Courtney (00:00):

Mark McDonald was named Chief Architect for the Space Technology Mission Directorate at NASA headquarters, in August of 2019. He has a bachelor's degree in electrical engineering from Texas A&M University and a master's degree in aerospace engineering from the University of Southern California. He has received numerous NASA awards and honors, including a 2013 NASA Exceptional Achievement medal, a 2004 Silver Snoopy Award, 2000 and 2001 Space Flight Awareness awards, and two NASA Silver Achievement medals.

Courtney (00:50):

McDonald was the international formulation team lead for Gateway Lunar Architecture from 2012 through 2018. Previously, he served in many managerial roles at Johnson Space Center, including Deputy Manager of the Design Integration Office in the Constellation program, the Branch Chief of Avionics Systems Division's Product Development Branch, the Deputy Manager of Avionics Project Management Office, and Chairman of International Space Station Architecture Integration Team.

Courtney (01:30):

Today, Mark McDonald will give an overview of Artemis and talk about strategic technology framework.

Mark McDonald (01:39):

Thank you, Courtney. I started at Jet Propulsion Laboratories probably about a 100 years ago. Actually, it was when I was a co-op in college, in probably about 1985. And we were working on a program called Galileo, which went to Jupiter ,and we actually had, what the previous speaker was talking about, an entry descent and landing, there's no land on Jupiter, but we dropped a small probe into Jupiter's atmosphere to measure the atmosphere. And it looked just like the ones the previous speaker was talking... So I applied to be an astronaut, came out to Johnson Space Center, spent most of my career at Johnson Space Center. And recently I was moved to headquarters to be the Chief Architect for Space Technology.

Mark McDonald (02:27):

So I look forward to talking to y'all today and hopefully we'll teach you something about the breadth of what NASA is doing for the Artemis mission and a little bit about our overall strategic technology framework.

Mark McDonald (02:38):

So the Artemis mission you may have heard about on the news, it uses the Orion spacecraft, which Zach worked on as the method of getting the crew to the moon and back. We used the space launch system to fly it out there. And you'll see the first launch, Artemis 1, either late this year or early next year. We're currently slated for November, December of this year, that might slip into early next year. But you'll see the first launch of Artemis I. That'll be the biggest spacecraft flown since the Apollo program. It's huge and worth seeing.

Mark McDonald (03:13):

Artemis II, we put crew on it and similar to what we did in the early Apollo flights, where before landing on the moon, we flew out on a test flight beyond the moon, came all the way back. We'll be doing that on Artemis II. And just like Zach said, we'll be testing out the EDL systems there, testing out the rest of the spacecraft to make sure everything works together. In parallel with that. This is where we're doing things differently than done in the past.

Mark McDonald (03:40):

We're building, what's called a gateway. And Gateway is going to orbit the moon and we're going to use it to enable ourselves to do a lot of things we couldn't do before. It's what you see on the right hand side of this page is the build up of Gateway. The first launch there has the solar arrays and the initial habitation element on it. That's going to be using electric propulsion as opposed to chemical propulsion, in order to hold its orbit.

Mark McDonald (04:06):

We build that up, then the second flight is a habitat. And with that, we can have one crew orbiting the moon while another crew goes down, and we can also enable longer duration missions in order to simulate what we're going to be doing, going to Mars.

Mark McDonald (04:23):

Artemis III is currently planned to be the first human mission returning to the moon. That'll have the first woman landing on the moon. And this time we're going to go to the south pole. If you picture the equator of the moon, the middle part of it, most of the Apollo programs went to what are called equatorial missions or just north or south of the equator of the moon. The reason for that, quite honestly, is it's easier to get to. The south pole or the north pole are very hard to get to, comparatively.

Mark McDonald (04:57):

But what we've discovered since then, since the Apollo mission, is that we believe there's water at the poles of the moon in the permanently shadowed craters. So that's why we want to go to the south pole to be able to access that water. Because once you have water, not only can you drink it, but you can split that H2O into the Hs and the Os, and that is rocket fuel. And being able to split that water into the hydrogen and oxygen is of great value for being able to stay at the moon long term.

Mark McDonald (05:27):

So I'm going to talk to you about just some of the elements that make up this overall architecture. The Commercial Lunar Payload Services contract, we've got 14 different companies around the United States that are authorized to bid on contracts to put lunar landers on the surface. You'll see those starting to fly next year. And these are small landers that can take payloads as small as a hundred kilograms of payloads down to the surface, up to maybe a metric ton of payloads down to the surface. And we're going to be flying two of those a year, every year, starting next year. So we're going to be doing lots of lunar landings around varying parts of the moon.

Mark McDonald (06:04):

And just like Earth, where the science you would learn in the desert is different than you'll learn in the mountains, is different in the tropics, there's different features around the moon that are of interest to scientists. There's lava flows and permanently shadowed craters and different features that the scientists want to look at. So that's why we're using these smaller landers to go to varying places to see them.

Mark McDonald (06:28):

So this is the rocket that we were talking about. It shows you this next to a Saturn V. It's huge. All right, it is really, really big. Later this month, you'll see the final test of the first SLS in what's called a green run. After it passes that green run, they will ship it to Kennedy Space Center and start its launch processing. This is the rocket that you'll see fly in late this year or early next year, in its first unmanned test flight.

Mark McDonald (06:55):

So Orion, Zach did a good job talking about it. It's bigger than Apollo. Apollo could carry three guys. This one we're going to carry four. It was actually originally designed to carry seven, so it's got some more space in there for longer duration missions. Since Zach went over this earlier, I'm going to skip over it here. Next chart.

Mark McDonald (07:14):

So Gateway, we talked about a little bit. On the far left, you see the power propulsion element and the solar arrays. There's basically two ways you can get thrust, to say very simply. You either have some form of a chemical reaction, all right, in order to cause that high force of the kinetic energy flying out the back of the vehicle, to give it thrust. Electric's different, what you do is you ionize and gas, all right, so where you have a positively or a negatively charged ion, you put a magnetic field around it, and that causes the ion to accelerate super fast. And the beauty of it is, with chemical propulsion, you've got relatively heavy chemicals and explosive forces, so that's where you get your momentum from. But the explosive force isn't nearly high in the speed you get, then you do out of electrical propulsion.

Mark McDonald (08:11):

The difference is that the propellants in chemical propulsion are really heavy, and the propellants in electrical propulsion are really light. So high mass, lower speed in chemical propulsion, super high velocity, super low mass in electrical propulsion, what ends up happening is your analogy is a sports car. Sports cars are chemical propulsion. They go really fast, but they get really bad gas mileage. All right, electrical propulsion is compact vehicles or a Tesla, you get really great gas mileage, all right, but you don't get to go as fast.

Mark McDonald (08:54):

All right. So in this particular orbit, we don't need to go fast. We are very happy going very slow. So electrical propulsion is the most efficient way to do it. The rest of these modules, the one in the middle, is the habitation element that we dock to. In the lower side, you see an artist's conception of what a lunar lander might look like. And on the top side, you see logistics. So Orion's on the far right, in the middle of that would be like an airlock and another habitation element.

Mark McDonald (09:24):

So we're going to orbit the moon with those, so that we can do observations of the moon from orbit over an extended period of time, much closer than we are from Earth. And we're going to use it as a staging point for the human lunar landings. So it's primary purpose will be staging the lunar landings prior to going down to the moon.

Mark McDonald (09:44):

So we've got three contracts in place right now with Blue Origin, Dynetics, and SpaceX, to look at different lander concepts. Later this month or next month, we'll announce the winners of that initial selection. And then we'll select who is going to build our landers to go to the moon later in the 2020s.

Mark McDonald (10:05):

So after we get that first winter landing, we don't want to just land and come back like we did in Apollo. We want go and stay. So we're launching some more infrastructure than we did in Apollo. On the far side there, you see the lunar terrain vehicle, that is analogous to the lunar buggy that John Young drove around on, on the surface of the moon. But it's all about mobility. You need to be able to move around at different locations, to find more science and find more things.

Mark McDonald (10:32):

On the far side, though, that's where you see it, it differs greatly. The first thing we do is we have a pressurized rover. In that rover, we can travel miles away from our launch site, much farther, and you can actually live in that thing for up to two weeks. And you can go on quite an excursion far away from where your base is to explore more of the moon. In order to live on the moon for long periods of time, we're going to fly a surface habitat, where the crew can live for a month or more. In order to power that, you got to talk about on the moon, sunlight's a problem. All right, so if you picture a new moon where the moon's all black and a full moon, where it's all fully lit, there's 14 days between those two things, so a solar month is 28 days.

Mark McDonald (11:24):

And what that means is, is that if you're on the equator of the moon, you can go through a period of 14 days with no sunlight at all. So solar power won't work, so that's why we have fission power. As you go down to the poles of the moon, you can get more light, but it's still the temperature ranges, and we have some real problems getting power. So that's where nuclear fission power comes in, to where we can survive the lunar night, and have longer duration missions and have power to keep the crew alive.

Mark McDonald (11:57):

So this is just a picture of the unpressurized rover. I wanted to leave you guys with some takeaways, that's where everything that you see here requires new technologies to do, all right. So to be able to have a wheel, for example, caveman invented the wheels. Why would that be new technology? Well, a wheel has to rotate on an axle, but the temperatures that we're going to be at are so cold that, literally, atoms are close to stop moving. So if you've taken chemistry, what happens at zero degrees kelvin? Literally, atoms freeze, all right, they don't even vibrate anymore.

Mark McDonald (12:44):

So any material that we have today, when you try and rotate it, the temperatures that we're going to be at are going to be like 40 degrees kelvin, and any material we have today would just freeze up, and the wheels wouldn't spin anymore. So even though this looks like an Apollo buggy, the technology in it is going to be very different, in order to enable it to operate in the environments we're going to be in. The pressurized rover, I've already spoken about. This is to enable long duration excursions from the lunar base, so that we can explore more surface.

Mark McDonald (13:16):

The base camp is where we're going to put the habitat. We're going to try to put that near a crater on the south pole of the moon that is permanently shadowed, where we think the water's going to be. So that we can explore that to the greatest depth that we can, and start to access that water. With all of this, in this presentation, I'm just talking about the lunar elements, the Artemis missions. All right, to give you an idea for that.

Mark McDonald (13:42):

We're also planning on going to Mars and these same elements that we're using on the moon, part of the purpose is to test those elements out on the moon before we send the next revision of those elements to Mars. So that same pressurized rover that you see on the moon, the second version of it, we're going to send to Mars for the Mars mission. All right. So many of the capabilities you see in the Artemis program, their true purpose is to get us to Mars in the long run.

Mark McDonald (14:13):

The way we organize our technology investments is in four thrust areas we refer to as go, land, live, and explore. Go is about all the technologies necessary for the rockets in order to get there. So that's the chemical and electrical propulsion necessary to get us to the moon and Mars. Land is what Zach talked about, that's the entry, descent, and landing, and the precision landing in order to land on the moon and Mars. Live is all the technology it takes in order to keep the crew alive. And explore is everything we need in order to enable scientific exploration.

Mark McDonald (14:50):

So the way we organize these things within go, land, live, and explore is based on key capability areas. So what Zach was talking about is landing heavy payloads and precision landing. And there's a set of technologies associated with those. When you talk rockets, you're talking cryogenic fluid management and advanced propulsion. When you're talking the power problems, the nuclear power and the solar arrays, that's advanced power systems.

Mark McDonald (15:18):

In situ resource utilization is a couple different areas. It's not only how can we utilize that water that we find on the moon or the water that we find on Mars, but how can we extract metals from the soils in order to mine the regolith, in order to build structures on the moon and things like that. Advanced materials and structures, I touched on that too. You need special materials to handle the super cold temperatures. All right, or special structures, design, or manufacturing in order to go beyond. If we always carry everything from Earth, it's going to be super expensive, in order to really use the moon and in order to stay at Mars.

Mark McDonald (16:01):

So we need to find a way to be able to manufacture things on the moon in order to eventually build larger structures, greenhouses, grow our own food, in order to really make it an exploration camp beyond just something we visit. To do all of that, we need more robotic systems, because we can't keep the crew there all the time. So we need robots that can operate autonomously and do work for us while the crew's not there.

Mark McDonald (16:29):

But when the crew is there, now, we need advanced life support. So a life support system today on Space Station is about 80 to 90% efficient, but we still have to fly up lots of new things for them, in order to replenish it, because it's not a 100% efficient. In order to go to Mars, we need to get those human life support systems far more efficient than they are today. So if you had all of those things, you notice, I went down the right side of the page, all of that's powered by avionics. The avionics to control it, the communication systems to talk back to Earth. So that's the span of what I work on as chief architect, with respect to moon and Mars.

Mark McDonald (17:12):

But at NASA, we're also doing things in low Earth orbit, in small satellite technologies, in on-orbit servicing assembly, to where, if a spacecraft breaks in orbit today, we want the capability instead of flying a new one to go up there and fix it. So that whole span from doing the low Earth orbit stuff on Space Station and orbit servicing, small spacecraft technologies, the avionics and comm that spans it all going all the way out to Mars, those are all the technology fields.

Mark McDonald (17:42):

And for you as a university student, I noticed that we had students ranging from freshman to grad students, all of these areas are areas that you can work in and move forward. So if any of this excites you, there's an opportunity for you. So the one thing I'll leave you with, and then I'll stop for questions is, you can make a difference today as a co-op, if you need a summer job or a job as you're going through college, you can apply to NASA's internship program or to any of NASA's contractors for their internships program. And you can make a bigger difference than you think.

Mark McDonald (18:19):

When I was a Branch Chief in the Avionics Branch at Johnson Space Center, I had a co-op go out to Kennedy Space Center and install hardware in the space shuttle that flew. There are amazing opportunities you can get to do things, more than you would think as a college student. So please don't limit yourself and truly reach for the stars. You can do more than you think. So I'll stop for questions at this point.

Courtney (18:46):

Okay. Thank you so much Dr. McDonald. If anyone has questions, you should be able to unmute yourself now. You may also submit questions in the chat. One of our hosts from the talk will read your questions, and please complete the short poll at the time.

Mark McDonald (19:03):

So while they're being shy, I'll answer the one in the chat on Perseverance. The temperatures in Mars are actually much warmer than they are on the south pole of the moon. So that's not as much of a problem. The beauty of engineering is there's always more than one way to solve the problem. So if you were at a moderately cold temperature and power is readily available, then you may choose just to put a heater on that wheel to heat up it locally, and it'll spin just fine. But you might have a different problem where that same wheel and the same temperature, but you don't have power available to you. So you can't use the easy solution of a heater. So you may need to put a lubricant or some thermal blanket around it to protect it.

Mark McDonald (19:53):

If it's really cold and you don't have power, you may need to go to a specialized material. So you have to look at the specific problems and that's where your engineering studies, where you often wonder, well, why did they make me take that class? Well, later on, you're going to have a problem presented to you where, "Oh, wait, now I know why I had to take thermodynamics. I've got to understand those things." So there's different solutions for different circumstances. On the Perseverance Lander, they don't have the temperature concerns that we have in the south pole.

Mark McDonald (20:28):

My history at NASA, and how did I get here? I started off as a co-op at JPL working guidance navigation and control, and writing fault detection software. And I was an electrical engineer, that wasn't electrical engineering at all, but it was interesting. And electrical engineering taught me how to think and how to solve problems, so I did pretty good at it. When I came back to JPL permanently, I ended up becoming a flight director in charge of the mission control team as we were flying the vehicle.

Mark McDonald (21:00):

And that required me to work across all disciplines. I had to work with electrical engineers and mechanical engineers and all different types of disciplines across the vehicle. And I just found that was really exciting, because working across all the disciplines, there are geniuses everywhere, and working with all those people from different backgrounds and different specialties, I liked it. So a coworker of mine had applied to become an astronaut out of my group and made it, and he encouraged me to apply as well. And I did and I did pretty well in that selection. And I ended up getting hired to move from JPL to Johnson Space Center.

Mark McDonald (21:42):

And that worked out really great right up to the point that I failed the physical. So once I failed the physical, I wasn't going to be an astronaut, but I decided if I couldn't fly them I could build them. And that is when we were starting the work on building the International Space Station. And I ended up being selected to be the chairman of the team that designed the overall integrated vehicle for the Space Station. Again, because I liked working across multiple disciplines, I kind of gravitated to that.

Mark McDonald (22:16):

And what I encourage you is, just because you picked electrical engineering or aerospace engineering or whatever your particular degree program is, when you get into the real world and you start working a job, you don't have to stay in one place. Go where your heart is, go where you're passionate about what you're working in.

Mark McDonald (22:38):

And I found that, for me, working the big picture and working the integrated vehicle was more where my passion was than working a detail circuit. There are other people that their passion is working the detail design and the detail things. If that's your passion, go there. But you spend a lot of time at work through your career, so I really just encourage you to be passionate about what you're doing.

Mark McDonald (23:03):

So once I had proven myself at the architecture level on Space Station, the rest of my career from there, they basically started building upon that strength with me. I ended up being the architecture lead for

Gateway, which you saw earlier, and then that became the lunar program we're flying today. So at that point, with all of that architecture experience behind me, you come to a point in your career where you want to help other people, and as Chief Architect for NASA working across all of these different programs, I can use my experience to help people in all these technology fields across the agency. And that's actually what I enjoy the most about my job today, is being able to help other people on what tomorrow's architectures are going to be, and tomorrow's technologies.

Mark McDonald (23:48):

So does NASA alter research funding priorities based on research of international partners? And how much cooperation is there? So yes and no. All right, yes and no. So first, I would say that there's great cooperation between the international partners and NASA. All right, you look at that at what we're doing in International Space Station, even when countries "don't get along" on the ground, we work together on-orbit. And that's one of the great things about working at NASA is you get to see the best of the world working together. So there is a lot of collaboration there.

Mark McDonald (24:25):

When it comes down to actual research and technologies, the countries do compete. Of course, the United States wants to have our aerospace industry be the best in the world, and the other countries want the same. So there's some technologies we share and some that we don't, all right. And that's understandable, because they're doing the same thing with us, all right. When it comes to funding and sharing and things like that, by law, know that your tax dollars are not spent on other countries to develop technology. Any technology money we spend out of NASA, we spend on US companies and US universities doing research.

Mark McDonald (25:05):

Oh, that's a good question. All right, when making architecture decisions, how do I differentiate the radical plausible technologies from pipeline dreams? All right. Have I had crazy ideas? Every day. Every day people bring me crazy ideas. The way you distinguish things is twofold, all right. The first is my physics one, physics two books from my freshman and sophomore years, I have literally used those books over and over and over again. All right, because in the end, no matter what engineering you're in, it really comes down to physics and chemistry. When you really get to it, it's all physics and chemistry.

Mark McDonald (26:02):

So when you get some radical new idea, the first thing that I do is I look at the first principles physics of it, all right. If it's breaking Newton's laws, odds are, it's probably not going to work, all right. And you got to look at it closely, because somebody may have come up with something clever, all right. But first thing you do is go back to first principle physics, and see if it will work, all right.

Mark McDonald (26:27):

The second thing is experience in building things. And that's where, after having done this a number of years, and it's hard when you talk to students, but there is a difference between somebody that's just out of school and somebody that's built things for the last 10 years, because in that experience, they say, "No, that's really not going to work, because when you actually build it, there's a problem here." That experience does matter. So you'll see things to where designs come in for new technologies that they didn't account for things, that if they had built it before they would've known, they had to account for that.

Mark McDonald (27:09):

And I'll use an example. Somebody builds their own computer and it's going to be super awesome. And this is going to be great and da, da, da, da, da. But they forgot to put a cooling fan on the CPU. What's going to happen? It's going to heat up and burn up, and it's not going to work. But if they had built one before, they would know that the new high power CPUs may need liquid cooling or super cooling on it, because of what the CPU is. If they didn't account for that cooling, because they hadn't done it before, they wouldn't know that.

Mark McDonald (27:41):

So it's a combination of basic physics and basic chemistry and the experience to ask the questions, "Hey, did you think about the cooling fan?" That you typically use to distinguish it. But I will say you need to be aware that maybe the laws of physics will change. That maybe there is something new out there. There's one researcher out there that's literally working on a warp drive. He is working on something that is unlike anything we've ever seen before. And it defies the laws of physics.

Mark McDonald (28:16):

The problem is that I can't prove him wrong, all right. I can't say that he's not right. So on one hand, yes, you use those things to cut out the radical and the implausible. And on the other hand you still got to be open-minded to new ideas, because they are out there. Hope that answered your question, Lucas.

Lucas (28:36):

Yeah, this is Lucas. Yeah, that answered my question. Thanks again for the talk.

Mark McDonald (28:40):

No problem. Anything else guys or gals? What technology am I looking forward to? I'll tell you about the one I was just talking about. So look up Sonny White, Dr. Harold White. He's working on something called Q-Thrusters. And what a Q-Thruster will do, let's see, how do I describe this to you? It will change everything, if he's right. So what Q-Thrusters do is that they do not have propellant, they basically use quantum mechanics in order to generate thrust. So in quantum mechanics you have virtual protons and virtual electrons that pop in and out of existence. And what they're using is using the infinitesimal mass of an electron, picture, how small that is and the infinitesimal mass of a proton, and for the instant that they're in existence in quantum mechanics, applying electric field around it in order to get thrust.

Mark McDonald (29:44):

Now, as Zach talked earlier, 80% of the mass of a rocket is the fuel, all right, that we throw out. Well, if we made that rocket 80% lighter and had Q-thrusters on it, and had enough of them, things like the rocket ships you see in Star Trek become possible, all right. But it's not only that, every car becomes obsolete, every everything that moves, every train, every boat, every airplane. That physics would fundamentally change our understanding of the universe and fundamentally change where we are. And Sonny White's actually making progress on that. So there are exciting new fields that really challenge our understandings. I'm looking forward to breakthroughs like that.

Mark McDonald (30:35):

Since you didn't ask me, I wanted to tell you two things. One, what's the most exciting thing I've ever gotten to do? I was hoping you would ask me that question. I'm so disappointed you didn't, I'm going to answer it anyway. I got to fly on NASA's Vomit Comet three times, all right. So that's an airplane NASA users to go fly zero G and floating zero G for periods of 20, 30 seconds. That was super cool. Got to do that.

Mark McDonald (31:02):

They've sent me all over the world. I've been to Kazakhstan to see launches. I've been to Japan and Europe and Russia. And just seeing how the different people of the world think, how engineering cultures work around the world, it has been so rewarding. And having a Russian and a Japanese and a European and an American engineer, all working on the same problem together, really gives you hope for what we are capable of as a people on this Earth. So those are some of the highlight things that I've done.

Mark McDonald (31:36):

That's it. I'll just leave you with that. Any other questions? And then I think we're done. I think we're a little bit over time.

Speaker 4 (31:43):

I had one last question.

Mark McDonald (31:45):

Go for it.

Speaker 4 (31:45):

So I was wondering, well, you were just talking about how you really like the collaboration between different countries. So what was one specific thing that you have worked on, where someone from a different country thought of something in a way that you never would've thought about, that really helped with the project?

Mark McDonald (32:09):

I'll give you a specific example. There are many, but if you look at Russia's history, the Russian people look at themselves as a people with a history that's thousands of years long. And that country in particular has had war after war, after war fought on it. So if you look at the United States, in World War II as an example, we lost about a half million troops and casualties in World War II. Russia lost over 20 million, all right. And that type of thing changes how a culture thinks, all right. And that's just a simple example.

Mark McDonald (32:55):

The point is, is because they think about things differently and how they think about loss of life and loss of crew, it changes how they design things. So if you look at a US piece of space flight hardware, and I'll use entry, descent, and landing, as an example. If you walk up to the bottom of Orion and you hit the heat shield with a baseball bat, it'll crack and break, all right. And that's how the US designed it. It's very high tech, very delicate, all right, on how you would use it.

Mark McDonald (33:31):

If you go up to the bottom of the Soyuz and hit it with a baseball bat, it won't care, all right. It won't care at all. So Russian designs tend to be much more rugged, all right, much tougher designs. They may not have the precision that we have, all right, but they have other features that you have to learn to value. So for example, and a specific example, when we were designing the Space Station, all right, and we were looking at how to do our heat pump designs, for our thermal systems, the Russians came in with this super simple pump. It was simple. You could hit it with a baseball bat and it would work fine, but it didn't have all of the computer control and fanciness of the US design.

Mark McDonald (34:26):

But in the end, it didn't matter if there's... We put all of the fanciness of ours in order to make all the reliability work and to make it meet every requirement. Their approach was totally different. They just said, "We don't care if it breaks, we'll put eight of them on there." Or we were only going to put two, their design was simpler. I can use examples from that from every different culture, but learning to respect that men and women do approach things differently, and people from different cultures do think about things differently, and learning to value that and look for the good ideas, no matter where they're coming from, that's what will make you a good engineer. Because it could be that person is looking at it from a different point of view, and sees something that you don't see.

Speaker 4 (35:18):

Okay. Thank you.

Courtney (35:23):

Okay. If there are no other questions, I would like to thank everyone for their talks today. Thank you, Dr. Zachary Putnam. Thank you, Mark McDonald for sharing with us today. And if everyone could please join us for future space talks on Wednesdays at this time, for the spring semester.

Mark McDonald (35:42):

All right. Look forward to seeing what you guys contribute in the future.