Tracey Peake: [00:02](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=2.24) Welcome to NC state's audio abstract. I'm your host, Tracey Peake. Ever wondered how humans or their robot proxies might explore an asteroid? NC state physicist Karen Daniels has. Recently, she and several undergraduate students conducted experiments on low gravity digging while in zero gravity aboard a parabolic flight. Karen and senior Tristan Emm. Join us today to talk about the challenges of asteroid exploration, how we might overcome them, and whether or not a ride on the vomit comet lived up to its name. Welcome, Karen and Tristan.

Karen/Tristan: [00:33](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=33.65) Thank you. Thank you.

Tracey Peake: [00:35](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=35.39) Let's start off by asking the most obvious question to a non scientist. Why can't we just land a spaceship on an asteroid?

Karen Daniels: [00:42](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=42.43) Well, we've certainly seen people do it in movies, um, and it looks realistic when they do it. So it might seem surprising that there's a problem. Um, but actually just today in my physics class, we calculated, you know, how many g force you get on the surface of, say, a small planet or a large planet. And in fact, small planets because they're not very massive, tend to have low. Gs as a result. And so because of that, um, any material that's on them, if it's not actually solidly part of the body, can easily be bumped off. Um, and escape philosophy is extremely small.

Tracey Peake: [01:21](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=81.44) So an asteroid, if it's not actually just a big solid hunk of rock in space, if you landed on it and it was made up of like grains sort of loosely held together, they'd all just kind of, we don't really know actually, we had few enough experiences, um, but we do know how to calculate the escape velocity.

Karen Daniels: [01:41](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=101.29) Um, and for many small asteroid bodies, new sort of the football stadium size to kilometer size, uh, it's gonna be a few inches per second, the escape velocity. So it's quite likely that we caused a lot of large disturbances. We have in fact landed safely on asteroids. We have missions that have landed, um, however, most of them have haven't gone as well as we would've hoped they were, bounces and tumbles. And we had trouble getting information back. So we know that there have been challenges and what, you know, to what extent those are associated with them being low gravity bodies is part of what makes this something that's of interest to study.

Tracey Peake: [02:17](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=137.28) You're going to set out and study this and since we can't just ship you off to an asteroid somewhere and see what happens when you land on it, we have to design experiments to do that. So what is your idea for figuring out how we might want to land?

Tristan Emm: [02:30](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=150.54) Yeah. As, as Dr Daniels said, one of the biggest problems with attempting to land on an asteroid is. Well, I mean, I guess we identified two problems. One is extremely low gravity, like a baby could sit on an asteroid and throw a ball and it could escape, um, depending on the asteroid. And the second is that unlike in the movies, it's not like this big solid chunk of rock. Um, a lot of it will have surface regolith or as you said, like gravel pretty much or soil of some sort. Everything's at surface and it's very loose.

Tristan Emm: [03:01](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=181.48) And combine that with the fact that it's a very low gravity environment. It's like, okay, well how do we land on this? Uh, so there are a few ways to try. Um, what most landing missions have done is they kind of fire harpoons at it, which as ESA found out is not always a great idea. Um, so that's why we tried to look into, you know, how do the grains react to, I guess probing at different speeds, you know, how much ejecta or how much dirt do we get flying up off the ground in various gravitational environments based on what velocity we poked the dirt with. That's what we set out to look at.

Karen Daniels: [03:43](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=223.95) So another way of thinking about this as, you know, we have, um, as we know in our human interactions, you can force somebody to do something or you can gently influence somebody to do something. And, um, I think that it's worth trying some interaction ideas where instead of hitting an asteroid very hard and fast and hoping to make an impact that way that you sneak something flexible between the grains. And that is a possibly more successful strategy, much like roots are able to grow down into dirt - roots are actually quite weak. Um, you know, dirt as we know from digging in North Carolina, so this can be quite difficult to dig into when you work with a shovel. So maybe something that's flexible and sneaks between the grains would be an easier way to make the same problem work without generating ejecta.

Tracey Peake: [04:35](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=275.78) So you would have something like an anchor that would kind of creep into, in between the grains and then the spaceship could kind of, or the probe or whatever could follow it.

Tristan Emm: [04:44](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=284.78) It'd be like, I'm a much slower, lower impulse way of anchoring yourself too.

Karen Daniels: [04:50](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=290.18) And maybe you need many of these ultimately to do the trick and maybe they need to link up. Um, but it's just the beginnings of, if you will, you know, civil engineering in an unfamiliar environment. So we're used to civil engineering on Earth's environment. We have arrest gravity and we have cohesive. I mean, our dirt on this planet is, tends to be cohesive. It sticks together. Um, we don't really know that much about the regolith in other environments,

Tracey Peake: [05:13](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=313.55) So you guys designed an experiment that would essentially probe this dirt or regolith in different levels of gravity. And in order to do these experiments on earth, you have to ride in a parabolic flight, a plane that makes parabolic flights, big swooping arcs in the sky, also known as the vomit comet. In common vernacular. So tell us a little bit about how that experiment works. You've loaded onto this jet and then what happens? Walk us through kind of what a parabolic flight is like and what you guys do.

Karen Daniels: [05:51](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=351.65) Well, so actually we spent basically a day and a half down at the launch site, not I'm not real launch site visit airport. So we sat at the airport so they have a regular what looks like a commercial plane, but with very big cargo doors on the side and they carry our experiment out there on a forklift and we're allowed to go up and bolt it down and do test runs and earth's gravity and make sure that things are hopefully all set up as we planned. This was, this was fairly stressful, of course not everything went exactly as we had hoped, you know, um, and then we all go to sleep and we eat a light dinner and the next morning we get up and half of our crew went the first day. Um, and so I watched Tristan, walk off with, um, Riley another NC state student and one of our collaborators in the University of Central Florida and they boarded, we watched them boarded the plane and then we waited. And so from the ground it was nerve wracking because we'd spent many months building these experiments and we had no idea if they were going to be successful up there. And I'll let Tristan explain what happened.

Tristan Emm: [07:00](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=420.17) Uh, myself, Riley and Sean got on the plane. There are some seats in the back that you just strapped down into for take off the beginning of cruising. And then once you're at cruising altitude, they give you the clear to get out of your seat, walk over to your experiment. They give you some time to make sure everything's operational. If you need to make any last minute changes while you're at cruising altitude, you're allowed to do that. Um, and then once every team gives their go, uh, they go ahead and a pull up at about one point eight g, so you're, you're going to feel about twice as heavy as normal. And then right after that they'll, they'll, they'll yell, pushing over, and then that's when they start the dive into this parabolic curve. And the first dive we did was in Martian gravity, I believe we did three Martian gravity and that's about one third that of earth's. So you feel about a third of your weight and you kind of bounced around and you're like, okay, well that's pretty cool. Uh, and then after that, uh, you go into lunar and then eventually into microgravity. And in terms of the actual experiment, we had three people. Um, so the experiment was split into two slightly different experiments. Uh, there was a two dimensional one which allowed us to see how force change propagated through the regolith or the dirt. And then the bottom half was a 3-d experiment that had actual crushed gravel, it was basketball, but it was crushed into a fine powder with a mix of, of slightly rougher pieces in there. Um, and that was under vacuum and that also was tested.

Karen Daniels: [08:34](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=514.21) One of the techniques that my lab uses is that because we can't see inside of really any soil like material, it's new, they're opaque, so you can't tell, you can't tell how things are moving inside there, you can't tell how forces is being transmitted. And so as physicists, we want to sort of know the forces on all objects, the velocities of all objects want to be able to track everything. Um, and this helps us inform our theories of how the world works. So we as physicists have tended to use plastic fake sand, um, and so by using a polymer fake sand polymers have some interesting optical properties that if we use a flat layer of them, we can actually see which of the grains are transmitting forces and which ones are not supporting any forces. And what we see is that when you push on one of these materials, the forces are often transmitted through chain, like structure, so grain to grain to grain in a line.

Karen Daniels: [09:30](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=570.3) So one of the advantages of using two dimensional material that we can see everything, one of the disadvantages that it's not actually regolith. And on the counterpoint is in this three dimensional experiments, we're using something that's much more like regular, if it's stimulated regolith that is created by our collaborators at UCF. But that material, we can't see what's going on. Uh, so in both experiments we can conduct, um, mechanical probes where we measured the forces as we insert a flexible probe into the material. And in one of the two experiments we can see what's going on. And the other experiments we can't see as much. And so we hope that by doing both kinds of experiments, we can have the best of both worlds.

Tracey Peake: [10:09](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=609.601) You did your experiments for two days, was it?

Karen Daniels: [10:12](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=612.63) So the second day of different three people went up and we knew some things that already had gone wrong the first day. Correct your errors. We had some time that evening and the next morning to get there early and make some adjustments. Um, and we definitely fixed some things. Um, and then the second day we went up and I was up that day and it was fascinating for me. Uh, so we hadn't been there to see what they saw and we only saw what we saw. We certainly had times when we were either starting or finishing the experiment where you accidentally pushed too hard on the button on the experiment - Newton's Laws, they really are a thing.

Tristan Emm: [10:49](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=649.11) Don't think about it while you're on the ground. But, uh, when you're floating and you push something you float backwards.

Tracey Peake: [10:54](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=654.901) You've got your data. What are the next steps with this process?

Karen Daniels: [10:58](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=658.081) So we've downloaded all the data and we've got it on our servers in the lab and we have students who are doing two things with, um, some, some of us are actually taking the scientific data and trying to look to see if some of our ideas are born out by the data that you know, how hard you have to push and how many grains are disturbed depends on whether we are flying at, Martian or lunar or zero gravity. And so we have both camera images and we've got four sensor images from the diggers and so now we're into data analysis mode. What I would hope to get from it is two things. So one is we have not flown on one of these before. We were new to engineering a scientific apparatus that would work in this environment. So some of the things that didn't go as well as we hoped it was because we were beginners at that. Um, we're now not beginners, so that's good. So that's good. And so we have, so NASA talks about advancing the technological readiness level, right? And so by doing these experiments, we advance our readiness level at conducting experiments that would then help us lead us to the kinds of things you're talking about where we actually can propose better protocols.

Tracey Peake: [12:04](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=724.51) Alright. And aside from Newton's law being a thing, um, and when you push, you kind of fly away from the experiments. Uh, what were the biggest surprises or a surprise, something you were not expecting?

Karen Daniels: [12:17](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=737.11) So we, I had been warned but didn't fully believe it until I flew of the whole process of doing an experiment runs extremely quickly. So you'd go out 20 seconds in double gravity, you got a couple of seconds where they switch over, I got 20 seconds in zero gravity and a few seconds to switch over and you do five of these in a row before they give you a little break. And so for me it's like the experience a bit of having trouble keeping up with some 80s aerobics class where there's always something out because we had choreographed what we were supposed to do to start each experiment and to get safely out of the experiments.

Karen Daniels: [12:52](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=772.78) But then you push off the experiment too hard, you're pushing off over to somebody else's apparatus, they're going to get mad at you. There's a half dozen of us in the plane and we don't want to mess up someone else's experiment. Right? And so sort of just the work to just accomplish this basic task of sit up, push the button, watch it to make sure it's going well and then lie back down. When they say that you're coming out of gravity and do that again five times in a row without screwing up. That took a fair bit of effort.

Tracey Peake: [13:20](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=800.97) I'd never thought of that.

Karen Daniels: [13:22](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=802.09) And it didn't seem like it should be that hard to do. Sit Up, push a button, lie back down. But like, but it actually was. And that's again, because this is a new environment where humans are so used to operating.

Tristan Emm: [13:34](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=814.9) Definitely an amount of sensory overload when you do it for the first time.

Tracey Peake: [13:40](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=820.33) And speaking of sensory overload. And my final question is, you know, they call this thing the vomit comet. Indeed. Did you all make it through?

Karen Daniels: [13:47](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=827.5) So we didn't all make it about 10 percent of the people flying made it - five out of six made it.

Tristan Emm: [13:54](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=834.17) We did have one casualty.

Karen Daniels: [13:56](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=836.23) But I would say that they actually do some things to teach us to not throw up. So among us, they advise, you know, using drugs that suppress nausea. Um, they actually said that all beginners should be lying down during the two g stretches because that way we'd have a chance to rest and not make it worse. Um, they warned us against spinning around for fun, like you could damage the experiments but also out of control. But they also say that once you start to get sick, you won't get unsick Oh, okay. It just gets worse so that the staff are all standing up and moving around just fine. They're not getting sick. They're used to it. But as beginners, we were advised to take it pretty easy and I will say the last few parabolas we started relaxing it on ourselves a bit and had a little bit more fun moving around because at that point we already feeling a bit more confident.

Tracey Peake: [14:49](https://www.temi.com/editor/t/_ZlkSvaKDz1obe0XNuVDyXsxVWtOXXh_457x7-HHvog3qSU_RXkJT_8gRspmxwOzD9iOVtCsK8DqLNZJreEhKebPffI?loadFrom=SharedLink&ts=889.99) Thank you so much for being here and telling us about the experiment, the work you're doing and the experience that you guys had aboard the parabolic flights. This has been NC State's audio abstract. I've been talking with Karen Daniels physicist at NC state and Tristan Emm, a senior here at NC state. My name is tracy peake. Thank you so much for listening.