZ [00:53:18] Yeah, that's a great question. So for me, having come from Mars and then now focusing on an asteroid mission, that was an orbiter, right? We went from a rover and a lander and a helicopter to now it's an orbiter going into space. So from an engineering perspective, completely different environments, right? So we have to design our spacecraft to survive where we're going. And so that was one, one difference, right? So our engineering techniques, the materials that we use were different. Also for an asteroid mission, right, we're worried about getting really cold, right, as we go past Mars. And so we've gotta make sure that if our electronics need to stay a specific temperature, but maybe some of our camera lenses need to stay warm. Right. We kind of balance that out. And so that's the challenge. Additionally, when it came to Mars, right, we were kind of on a direct path, right? Mars isn't an asteroid, but we were landing on that planet and nailing that. But for Psyche, we're using orbits, right? So we have to be able to use the solar system and orbital mechanics to kind of guide our spacecraft using our brains, our software, our different types of propulsion systems. So that was the difference from an engineering perspective.

JVN [00:54:39] So with it getting so cold, do you just have to put the camera, like, more on, like, the inside of the thing so it stays warmer? Or, like, do you have to put a little heater on there?

CHRISTINA HERNÁNDEZ [00:54:47] Yeah, exactly. So our cameras need to be on the outside. We don't want to have our lens cap on, right, when we, when we get to Psyche. And so we use heaters and thermal blankets, which are kind of like those emergency blankets that come on the first aid kits that everybody should have, just in case. We use that to keep our spacecraft warm on the areas that need that heat. So in combination with all of that and our battery power, we can really isolate our electronics and other systems to the temperatures that they need to be to work properly.

JVN [00:55:22] How warm do they need to be to work properly?

CHRISTINA HERNÁNDEZ [00:55:24] So it depends, right. So electronics like to be, you know, nice and cool, right? If you've ever used your laptop on a hot day by the pool? The fan is kind of whirling and, you know, it's not happy. So our electronics like to be closer to, like, room

temperature or cooler. Right. But at the same time, when you're at Psyche, it's really cold, freezing cold.

JVN [00:55:46] Isn't it, like, -500 or, like, just super duper cold out, way out there?

CHRISTINA HERNÁNDEZ [00:55:50] So I don't have the number off the top of my head. Right. But it's cold enough where if you didn't have a heater, your metal would start to get really cold. Any fluid that you have through your propulsion system starts to freeze. And so it's this really fine balance and that's why we do testing. So in addition to the testing, like, that Terik was saying where we are using software to determine where we're going and meeting our objectives, we also put our hardware through thermal tests, right? We make it really cold, we make it really hot, and we make sure that we can operate at those temperatures.

JVN [00:56:27] Does temperature work the same in deep space as it does here?

CHRISTINA HERNÁNDEZ [00:56:30] Yeah. So temperature is just a measure of how much energy, really, something has, right? How warm, how hot it is, right, to the touch, you can imagine. The thing with space is that we don't have an atmosphere in vacuum. Right? So we can't be kept warm by the, the atmosphere that we have here on Earth. So we have to use conductive measures, right, or radiative measures to balance out the heat and temperature. So that's the challenge with being in vacuum, right, is that our thermal properties our heat transfer– how we keep things warm or keep things cool– is a little different than if you were on Earth or another planet.

JVN [00:57:12] So you can't really say, like, what temperature it is, like, way out there because it's, like, not the same?

CHRISTINA HERNÁNDEZ [000:57:18] I have to look up what the number is, I could probably Google it really quick.

JVN [00:57:21] Christina, I'm dying to know! You have to Google it! "How cold it is in deep space?" I just have to know.

CHRISTINA HERNÁNDEZ [00:57:26] "How cold is deep space?"

JVN [00:57:29] Or, like, the asteroid belt. Like what do you have to formulate it for?

CHRISTINA HERNÁNDEZ [00:57:33] [CROSSTALK] Where would we be without Google? Go for it, Terik!

TERIK DALY [00:57:36] It depends on how close you are. So for example, like, in deep space, at Mercury, it's really quite hot. So, or by the sun, like, you have to have thermal protection. If you're out by, like, Pluto, it's even colder than the asteroid belt. So one of the things, as

Christina was saying, the engineers have to design for different kinds of missions is what are the temperatures that the spacecraft has to survive? Because that's different if you're sending a spacecraft to Venus or Mercury than if you're sending to Psyche or Jupiter.

JVN [00:58:03] Neptune. That silly Neptune and Uranus and Pluto. How cold is it out there, like, is there anything, like, on the North Pole or South Pole where it's that cold or is it like negative, like, 10,000 or something crazy?

CHRISTINA HERNÁNDEZ [00:58:14] So, I mean, I just Googled this, right? So it's really important as scientists and engineers that we always know the source where information is coming from. But, you know, in looking at it, it looks like in, in certain places where there is no heat source, like, even from a planet or a solar system, it can get -450 degrees Fahrenheit. So that's pretty stinking cold.

JVN [00:5836] I literally said -500, that was my first guess.

CHRISTINA HERNÁNDEZ [00:5841] So I think you, again, you're a scientist.

JVN [00:58:44] I have, like, a freakish way of predicting, like, numbers! Like that one time on Getting Curious the TV show and they accurately guessed that there was like 100,000 pounds of sugar in that silo. And I was right.

CHRISTINA HERNÁNDEZ [00:58:54] That's impressive. I am terrible at estimating. I always have to count or Google.

JVN [00:58:58 Wow. Who am I? Okay, so that's fierce. This is, like, end of the podcast. Is there anything that you guys want to say about your work or to, like, young aspiring scientists or, like, people who know people who want to get into engineering or this type of science? Let's go to you first, Terik.

TERIK DALY [00:59:14] I think in terms of people who are looking into their field is that the field is changing. It is becoming much more welcoming to people of all identities. It's becoming much more welcoming to people bringing their authentic selves, whatever that is. And so if you don't yet see yourself, when you look at pictures of NASA missions or engineers, know that people are working to make it so that you can see yourself there one day and so go for it because you do belong in these communities.

JVN [00:59:46] Yes! Christina?

CHRISTINA HERNÁNDEZ [00:59:48] 100%. And, you know, I think that's what makes space exploration amazing, right? Because, you know, just the three of us together today were asking each other questions. We're learning different things and exactly what Terik said. Right. When you bring your authentic, curious self, that's how magic happens. That's how we learn

about the solar system around us. And so my, my takeaway too is stay a lifetime learner, right? So, Jonathan, right. You got it, right. You've gotta stay curious, right? Because that's how we learn. That's how we push the boundaries and that's how, you know, one day we might be walking on other planets, right? We might be exploring other solar systems in galaxies. And, you know, it all means getting curious.

JVN [01:00:36] Christina, Terik, we're going to have to catch up with both of you again. We got to find out how these missions go. Terik, I hope you guys blow the hell out of that. Um, what's it called?

TERIK DALY [01:00:44] Dimorphos.

JVN [01:00:45] Yes! Dimorphos! Get fucked, Dimorphos. Not really, but I just hope we nail it. Psyche. I hope you just get all up in there and just observe the shit out of that one and figure out what causes the metal it is. I mean, I'm just so grateful for your guys's work and for sharing your knowledge with us so freely. And thank you so much for coming on Getting Curious.

TERIK DALY [01:01:02] My pleasure.

CHRISTINA HERNÁNDEZ [01:01:03] Yes, absolutely.

JVN [01:01:04] Yay! You've been listening to Getting Curious with me. Jonathan Van Ness, our guest this week with Christina Hernández and Terik Daly. You'll find links to their work and the episode description of whatever you're listening to the show on our theme music as Freak by Quiñ. Thank you so much to her for letting us use that. If you enjoyed our show, introduce a friend honey! Tweet about it, Insta story about it, put it maybe even on your feed. I don't know. Make a TikTok, honey. Is that what they're doing these days? Let us know, we're all about it. We love to spread the joy of Getting Curious. Our editor is Andrew Carson. Getting Curious is produced by me, Erica Getto, and Zahra Crim.