MARC SANCHEZ: Test, test. I think we're rolling.

SANDEN TOTTEN: Hey, *Brains On* listeners, this is Sanden.

MARC SANCHEZ: And Marc. And you might be thinking, where's Molly?

SANDEN TOTTEN: She's fine, she's fine. She's taking a well-deserved break. So Marc and I are filling in.

MARC SANCHEZ: Of course, we've never done this before. So we called in a pro to help us out. Welcome back Sophia Chu.

SOPHIA CHU: Hey, guys.

SANDEN TOTTEN: So you might remember Sophia from our Cats Versus Dog show and our episode on GPS. She'll be helping us out today.

SOPHIA CHU: Don't worry, you guys will do fine.

MARC SANCHEZ: Should we get started?

SANDEN TOTTEN: Yeah, let's do it. Sophia, would you do the honors?

SOPHIA CHU: You are listening to *Brains On,* where we're serious about being curious.

[MUSIC PLAYING]

MARC SANCHEZ: If you look up at the night sky at just the right moment, you might see it.

SOPHIA CHU: It looks like a star, but brighter. And it'll be moving faster than a plane.

SANDEN TOTTEN: It's not a UFO.

SOPHIA CHU: Or a comet.

MARC SANCHEZ: It's the International Space Station. And if you see it, wave. Because there are astronauts living up there.

SANDEN TOTTEN: On this episode of *Brains On,* we're going to find out how it got there.

SOPHIA CHU: What it's used for.

MARC SANCHEZ: And what life is like on this base in space.

SOPHIA CHU: So keep listening.

SANDEN TOTTEN: Welcome to *Brains On.* I'm Sanden Totten.

MARC SANCHEZ: I'm Marc Sanchez, and with us is 10-year-old Sophia Chu. Hey there, Sophia.

SOPHIA CHU: Hi.

SANDEN TOTTEN: Today, we're answering your questions about the International Space Station.

MARC SANCHEZ: Commonly known as the ISS. It's a laboratory orbiting about 250 miles above the Earth, moving at a speed of five miles per second.

SOPHIA CHU: There can be anywhere from three to 10 astronauts living there and working on experiments. Some stay a few days, others stay for months.

MARC SANCHEZ: And those astronauts come from all over the world. More than 200 people from 15 different countries have visited, making it-- what's the word I'm looking for?

SOPHIA CHU: International?

MARC SANCHEZ: Exactly.

SANDEN TOTTEN: It's big, too. About the size of a football field.

SOPHIA CHU: And it's powered by the Sun. It's covered in huge solar panels.

SANDEN TOTTEN: And they reflect a lot of light.

SOPHIA CHU: Besides the Moon, it's the brightest object in our night sky.

SANDEN TOTTEN: You can even see it without a telescope.

SOPHIA CHU: Pretty cool.

SANDEN TOTTEN: Pretty cool indeed. So Marc, Sophia, do either of you think you might want to live in space one day?

SOPHIA CHU: Maybe.

MARC SANCHEZ: I don't know. I think-- I don't want to be first. I don't want to be one of the first inhabitants.

SANDEN TOTTEN: Have them work the kinks out first.

MARC SANCHEZ: Yeah, maybe.

SOPHIA CHU: Yeah.

MARC SANCHEZ: Maybe go on vacation, try it out, and then see if I like it. What do you guys think the best part of living in space might be?

SOPHIA CHU: Zero gravity.

MARC SANCHEZ: Oh yeah.

SANDEN TOTTEN: I think it will be really cool, just the view you would get. You'd be able to see Earth from this totally different perspective. I heard it blows your mind if you see it, and it changes your whole feeling about the planet. I want to see that one day.

What do you think you guys would miss the most if you were living in space for, say, a whole year?

MARC SANCHEZ: What do you think, Sophia?

SOPHIA CHU: My mom's home-cooked meals.

[LAUGHS]

MARC SANCHEZ: Yeah. I might miss some food, too. Like pizza.

SANDEN TOTTEN: Yeah. I don't think they deliver to the International Space Station yet.

MARC SANCHEZ: Ooh, maybe that's when I would move to space. When they started delivering pizza.

[LAUGHS]

All right, let's get to some questions that were sent in to us. First up, we've got this one from a fan in Melbourne, Australia.

AURORA: Hi, my name is Aurora, and I'm seven years old. My question is, how did they build the Space Station?

SOPHIA CHU: Good question.

MARC SANCHEZ: There's no way something that big just flew up there on a rocket one day.

SOPHIA CHU: So how did it get up there?

SANDEN TOTTEN: To find out, we're going to tune in to a special show. Let me see if I can get the channel. Hold on.

[STATIC NOISES]

[MUSIC PLAYING]

LEE APPLETON: Welcome back to Under the Hood, the show where we interview important machines about their jobs. I'm your host, Lee Appleton. Joining me today is a special robot that's always up in arms. And by that, I mean this robot is an arm and not much else. It helped piece together the International Space Station and lives and works there to this very day. Let's meet the fascinating and multi-dexterous Canadarm.

[APPLAUSE]

CANADARM: Great to be here, Lee.

[ROBOTIC NOISES]

LEE APPLETON: Wow. What a handshake.

CANADARM: Thanks. I'm known for that.

LEE APPLETON: Now, Canadarm, I want to know what makes you tick. What drives you? Who is Canadarm, really?

CANADARM: Well, I was built in Canada. And I'm a giant robotic arm. Canada, arm-- Canadarm. Get it? That's where the name comes from.

LEE APPLETON: So interesting.

CANADARM: Let's see. I'm about 57 feet long. Unlike human arms, I have seven joints. That's like seven elbows. So I guess I'm pretty flexible.

LEE APPLETON: Any hobbies?

CANADARM: I'm really into grabbing stuff and moving stuff. Oh, and dropping stuff off.

LEE APPLETON: I've heard in space, you can move around 250,000 of equipment without breaking a sweat.

CANADARM: That's true. I can do that. And I don't sweat, because I'm a robot.

[APPLAUSE]

LEE APPLETON: Amazing. I wouldn't want to arm wrestle you.

CANADARM: I am processing that you are joking. Ha, ha, funny. Also, you would totally lose.

LEE APPLETON: Tell me, Canadarm, what was your involvement with building the International Space Station? Any challenges?

CANADARM: Oh, you bet. Remember Lee, all told, the station's about the size of a football field. There's no way just one rocket could carry up the whole thing.

LEE APPLETON: So how did it get there?

CANADARM: It was sent up on separate rockets and pieces built by countries all over the world. Some of those pieces attach to each other automatically using special radar sensing equipment.

LEE APPLETON: I understand you brought along a clip of two Russian sections joining up. Maurie, can you roll that?

ASTRONAUT 1: [RUSSIAN], move it in, friend. Slowly.

ASTRONAUT 2: I am moving it in slowly, friend.

ASTRONAUT 1: Well, keeping moving, but slow.

ASTRONAUT 2: Da, I'm still moving. I'm slow.

ASTRONAUT 1: Are you done moving?

ASTRONAUT 2: Nyet. I'm not done moving.

ASTRONAUT 1: Maybe move a little faster.

ASTRONAUT 2: Make up your mind.

ASTRONAUT 1 AND 2: Phew, finally. We are connected and synced.

[APPLAUSE]

LEE APPLETON: Riveting stuff.

CANADARM: I know, right? Radar sensors are pretty cool.

LEE APPLETON: What about the more complicated jobs?

CANADARM: That's where I came in, to give a helping hand. And arm. Well, me and the other Canadarm.

LEE APPLETON: There are two of you? Do tell.

CANADARM: I'm actually Canadarm2. Canadarm1 helped build the Space Station before me. But it didn't live in space. It was attached to space shuttles that flew up. It would help move stuff around, then flew back down. Not to brag, but I'm much bigger and way more flexible than good old Canadarm1.

But we've got no hard feelings. In fact, when I flew up to the station in 2001 to start my job, Canadarm1 and I actually shook hands. It was the first robotic handshake in space ever.

LEE APPLETON: Groundbreaking stuff.

CANADARM: More like space breaking. So anyway, I live on the International Space Station. I can hold on to it with grabbers on both ends of my arm. So I can crawl around on the outside of the station, like an inchworm. Once I get to where I need to be, I simply hold on with one end and grab a new piece of the station from a visiting space ship with my other end.

I maneuver that piece into place. Then the astronauts come out in their suits and start hooking up all the wires, cables, and tubes to seal the deal.

LEE APPLETON: What a job you do. A true hero.

CANADARM: I'm just following orders. That's what we robots do. Astronauts in the station or flight controllers on Earth are the ones telling me what to pick up and hold on to.

LEE APPLETON: Well, I'm still impressed. Before we let you go, we have a special message from some of the pieces you helped put together. Roll it, Maurie.

[MUSIC PLAYING]

PIECE 1: Buongiorno, it's me, Permanent Multipurpose Module, built by the Italians. But moved into my new home in space by you, Canadarm. Grazie.

PIECE 2: Hi, Canadarm. It's me, the Japanese Space Agency's HTV. I deliver supplies to the astronauts. But you always helped deliver me to the right place on the station. Arigato gozaimasu.

PIECE 3: Hey, buddy. Remember me? I'm Quest, the airlock. I'm basically the back door for the ISS. And it was you who got me here. Thanks, pal. High five.

CANADARM: Wow. That's all very sweet. If I had emotions, I'd probably be feeling them right about now.

LEE APPLETON: True. I think you would. Such a touching moment.

CANADARM: Are you OK, Lee?

LEE APPLETON: I'm OK. Yeah, I'm OK. Such a beautiful scene to end our segment. That's all we have time for today. Thanks to Canadarm. And tune in next week, when we'll have an exclusive interview with the President of the United States of America's airplane engine. Don't miss it.

[APPLAUSE]

[VOCALIZING]

AUDIO TRACK: Brains On.

SANDEN TOTTEN: It must be pretty strange living 250 miles above the Earth.

SOPHIA CHU: You can't just swing by any of your favorite restaurants or go see a movie.

MARC SANCHEZ: Plus, there's the whole feeling like you're weightless thing.

SANDEN TOTTEN: We wanted to know more about what that's like, so we got in touch with astronaut Don Pettit.

SOPHIA CHU: He worked with NASA. If you add up all of his missions, he's spent more than a year's worth of time in space. Welcome, Don.

DON PETTIT: Sophia, it's good to be talking to you.

SOPHIA CHU: It's good to be talking to you. I'm talking to an astronaut. This is really cool. My first question is, what is it like to sleep in the ISS?

DON PETTIT: It's a most wonderful feeling, because you're just floating in your bed covers. And your bed covers on Space Station are more like a loose fitting sleeping bag. And so you just float inside your sleeping bag. It's wonderful. You don't need to worry about a lumpy mattress.

SOPHIA CHU: What's the food like?

DON PETTIT: It's tasty food, but it is like camping food that come prepackaged in a meal ready-to-eat or a freeze-dried. And if you go out and buy a bunch of the freeze-dried camping food and you eat it for dinner at home, you'll say, it's OK, but it's not like your favorite.

But then you take that same food and you're out camping. And maybe there's a foot of snow and you're really hungry, and you've just crawled into your snow shelter for the night and you're making your dinner. That same food under those circumstances tastes really, really good. And so I think it's that way with the space food. If you eat it down here, you'd say, it's OK, but it's not my favorite. I prefer home cooking.

But then when you get on Space Station, it tastes really, really good.

SOPHIA CHU: I have a couple questions from kids in and around North America.

LILIA: My question is, what is it like to live in space?

SOPHIA CHU: That question is from eight-year-old Lilia in Minneapolis.

DON PETTIT: Well, living in space, you're inside of your spaceship. From that point of view, you're surrounded by machinery. And all the machinery that is needed to keep you alive and to provide atmosphere and water and all of that. So it's like living in an engine room on a boat or on a ship. But you are weightless, and so you can fly around the room like Peter Pan.

If you want to go from one side to the other, you just push off from the wall and you just float across the room, which is a most wonderful feeling. And then you get to look out the windows and you can see Earth and the vicinity around Earth. And it's this most beautiful object from the perspective of orbit. So living in space is really a wonderful experience.

THERON: Hi, I'm Theron. And I'm 11 years old.

RYAN: And I'm Ryan, and I'm eight years old.

THERON AND RYAN: Our question is, how long do astronauts stay in space?

DON PETTIT: Right now, the standard mission to space is six months. And so we will launch on a rocket. We'll go up to the Space Station, and we'll live on the Space Station for a six-month period.

SOPHIA CHU: Is it hard to take showers in outer space?

DON PETTIT: Yes, it is very difficult to take a shower in space. It's so difficult that we don't take a shower. You clean up by wiping off with a damp wash rag. And that's about it in terms of your bathing practice. And so imagine, if you want to pretend that you're on Space Station, you can tell your parents, I'm not going to take a shower or a bath for six months.

[MUSIC PLAYING]

SOPHIA CHU: We'll hear more from Don in a bit. But first, we have some business to take care of. Did you guys remember to bring a mystery sound?

SANDEN TOTTEN: Yeah, we have a mystery sound. We totally have a mystery sound, you bet. Marc, do we have a mystery sound?

MARC SANCHEZ: Yeah, Sanden. Don't worry. I got this covered.

[MYSTERY SOUND CUE]

AUDIO TRACK: Mystery Sound.

MARC SANCHEZ: Ready? Here it is.

[MECHANICAL REVVING]

[CHUCKLES]

Well, Sophia, any guesses?

SOPHIA CHU: I have a feeling it has something to do with Canadarm2.

MARC SANCHEZ: With Canadarm2, that's a good guess.

SANDEN TOTTEN: We'll have the answer soon. In the meantime, why not head to brainson.org? You can sign up for our newsletter, where we'll tell you about live shows, new episodes, and other cool stuff.

MARC SANCHEZ: You can also find us on Facebook. Search for Brains On.

SANDEN TOTTEN: Or follow us on Twitter and Instagram. We're @brains_on.

SOPHIA CHU: And we love it when you send us letters. You can find our address on our website.

MARC SANCHEZ: Now we want to give a big Space Station sized shout out to all the fans who keep us pumped up with their questions, comments, drawings, and high fives.

SANDEN TOTTEN: Here it is. The latest group to join the Brains Honor Roll.

[MUSIC PLAYING]

[LISTING HONOR ROLL]

SANDEN TOTTEN: Welcome to the world, little buddy.

AUDIO TRACK: Brains Honor Roll. High fives.

AUDIO TRACK: Brains On!

SANDEN TOTTEN: You're listening to *Brains On.*

MARC SANCHEZ: We're here with 10-year-old Sophia Chu.

SOPHIA CHU: And we're talking about the International Space Station. Let's get back to our conversation with astronaut Don Pettit.

MARC SANCHEZ: He told us that every day, astronauts are busy conducting all kinds of research in the microgravity environment of the Space Station.

DON PETTIT: There's a wide variety of experiments. We have experiments dealing with biology, particularly how human beings react to a weightless environment. So we are actually guinea pigs on Space Station. We do all kinds of experiments on ourselves. There's a number of quirkish things that happen to your body when you go into a weightless environment.

One of them is your bones do not need as much integrity. And so they start to decalcify. They say, hey, why do I need this big strong femur? Because it's not being loaded anymore, and so your body starts to get rid of your bones. And they start dissolving. This, of course, is not a very good thing for a human being that plans to come back to Earth, because you don't want to turn into an amoeba. So we're studying why your body tends to decalcify the load bearing bones when you're in a weightless environment.

Another example is our eyeballs. The retinas in our eyeballs are doing funny things. Like they're getting wrinkles. And they develop these little spots on the retina that look like a blob of cotton. And then the optic nerve is starting to push into the eyeball and making a bulge at the back of the eye. So we're having these maladies associated with your eye particularly that affect the retina. And there are comparable maladies for people on Earth.

So those are two examples of bone decalcification in the retina. They're really important things, and it's important to realize that human beings going into this radically different environment, you'll get disease-like symptoms instilled in your body. And if we can figure out why that is happening, it's going to help all the people on planet Earth that have similar problems.

SOPHIA CHU: Will humans ever be able to live in space full time?

DON PETTIT: I hope we get to the point where he would beings are continuously living in space as an individual. But right now, we have had human beings continuously living in space since the year 2000. So for more years than you've been alive, Sophia, we have had human beings continuously living in orbit on the International Space Station. They've just been changed out every six months.

And eventually, I hope we have the satellite platforms and spacecraft in deep space where we will basically have human beings living continuously in that environment.

[MUSIC PLAYING]

MARC SANCHEZ: Maybe one of the coolest things about the International Space Station is that it really tries to include everybody.

SOPHIA CHU: Not only have astronauts from around the world stayed on the ISS, but experiments from around the world have gone up as well.

MARC SANCHEZ: Some of those experiments come from students right here in the US. Producer Lauren Dee recently paid a visit to a class at Minnehaha Academy in Minneapolis. These high school students are designing and building experiments to go on the International Space Station. They're divided up into two teams. One studying the physics of vibrations, and another looking at how plants grow. Here's Lauren.

LAUREN DEE: When I got to the school, the first thing I saw in this new classroom-- it's a big lab and the kids have their computers, their laptops set out on the counters. Some of the kids are working out math problems on paper and pencil. Some of them are working on their computers. Some of them have got 3D printers and drills, and they're working on building all the parts to use for their experiment.

ALEX WILSON: My name's Alex Wilson, and I am the project manager of the Plants Team. What we're doing is we're designing two experiments to send to the International Space Station. My friends and I right here are all on the Plants Team. And our goal is to grow plants in space and observe the effects of what's called phototropism in the absence of gravity.

And phototropism is the tendency of plants to grow towards a light source. So if you put a potted plant by a window, you're going to see it growing perhaps towards the window, towards the sunlight that it's sensing. And we want to see if that response in plants is stronger when there's less gravity that they're sensing.

LAUREN DEE: Before the experiment can go into space, they have to figure out what kind of seed will grow on the International Space Station. That Sam's job.

SAM: One of the biggest roadblocks was the different types of seeds that just wouldn't grow. Because the growing conditions on the ISS are extremely hot. We don't really know why, but it's just really hot up there. So a lot of the different types of seeds that they've used in the past won't be able to grow in the high temperatures. Well, we've grown them in an oven that we have that simulates the heat on the ISS. And they didn't grow very well in the oven.

So we've had to resort to using rice seeds. We've tried broccoli seeds. We had to go to some more exotic plant species, because some of the original ones just won't work in space.

LAUREN DEE: So once Sam and his friends found out that rice seeds would grow on the International Space Station, the class got to work building the rest of the experiment. Picture this. It's a little box that's 2 by 4 inches big, about the size of a small brick. And inside, they have a rice seed that's suspended over a clear gel. In that box, they also have a little bag of water and a pump that moves the water into the gel so that the seed can drink it. They also have a little LED light bulb for the plant to grow towards and a tiny camera to take pictures of the plant as it grows.

They built parts of their experiment with a 3D printer. They also wrote the computer program that will tell their experiment what to do and when to do it when it gets into space.

SAM: I'm excited to see the final test results. Because in space, we have it set up so it sends back information every 12 hours. And we'll be able to see that information, so we'll be able to see the plant growing. And then once it kicks in to the phototropism part of the experiment where it grows towards a certain LED-- we think it will grow towards a certain LED. That's what we're monitoring, so that'll be a cool thing to just visually see back on Earth.

LAUREN DEE: Every day for 30 days, a photo will be sent from that tiny little camera inside their experiment down to their classroom on Earth. But before any of that can happen, the experiment has to make it into space on a rocket. And last year, that didn't go so well.

ALEX WILSON: Last year, our experiment was supposed to go up on a SpaceX rocket. And the rocket actually blew up on the way up.

LAUREN DEE: The Plants Team has got their fingers crossed that this year's rocket launch goes better and that their experiment's a success. But no matter what happens, everyone in the class is excited that something they've built has a chance to go into space.

ALEX WILSON: I mean, it's hard not to be excited about something going into space. Especially because for me personally, that would be really freaky. I have some friends who would really like to be astronauts and go to space. And that seems like one of the more awful things I could do. I'm glad that I can create something to do what I am unable to.

[MUSIC PLAYING]

MARC SANCHEZ: All right, Sophia. Are you ready to check back in with the mystery sound?

SOPHIA CHU: Totally.

MARC SANCHEZ: Here it is.

[MECHANICAL REVVING]

What do you think? You sticking with your original answer?

SOPHIA CHU: I feel like it has to be something mechanical.

MARC SANCHEZ: Yeah, it definitely sounds non-living.

SOPHIA CHU: Yeah.

MARC SANCHEZ: It was actually recorded on board the ISS. It comes to us courtesy of Canadian astronaut Chris Hadfield. He was nice enough to let us use a video of him explaining what that sound is in front of a group of people at the Ontario Space Center.

CHRIS HADFIELD: When you go to the bathroom on Earth, you're relying on gravity. Imagine if you were halfway done and somebody shut off gravity. It would be a mess. And you'd float off the toilet. When we designed our space toilet, first, it has to have a seat belt on it to hold you down.

And then we decided to separate solids and liquids, because they're easier to store that way. So we just have a tube that you pee into. And it has air pulled into the tube. So it's not a big deal. For the women, there's a cup fits up against them. For the guys, it's just a little funnel. You just pee into this tube. And it goes into a sewage tank.

But the solids that come out of your body, that's a harder problem to solve. And it's an important medical one. Because on Earth, everything falls on the floor. But in space, it's going to float around.

[LAUGHTER]

So it'll really make you sick. If you reingest something that came out of your body, it will really make you sick. And we can't afford to get that sick. So we designed a toilet that instead of gravity pulling everything into the toilet, it has air flow. There's air pulled down into the toilet. Windy when you're sitting there. But it pulls everything out of your body.

And then in the storage tank, we just expose that to the vacuum of space. So it basically just freeze dries everything so it kills all the bacteria so that there's no smell. And then when you have a whole bunch of it's stored, we put it in a little unmanned supply ship. And we undock it, and it burns up in the atmosphere. So the next time you see a beautiful shooting star going across the sky--

[LAUGHTER]

That's what it might be.

MARC SANCHEZ: What do you think, Sophia? Yeah. Yeah.

[LAUGHS]

SANDEN TOTTEN: And just so we're clear, Colonel Chris Hadfield was talking about the vacuum suction noises that were used in a space toilet. That's what our mystery sound was today.

[SUCTION NOISES]

Well, that's it. Thanks for listening, everybody. Bye.

SOPHIA CHU: No, no, no. We don't end like that.

SANDEN TOTTEN: Wait, we don't? What's left.

MARC SANCHEZ: You're supposed to go over the stuff we just learned about.

SANDEN TOTTEN: The stuff we-- oh, right, right. The recap. I think we're going to need some music for that. Marc?

MARC SANCHEZ: Coming right now.

[MUSIC PLAYING]

SANDEN TOTTEN: The International Space Station was built all over the world, sent up in pieces, and put together in space.

SOPHIA CHU: Astronauts on board carry out all kinds of experiments to see how things behave in microgravity.

MARC SANCHEZ: Students send up experiments, too.

SANDEN TOTTEN: Astronauts also use the station to learn more about how human bodies change in space.

MARC SANCHEZ: The more we learn, the closer we'll get to one day, being able to live up there full time.

SOPHIA CHU: That's it for this episode of *Brains On.*

MARC SANCHEZ: *Brains On* is produced by Molly Bloom, Sanden Totten, and me, Marc Sanchez. Special thanks to Sam Chu, Molly Stauffer, Raphael Grau, Dan Hewatt, Rebecca Murray, Jasmine Tefaha, Chris Murray, Levi Petry, John Rabey, Sachy Kobayashi, Jacob Margolis, and Chris Hadfield for letting us use his sounds.

SANDEN TOTTEN: Make sure to check us out on Facebook and look for us on Twitter and Instagram. We're at @brains_on.

SOPHIA CHU: Thanks for listening.

SANDEN TOTTEN: Now are we done?

SOPHIA CHU: Yep. Now we're done.

SANDEN TOTTEN: OK, not quite done.

[MUSIC PLAYING]

This is Sanden again. I wanted to remind you real quick before we go, we've got our first ever Kickstarter happening right now. Seriously, right now. Check it out. Just go to brainson.org/kickstarter and click Back This Project to support us. You'll help us keep the show going strong, and you'll help us add some new stuff. Like more songs and a special series on national parks.

Plus, we've got some sweet rewards waiting for you. Like a*Brains On* t-shirt and a coloring book based on our favorite episodes. We love doing this show. But we need your support to make it even better. So please give what you can, and stay curious. Thanks.

AUDIO TRACK: Brains On!