

# @Risk: Rockets, Rovers and Reaching for the Stars with Dr. Farah Alibay and Col. Chris Hadfield

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**Jodi:** Hey, I'm Jodi Butts. Welcome to @Risk, brought to you by Interac. Rockets, rovers on Mars, and reaching for the stars are the stuff of dreams and rife with risk. But my two guests today turned their dreams into out of this world successes.

Dr. Farah Alibay was born in Canada and grew up in a small town where working at NASA was unheard of, but she's doing exactly that now as a systems engineer working on everything from mission concepts to the Mars 2020 mission. She went from student in England to NASA intern to her dream job at NASA's jet propulsion laboratory.

Colonel Chris Hadfield is an astronaut, engineer, pilot, educator, musician, and the first Canadian to walk in space and to become commander of the International Space Station, and now he's written a book of fiction.

Listen to how these two superstars engineer their successes in space and other life lessons relatable to our more earthy pursuits.

Thank you for joining us Chris and Farah, and welcome to @Risk.

**Farah:** Hi, thanks for having us.

**Chris:** Thanks Jodi.

**Jodi:** Oh, my absolute pleasure. So let's get into it. Tell us, and we'll start with Farah but Chris we certainly want to hear from you on this as well, where does the belief in yourself come from?

**Farah:** Oh, that's a good question. Well so I think for me working at NASA, as you mentioned it's not something that was really ever heard of and it's not something that I grew up thinking I could do. It's not like I knew someone that worked at NASA growing up. but as I was growing up, I became more and more interested in space. That's what I loved and that's what I was curious about, that's what I was interested in. And I was always sort of going around the house basically breaking things, taking things apart, trying to understand how they work, and then not really putting them back together, much to my parents dismay.

And that dream of working at NASA just kept growing. And one day I think I just realized well yeah sure there isn't that many people that work there, but someone's gonna work there and why shouldn't it be me? And so and I think part of me also always thought I that I was always going to regret it if I didn't apply, if I didn't at least try and give it my best shot. Right? And that's kind of how I live my life. It's not so much that I'll know where it's going to end up, but I've applied- I remember before I got my first NASA internship I probably applied to like 50 internships before someone said yes. Right? But that's the whole point is it only takes one yes, it only takes one success. It doesn't matter how often you fall to get there.

So I don't know if it was so much belief in myself as much as sort of stubbornness and determination to keep trying until someone gave me the opportunity and that's how I got where I am.

**Chris:** Farah, I know looking at my parents, they're somewhere in between supportive and surprised at the things that I did. But yours must have been the same. They must have been supportive of you as well.

**Farah:** Yeah, absolutely I think in my household, I remember my parents growing up there was no gender stereotypes at our house. I was the one helping- my dad was an engineer so I was the one helping him fix the car or fix the house. And my parents always said whatever you want to do in life, you do it. Just give it your best shot, try as hard as you can, and they've never prescribed something for me. And I think that's part of the reason why I'm where I am but certainly there's still a little bit of surprise also that I am where I am today.

**Jodi:** And how about you Chris? Where did that belief come from? Were your parents champions, did you have other mentors as well?

**Chris:** I just listened to Farah describe my childhood, which was kind of fun. And I had the same conclusion. I'm a generation earlier, but I watched the first people walking the moon and I thought well when they were little, nobody was astronauts. It didn't used to be hard, it used to be impossible, and now they've done it. And the only thing you can really count on is that things are going to change, and so the real onus kind of kind of falls on me. Can I change myself into somebody that, as Farah's said, eventually somebody will say yes?

And I got lucky, obviously Farah got lucky in timing too, because we weren't landing on Mars from throughout most of human history. But now every 26 months or something we're sending something there. Bo both of us I think have been the lucky recipients of supportive parents, a great educational system, and timing.

**Jodi:** So Farah, tell us what is your role in the Mars mission?

**Farah:** So now I work on the Perseverance mission, which is the rover that landed on Mars just under a month ago, it was February 18 of 2021. And I'm a systems engineer on that mission but I've worn many hats on the mission.

So prior to launch and prior to landing I was part of the mobility team, and I was helping with all of the testing of that system, basically making sure the rover's not gonna get lost on Mars, right, we don't have GPS or roads or maps on Mars. So my job was to get all of that testing done. And now that we're on the surface of Mars I have two main jobs. I am in charge of coordinating all of the operations between the rover and its little friend, the Ingenuity helicopter. So now the helicopter is attached to the rover, but coming up soon in the next month or so we're going to drop it on the surface of Mars. We're going to demonstrate the first power flight on Mars. And rover's job is to help with that. It serves as a communication relay, it's going to image the helicopter, take video, hopefully relay all that back to Earth. So that's one hat.

And then the other on a more day-to-day basis is that I'm one of the implementations leads for operations. So what does that mean, right, it's just a big jargon word. We like weird titles at NASA. But what it means is that I help plan the activities for the rover on a day-to-day basis. And when you're operating something on Mars, it's really far away. So it's not like- it's not like there's someone behind that console here like literally joy sticking the rover around. We communicate with the rover using radio signals. But Mars is so far away that it actually takes about 15 minutes at the speed of light, right, to get from earth to Mars and then back.

So if my job was to drive a rover from behind my desk, it would be a really boring day because I would say, hey, go forward one meter. And then it would take 15 minutes to get there and 15 minutes to get back. And 30 minutes later, maybe two coffees later, I'd get a response back.

So what we do is we actually work the Martian night, so I always say I work in the night shift on Mars. Right? So at the end of the day, the rover sends us all its data and its images and things like that. We analyze it then as a team we plan the next day on Mars. So there's specialists, right, someone knows how to drive, how to move the arm, how to operate the instrument. My job is to take all of that pieces of code, get those together into one plan that we then send up to the rover every day and we repeat that every Martian night and as we progress through our days on Mars. That's how that's how we operate missions on Mars.

**Chris:** All those years of schooling, all of that preparation and you're working the night shift. I did this, I worked in mission control for 25 shuttle flights, and yeah, it's just weird hours all around the clock. The mission takes over your own life of course. You try and squeeze your whole life into the little spaces that are around work, but it's got to be a pretty exciting time for you too though.

**Farah:** Yeah I mean for sure. And what makes it even harder on Mars is that I say I work the Martian night shift, but just to make it harder, sol, which is a Martian day, is 24 hours and 40 minutes. So that also means that even though I start at 6 pm every night on Mars, it shifts by 40 minutes on earth.

So what I did for my parents is I have this google spreadsheet that tells them what time I'm waking up and what time I'm going to bed and then what time I might have free time after my shift if they want to call me. I've got to say, my dog does not like Mars time. He's not happy about it. He's always tired, always wondering why I'm not home.

**Jodi:** So I have to ask a really practical question. I'll start with you Farah, but I want to hear from you on this too Chris. How do you sleep? So in those demanding circumstances where you're having to shift your sleep patterns all the time, are you able to sleep? And so many of us are having challenges in the pandemic with sleeping. How do you do it, what's your secret?

**Farah:** Well I don't know about you Chris, but I'm tired all the time. When I'm done with work, there are really long days. So sleeping, I think working 80 hour weeks for weeks on end until the Mars landing and then having to work really intense 10 hour shifts, like sleep is not a problem. So that's I mean on days where it's harder going for a jog, and self-care is really important. Especially when I'm when the night shift on Mars is the same as the night shift on earth, I have my little sun lamp. I

try and exercise, no matter how painful it is at four in the morning to be doing squats, but those things help. But certainly for me so far it hasn't been too much of a problem.

I do wake up with stress dreams of like, oh what's going on on Mars? And then it's hard to disconnect from what's happening, probably a lot harder to disconnect when you're in space on the space station. But yeah, I think good sleep hygiene, exercise, and just in general with how demanding the job is it hasn't been too hard to get sleep.

**Chris:** Yeah for me there's been two big phases of that. One when I was working in mission control around the clock, and like Farah I had pets at home but also had kids at home. And so I realized like because I need my family to sort of be able to function normally. And I think I sleep better when it's dark, and so I learned to sleep with a pillow on my head with just enough of a hole underneath to breathe. And so that way I could damp out the sound of my household, the sound of Texas, and the light of the window and sleep. And I end up doing that now all the time when I want to sleep, I just cover up my eyes and my ears.

But on a spaceship obviously you get a sunrise every 92 minutes. So it's confusing. So we make the spaceship dark and we cover the windows and we sort of turn down all the lights to pretend it's nighttime, and then try and make it quiet. And then each of our little sleep pods has a door, it's tiny but it gives you sort of that same sort of sense.

And then you try and run in some sort of regular cycle and just fool your body into thinking it's on a regular cycle, but moving every 40 minutes every day, of course that's just a constant dripping water torture on your sleep cycle and you just have to live with it. But I mean gosh, you're driving and flying helicopters on Mars. You can sleep later.

**Jodi:** Right, yeah. So getting back to what you're saying about your role in planning, Farah, what is the role of planning and success? Sometimes we hear these stories about in the tech world for example it's about moving fast and it's about breaking things. We don't necessarily hear as much about planning. What's your perspective on that?

**Farah:** Yeah, I mean it's not so much about moving fast and breaking things when you're on Mars. Right? Like you don't have that luxury. It's the same in anything that's space related. Once you're out there, there's no way to fix your rover, there's no way to fix your spacecraft if it's on Mars. So we work very differently.

So in development of course we move fast, we try, we test, we test all over again and then we test our designs. But when it comes to operations, it's again about testing but it's definitely about preparation. I always say that once we do something on Mars it's almost boring because we've done it like a million times on Earth before we do it on Mars.

And we have for example a replica of Perseverance called Optimism and we have a big what we call a Mars yard. It's a big sandbox essentially when we drive around our rover and we put it through its spaces. Like deploying the Ingenuity helicopter, that's the next big thing that's going to be happening, I've tested it at least 20 times in the Mars yard, and we test it over and over.

So that's what preparation looks like is we build our activities, we test them, we put it through all of the off nominal scenarios that we think might happen on Mars, and we make sure that we're robust against them. And then we do it on Mars.

And then sometimes it still doesn't look like the way we want it to, but most of the time when things go wrong we kind of expected it and know how to react. And if we don't, we can pause. And that's kind of one of the advantages of being on the surface of another planet rather than orbiting somewhere or going somewhere is if something goes wrong, the rover knows how to- has some automation. It knows how to react. It goes into what we call a safe mode and calls home and then we're there to fix it. So it's definitely about preparation, it's about expecting and planning for the worst, and being prepared for anomalies.

**Chris:** I love how the alter ego of perseverance is optimism. I think I'm going to adopt that as my own personal philosophy now. On my side of course, the stakes of perseverance, it's a vast amount of money and a very rare opportunity, but nobody's dying. Our stakes are even higher of course because if we get it wrong, everybody dies. So we even take planning, if you could possibly could from that description you just made, I think we take it even more seriously in human spaceflight.

Maybe for example I've done two spacewalks, and the spacewalks totaled 15 hours. So you'll probably be awake 15 hours today. I got ready for those 15 hours for most of my life, like I had to learn to scuba dive and then had a hard hat dive and all the rest of it. And then we had to build all the models underwater of everything we were going to do out on a spacewalk. So go to the model builders and get them built. So they were high fidelity.

And then I spent four years developing the spacewalks with a huge team of people. And then practicing them. And I know I spent 400 hours underwater, and there's only 24 hours in a day so that's a lot of days over and over and over again. And it's not like you're just training, but you're inventing, much like Farah's team is doing, they have to invent it all. You can't just look up in the book of how to fly a helicopter on Mars. They have to invent it.

And then they need a realistic enough test to then go convince themselves that maybe they got a good shot of it working. And then we face the same thing, and you're right. When you actually get in a rocket ship and launch, you're like oh, nothing broke today. Well, that was easy, which is exactly the way you want it to be that the actual execution becomes a relief.

But I think there is, Jodi, a business and life application of that. And there's almost always more time to prepare than people allow themselves, and if something serious is coming in your life or in your work or whatever, it's maybe good to spend just a little time simulating it in your mind and running over what are the possible consequences and which ones are you least ready for and maybe try and do the work in advance. Because it really optimizes your chances of succeeding.

**Jodi:** Chris, I quote you all the time. I say plan the flight and fly the plan. So there's absolutely applications in our daily lives. So to ask about another one, which is how do you not get overwhelmed by how much investment has gone into these missions? Every business book is

going to tell you ignore sunk costs, but that's easier said than done. How do you achieve that when you're working on such important missions?

**Farah:** Chris do you want to start on that one?

**Chris:** Sure. Well you do have to just accept it, to some degree. I think you also need to feel the sense of responsibility, what we call the public trust. There's an enormous unstated but overbearing public trust that nothing's cavalier. It influences our behavior, we call it expeditionary behavior, where the mission and the objective of what you're doing far outstrips yourself and your own preferences, and Farah's dogs preferences. You just have to kind of live with the fact that hey, this is the thing that is actually establishing the rhythm of my life and it's probably going to establish it for the next 10 years. And so now I need to start subjugating everything to that so that I can be part of the team that optimizes this success.

Because we recognize that the amount of sweat and tears that go into allowing us to be the people making the decisions to whether this is going to succeed or not, and to me the sort of biggest impact of that at my own level is a huge obligation to constantly try and get better at what I'm doing. Like a relentless dissatisfaction with my own level of competence all the time. And just constantly when the moment comes to have done everything that I possibly could to be able to do what I need to do in and amongst the team on that day.

That's how I deal with it. I just kind of recognize hey, I've got a job to do, and I'm going to make myself as ready as I possibly can. But then again, I'm not flying a helicopter on Mars.

**Farah:** Well, I think you kind of hit it there on the fact that we're doing something that's greater than ourselves. And that's kind of- that's kind of in a way the beauty of aerospace engineering or engineering as a whole is that like we're part of a big team and each of us brings something to the table and we hold each other accountable. And that's how you get through it.

And complex systems like the space station, like this rover, that's the beauty of them. Like no single human understands the whole thing. No single human could build that on their own. But as a team we make it happen, and we are a team player, we hold each other accountable, and we make things happen. So yeah, I completely agree with what you said, Chris, that you bring your best self. You bring what you can to the table and you become...

I mean that team that I work with has become my family. I call them my work family. We are there day and night. We push each other, we question each other. It's the only time that you want criticism from people. Like you take it. Tell me what's wrong, tell me, poke at this. I invite people to my meetings and say come look at what I did and ask questions. And that's how we succeed in big projects like that.

And it's definitely that concept of public trust, I definitely, especially in the past month have that sense of like wow the world is watching. And you can take it as stressful but you can also take it as something that gives you energy. To me the fact that the world is watching, it's so wonderful. I get to share what I do with the entire world. I get to bring them on this journey with me. I get to explain to them why it's difficult and share the successes with them.

So I think you have to take it as something that's positive, as something that's part of your job, and take energy from it rather than letting it scare you.

**Chris:** To me Jodi it's almost a little bit like singing in a really good choir where there's all those voices around you, and you've got your part. And if you just sing your part by yourself it's actually kind of boring. But when all those other voices are going and you realize wow, this is something way bigger than myself, and you can create something together that is beautiful and magnificent and it honors some artists who wrote the music. And you don't want to blow your part of course, and you want your voice to be sweet and on tune. But that feeling of capability that outstrips your own individual input, yeah, it's really intoxicating. And I think maybe that's how you get over the fact that you're inside a cathedral while you're doing it.

**Jodi:** You're both so inspirational, honestly. Farah, you've had to work differently with your team this time around though because of COVID. So what has that been like executing this mission in the time of a pandemic, and what have you learned about being a good team member under these public health restrictions?

**Farah:** Yeah, it has been interesting. So it's crazy because yesterday was our anniversary of the stay at home order here. And I remember March of last year I had gone climbing in the Sierras, the Sierras are the mountains here in southern California. And I came back to LA and I was climbing all weekend, no signal, no nothing. And then I come back to LA and there's no one on the freeway, which if you've ever been to LA that never happens. It is literally the apocalypse. And we get this email from work saying, hey, don't come in tomorrow.

Now March of 2020, we were four or five months away from launching this rover. We had shipped the rover already from here from California all the way to Kennedy Space Center which is where it was getting launched. And a lot of us were due to fly out to Florida to support activities we were all planning this big party for the launch and to be together, and all of a sudden they're like nope, you're doing your work from home. And by the way this is a planetary deadline because you can only launch tomorrow or every 26 months. So we still got to go. You still have to make this but somehow reinvent the way you work.

So the name Perseverance for the rover was announced in February of 2020. And when it was announced, all I remember saying is wow, that's really hard to spell. Why is it so long? And never has a name become so important and so representative of what our team did. And whenever people ask me what do you think the greatest achievement on this team is, yes the rover is complex. Yes, we had to invent new technology. But being able to adapt that fast, to somehow figure out how to work on a job that is inherently teamwork that uses people and to do it mostly from home, I still go to lab from time to time, that was a remarkable achievement.

I think one thing that helps us is that all of us kind of work remotely from Mars when we do operations. So we have the tools in place to help that, we just had to do it a little bit earlier than expected. But we adapted. And I think what it came down to is good communication. It came down to actually checking in with people a little bit more, understanding that we're all going through our stresses.

Like imagine having a multi-billion dollar mission you're going to succeed to and also a worldwide pandemic. And some of us- some people have kids at home. Some people have at-risk parents at home. So I think it's made us stronger as a team. It made us take the time to pause and not just talk about work, but check in with people and ask them if they need anything.

The amount of times that people have brought groceries for each other, shared masks or cleaning supplies because we needed them, as a whole it's made us a stronger team. But yeah so it was definitely a challenge, but I think we've gotten past it, we've surmounted it.

And but what I have to tell you is the one thing I miss is we're used to having happy hours every few weeks whenever we have big successes. And those Zoom happy hours are not the same. So certainly getting looking forward to getting vaccinated here in the next few months and getting to have those late celebrations of everything that's been accomplished in the last year.

**Jodi:** So Chris, you're obviously not on the International Space Station any longer but you're still involved in really big and complex projects. What has your COVID experience been like continuing to pursue projects? Is it similar to Farah's, or have you had some differences there?

**Chris:** Yeah it's similar. I think I actually I learned a lot while I was on the space station, Jodi, because obviously we were as physically isolated as any group of human beings could be. We were also perpetually surrounded by sort of an amorphous danger, you know, meteorites hitting our ship and things like that. And also you don't ever really know when it's going to end, you don't know for sure when you're ever coming home from a space mission. It's you've got a date in mind but you never know. So I think that psychology helped prepare me.

But something Farah's said really struck home to me, and that was you sort of have to be more communicative. And I find I'm applying it now, not only the way I organize my life under this sort of isolation, but also when you're talking to someone virtually you only get a small fraction of the normal cues that you would get if you were sitting face to face. And it's easy to forget the humanity of the person you're talking with. If I'm speaking to someone in mission control in Moscow or just outside of Tokyo or somewhere, it's easy just like you're talking to a help desk or something and to sort of not see the just the regular humanity of that other person.

They have imperfections, they may have had a terrible night at home, or who knows what pressures they're going through. And you miss all of those cues. And so I've really tried to be extra attentive during the COVID times, and I did from space, to cut people a lot more slack than you would normally. It may be too Canadian, but to be kinder. Just actually deliberately be kind to the people you're talking to. Especially since you're not going to get that chance to just go, hey at the end of the week oh we had all these things happen. But on Friday let's all do something fun together. Zoom is just a kind of a substitute for fun at best.

So I think looking for ways to celebrate, looking for ways to be kind and generous to each other, I think that's really important in a more virtual world.

**Jodi:** Yes, I couldn't agree more. And the absence of celebrations not just for the lack of fun but also that's what allows us to pick ourselves up and move on to that next project. It creates those feelings of satisfaction, it nudges important reflections. It's really hard to not have those moments.

And I think in about the summer I stopped my list of things to celebrate. For a period of time I kind of like oh, well we'll celebrate those after the pandemic. But now I'm kind of like okay, we'll have to do our best to be present and to try and do those things. And I guess we'll have to have a global party to celebrate all the different things that have been achieved throughout this period.

**Chris:** Yeah, the roaring 20s are coming for just that reason. I think people will be pent up and ready.

**Jodi:** Absolutely. So I want to pick up on something that you said earlier, Farah, and it's echoes of Chris in my head why I'm asking this. And you said when you're preparing part when you're playing in that sandbox to prepare, you plan for the worst. And I asked Chris this question on another time that we had chatted, and I want to ask you. How do you remain optimistic though when you're thinking about all the things that can go wrong?

**Farah:** Yeah so I mean because we've planned for the things that we can go wrong, that's how you remain optimistic. I think as engineers it's our job to understand the risks that we're buying into. So for every activity, we think okay, well this is how we've designed it. It's mostly gonna go this way, but let me think through all the possible things that can go wrong. And then some of them are outside of your control and there's nothing you can do about them. So if you're on your way to Mars and a mega meteorite hits you that's bigger than you expected it to, well the odds of that happening are so small that you can't plan against everything. So you take the big things, the big risks, and you worry about those and you try and reduce those. And you do your best to be ready for the things.

But I've learned from this experience that you can't be in control of everything. And that's something that took me a while. I'm very much, like I like being in control of my life. But you can't be in control of everything. The odds of getting a global pandemic, like it's not something that you plan for. It happens, and then you're like, well, got to deal with it. And we deal with what we can.

And I think that's something that engineering's taught me that you can apply to life is with anything there are risks. And you understand the risks and you take on a certain amount of risk in any activity that you take. I mean, you could walk outside the door and something could happen to you. You don't plan for every single bad thing that could happen in your life. And so the same applies to engineering, is you communicate those risks and you buy into them and you still decide to take that step, to do an activity, to do something on Mars based on that understanding. And that's really the best you can do is this. You can't plan for everything.

**Jodi:** Chris, did you want to build on that at all? You've spoken so eloquently about how you think about the things that could kill you when you're in space.

**Chris:** Well from an engineering point of view, every single component of Perseverance has an engineering factor of safety built into its design. And you have to decide how strong, to make it simple, how strong does this piece of metal need to be? And obviously you don't want it to be flimsy, but you don't need it to be cast iron. There's somewhere in the middle where it's the trade-off. And you have to decide where are my factors of safety limits going to be? And it's pretty

simple when you're talking about a piece of metal, but how do you apply that to your own life? And how do you decide how robust do my skills and my capabilities need to be?

I think the better way to look at it is what are the most probable things that might go wrong in a mission like Perseverance or in life or at work or family or whatever? And actually do yourself the favor of just like Farah and her team did for Perseverance, make a big list or in your case just make a list of the 10 things. These are the actual big threats from financial or health or whatever. And so and I acknowledge these are the biggest, get in a car accident or cancer or whatever. You can just decide what are your big threats, a fire in your house, and then say okay. Those are my big threats. When they happen, what are they going to look like, and am I ready to deal with that? And is there any way to head them off at the pass?

Can I increase my factor of safety? can I change the batteries of my smoke detectors or could I put in more smoke detectors? Or could I choose my patterns of activity? Actually think about it and then look at how you can understand it better and decide if this is a risk worth taking in your life. Because I don't know, Farah has been climbing in the Sierras but I'm not a thrill seeker. I'll take risks but only because they serve a purpose that I think is valid. And so think about the risks that you're taking too. Is this really what I want to be doing with my life?

And then when you come into it, it's a risk that you've considered. You've developed some sort of factor of safety, a set of skills you've got a background in. So when it happens, oh, my smoke alarm goes off, I'm not just stunned and panicked and incapable. I'm like okay, it's not what I wanted to happen but at least now I understand where I am on this and I can have my next actions somewhat planned in advance.

And I remember coming back from my first space flight thinking nothing went as planned. I mean it was so ad hoc, but everything was somewhere within the scope of what we trained for, sort of within our factor of safety. And that gave me a great comfort throughout the whole flight.

**Jodi:** Farah, I wanted to ask you. I heard the word balance there, and it made me think about the Ingenuity you mentioned, the Ingenuity, the helicopter that is a part of this Mars mission in terms of testing the technology. Can you just talk to us a little bit about the ingenuity and what it is you're trying to figure out with that particular piece of technology?

**Chris:** Yeah, I'm a pilot. I'm super excited about this as well. I really want to hear.

**Farah:** Yeah I mean we're attempting the first powered flight on another planet, that's what it comes down to. And what I think is so crazy, I don't even know how like we're daring to do this. We've only been flying on earth for about a hundred years and now like yep, we're gonna go to this other planet. Mars, by the way, only has like one percent of the Earth's atmosphere, one-third of the gravity. So that helps a little bit but doesn't quite make up for the lack of lift. And it has these strange wind patterns that we have to go through, but we don't we don't get anywhere with exploration without trying.

And rovers themselves started off as technology demonstration missions. There was the Sojourner mission that had a little rover, and that was the first rover. Actually some of the people that worked on that mission I work with now, which I think is really cool to have heard about them

and now get to get to work with them. And we built on that to a bigger mission, so that's what Ingenuity is. It's a technology demonstration. We're going to attempt to fly, we might fail.

But we were talking earlier about you don't get anything without trying. We've prepared as much as we can. We think the design should work on Mars. But Mars is another planet and it throws surprises at us. But if we succeed in this flight, and we're going to attempt multiple flights, that's going to give us, even if we fail, that's going to give us a ton of data to try to understand what it looks like to fly on Mars.

And hopefully the idea is that next time we bring a helicopter on Mars it might not just be a technology demonstration mission. It could be a scout for the rover. It could do its own science.

But let's talk a little bit about what it takes to build a helicopter. I just said Mars is a third of the gravity or one percent of the atmosphere. How do you test for that? We're here on Earth, can't really change gravity on Earth. I can't change the atmosphere, so we have these special chambers which we call thermal vacuum chambers where we can literally pull the atmosphere out of it. And we backfill it to about Martian atmosphere, and we can sort of simulate winds. And then the engineers on Ingenuity came up, literally use that ingenuity to come up with a testing rig to do like to have a gravity offset system.

And that that's something that people don't always think about. I mean Chris mentioned it a little bit earlier that it's not just the doing or the building of the spacecraft that's hard, the testing and the rigs that you have to use, you have to invent that too. And sometimes that's even harder than what you're building yourself. So that yeah, that's how they tested it. And for reference the helicopter itself is only about 1.2 kilograms and it has its blades, so that counter-rotated blades, there are two of them. They're about four foot long, so just over a meter long. So we think that ratio should work.

And in our tests we were able to achieve lift and stability. But there's certainly a little bit of a sentiment of nervousness. Like we've prepared as well as we can, but the risk on this one is definitely greater. But the reward's also greater, the stakes are lower. It's obviously a simpler instrument than the rest of the mission. So we'll have to see how that goes. But I mean I think either way on this particular part of the mission we're going to learn so much, failure or success. And I mean, that's true.

**Chris:** Didn't I just see yesterday though in the background video from Perseverance there was a little tornado, a little dust devil close to where you're gonna be flying your helicopter?

**Farah:** Yeah, we've seen a few dust devils on Mars already, which we don't always see. I worked on the Insight mission before this and it took us months to even catch a single dust devil, so that was a little surprising when we saw that. And so we've actually asked the team to be like hey, can we watch for these a bit more and figure out if they come at a certain time of day?

One thing that's strange or different from Earth on Mars is that is that the weather patterns are usually pretty predictable once we know what they are. So the high winds would come at a certain time of day, and it's quieter and others. So we're trying to understand that weather pattern

as fast as we can in order to choose, for example, a better time to fly. Because yeah, flying through a dust devil wouldn't be too fun.

**Chris:** Yeah, before every flight, I've been a pilot my whole life, I've always asked so what's the winds, what the weather? Your weatherman's a long way away. But who's going to clear ingenuity for takeoff? Who actually gets that responsibility?

**Farah:** So it's a team effort, again. And by the way, we do have a weather station on the rover and that's why we meet with them every day, the instrument team that's in charge of that, to give us the what... Literally we get weather forecasts on Mars. But yeah, it's a team decision every day as to whether we fly or not, and it comes into... It's the same as flying on Earth. And then we do have a team of pilots for our helicopters. So we have three engineers who are the ones actually designing the flight, but all of us look at the data separately and come together to give that go for flight whenever it happens.

**Jodi:** Gosh, that is just so fascinating and so exciting. So talking about that scientific and technological aspect of building the Ingenuity, and you saying no matter what you're gonna learn so much. So there being this educational purpose. When you're about to embark on something complex, what is the role of purpose in your thinking? I'm gonna ask Chris to answer this first how important is purpose in terms of coming up with that plan?

**Chris:** I think it's, especially in the various jobs that I've had, it's the ultimate decider. Form follows function. And it's easy to get distracted by things that don't matter. But purpose is a beautiful clarifier of what's actually important or what's not. And when you define what are the things that are your measures of success, like if we have to get this done and these eight things are slightly less important, okay. Well that will help us then prioritize all of the trade-offs you need to make. How big can it be, how heavy can it be, how much of this can we carry, how long can it work. Everything else everything is going to be the daughter of purpose when you're doing it. And I actually think it really helps.

And when I was sitting in the cockpit of the space shuttle during launch, I think you just said it. One of the things we would often say to each other is, so what's the next thing that's going to kill us? Not because it's negative, but because that actually lets ever gives everybody permission to stop being distracted by things that aren't purposeful. You can actually say gosh, the next thing that's going to kill us, that is our purpose now. We have to be ready for that, and if we make it through that one, then maybe we have a little bandwidth to deal with something else.

And so I find it's a wonderful aid through everything I do in my life, but specifically for the moments of really high consequence.

**Jodi:** Farrah, can you build on that? What's the role of purpose in your work?

**Farah:** Yeah, I think Chris hit it on the head there. It drives everything. When you're designing missions or when you're doing anything, it's very easy to get distracted with the million things that you could do or the million things that could matter. But it's really important, I hear it so many times at work. Let's take a step back. What are we actually trying to achieve here? What are we trying to

do? Does this really matter? And I'm worried about this part here but I'm trying to do this. What's the bigger picture?

And I think as engineers it's very easy, especially when you're focused on the little part of something to really dive down and worry about something small. So it's really important to remember what am I doing here and what's my purpose. Not only in design but also Chris mentioned what are your success metrics. What are you trying to achieve? That's important to keep in mind even in the bigger picture when you're doing something, when you're doing the thing and things go wrong here and things go wrong here. You have to go in with the mindset of what is it that I'm trying to achieve?

So for Ingenuity, we're trying to understand what it's like to fly on another planet. If things go wrong, I'm still working towards that goal. Even if I don't achieve flight, I'm still working towards that goal. And I think that's what allows us to measure our success. It's what we build too and that's what we measure ourselves against. So yeah, I think it drives everything. And that's where we design with intention is how we say it. So you figure out what you want and you design and operate around it.

**Jodi:** That's fantastic and so helpful. I want to talk about diversity, equity, and inclusion. You've both mentioned teams. And Farah I wanted to ask you, I've read some of the some of your interviews and you've described yourself as not necessarily fitting the mold. What is the role of diversity, equity, and inclusion in the success of teams?

**Farah:** So I think it's incredibly important, yeah, we've talked a lot about teams today and the fact that we're problem solvers and we work as teams to solve problems. And to me a diverse team is the best equipped team to meet a problem. If we have- you don't want your team to all have the same background, all have the same way of thinking. I don't need someone else next to me who thinks the same way, who's not going to challenge me in what I do. I mentioned this, I like being challenged as an engineer. I like being questioned.

And to me having people with diverse backgrounds, diverse life experiences, who've approached problems in their lives in a different way, that makes them better team members. That very team. We will look at the same problem with different sets of eyes. And I think that's important in achieving and in meeting complex problems and achieving complex goals. And then the other thing that's really important is if I'm gonna have a team, I want the best team that I can have to work on this problem. I want anyone to feel welcome. I want them to be their best selves and to come to that table. And so we need to make it an inclusive environment for people to feel like they can apply for these jobs, that they can fully be themselves when they're working in a team and not have to worry about like, well, is someone judging me because of my skin color or my hair color or my heritage or whatever?

So to me, I always say I do a lot of work in D&I, and I encourage a lot of people to try and see themselves in these positions. I always say that it's a little selfish in a way, because I want the best people to come work with me. And the way that we can achieve that is by giving everyone that job, or giving everyone the willingness to dream themselves into that place. That's something that I had a hard time with growing up. I didn't see anyone at NASA that looked like me. And I didn't

really imagine. It took me a while to even allow myself to dream to be there because there wasn't anyone like me there.

So by giving more people that dream and that opportunity, the belief that they too can be there, I think that gives us a better pool of applicants and essentially and eventually better teams to achieve these complex missions.

So yeah, I think diversity is incredibly important in teams and it only makes us stronger.

**Chris:** Yeah, I think diversity is where you get options. You get different ways of solving the same problem. I got to know Stephen Hawking very slightly. Imagine if there was no hoopla, if Stephen Hawking was just someone next to you on the sidewalk. It would be very difficult given our cultural biases and our norms of perception to look at that man completely physically incapacitated sitting in a chair where he can't do any of the functions that all of us take for granted, to recognize the brilliance that was going on inside that man's brain. And we had worked so hard to develop a different set of rules and a different system, this mostly technological, that would allow that person's wild diversity, his brilliance, to still be able to affect the lives of other people.

And you could look at, I don't know, Helen Keller or someone else that it would be so easy to dismiss. I was lucky growing up that most of the American and Soviet astronauts, they sort of looked like me, a white male. So it was easy to sort of visualize myself being one of them. But I think NASA and the space agencies probably lead most organizations in recognizing that all we really care about is that you're really good at your job. And we need that skill.

And so the visible diversity of the people that are working on the projects, whether it's on Perseverance or whether it's in the human space program, I think becomes sort of a great shining example of what a lot of people should aspire to. And that is your own initiative and your own set of skills and your work ethic and your own, if I get your own, perseverance. That's what is going to give you opportunity in life.

And it's really nice when you see someone like Farah who most people would cast in a different role just a generation or two ago to be in such a strong and visible leadership role. It's doing great work and also inspiring a whole bunch of other people too.

**Jodi:** Yeah, on behalf of so many people Farah, thank you so much for taking on the public aspects of this role too, just as Chris has. You both were part of really important complex resource intensive missions, but you also both really execute and serve the greater public as well. And that's just a huge benefit to us all. So thank you for that.

**Farah:** Absolutely.

**Jodi:** Before I let you both go, I did want to ask each of you one question, one last question about what is happening next for both of you. But starting with you Farah. What happens next on this Mars mission, and do you have a sense of what happens after that?

**Farah:** We mentioned this a little bit earlier, yeah. Like fully, like it's very all-encompassing now. And I'm literally living on Mars, we call it Mars time. So that will go on until mid-May. We do this Mars

time only for three months, it would be very intense to do it for much longer. But we have so much to achieve between now and mid-May.

I think I'm really looking at the next month and a half, two months here of hopefully flying on Mars. We're finishing in the checkouts of our rover. The rover I didn't mention it because there were so many other things to talk about, but one of the cool things of the rover is it's self-driving. And we're hoping to test out that self-driving capability to continue exploring Mars, to take off our sample on Mars. So there's so much to come just on this mission. And so I'm going to be with the mission at least till the end of the calendar year. I am hoping to take a few months off to also take care of my personal life, visit my family, spend a month climbing somewhere. It's really important. We get really passionate about our jobs, but I need to take that step back.

And then after that, there's so many opportunities out there. JPL is working on a mission, a spacecraft to Europa to look at that moon of Jupiter that potentially that has water and could potentially harbor life. We obviously have this Mars sample return campaign that Perseverance is the first step in a set of missions. Perseverance is taking samples on Mars that we hope to return.

I mean that mission, we're collecting samples on Mars now and you think that's hard. This next mission is going to go to Mars, land a small rover to go get those samples, but we are also landing a rocket on Mars and put the samples in there, and then launching the rocket to get it back to Earth. You think launching rockets on Earth is hard, now we're gonna go to another planet and do that too. And by the way, with a scientific cache that like the entire science community is waiting for, so it better not blow up. So that would be an incredible project to work on.

I just, I think I say to people whenever they ask me what's the next step, I always say well I don't know quite what the next step is. But I think my whole career will be spent exploring the solar system. And I'm totally fine with that, no matter what path I end up taking.

**Chris:** [conversation in French]

**Farah:** [conversation in French]

**Jodi:** And Chris, I wanted to ask you about what's next for you. We've chatted a little bit about it. You have a work of fiction coming out this year. Tell us about that, your other projects, and you have to tell us what's scarier: writing fiction or going into space?

**Chris:** I think, I mean when Farah and I address- I'm an engineer by original education. Engineering problems tend to have a or a wrong answer and a fairly clear outcome. Gosh, writing fiction, it's just infinite variables. And you have to do it with a team. Of course, obviously there's publishers and everybody else, book sellers and everybody that's involved. But when it comes down to it it's a whole bunch of blood sweat and tears, but then it's a roll of the dice.

I have to take this thing I've been creating, this story I imagine, the way interwove it with facts to create this big vision of a thing, and to then polish it as well as I possibly can so that other people will understand what I meant. But then I've just got to cast those dandelion seeds to the winds and hope somebody else enjoys the story.

So I'm nervous about it, of course. Launching a rocket ship, I just learned how all the pumps and the valves worked and knew what my reactions were. And it's okay, I can do that thing. So yeah, but I'm loving the creative process. It's called the Apollo murders and it's a thriller fiction book set in 1973 with the Soviet program the American program and going to the moon. So it's in the heart of what I love.

And I don't really have to ask too many people about details because I've done space walks and flown spaceships and things. So that gives me a lovely position to write from. But we're just in the final editing stage now and we should be done in a few weeks and be able to start sending it to the early printers and things for... And it'll come out in October.

But yeah it's a big part. I mean, I'm working with space companies and I run a technology incubator, and I teach at a university and I do a lot of other things. But writing fiction, writing a thriller, that's been a lot of fun for the last year. And I'm really looking forward to people reading it and seeing people's reactions and having that as something else that is part of my life.

**Farah:** Oh, I'm looking forward to reading that book.

**Chris:** The Apollo Murders. I'll send you a copy.

**Jodi:** That's awesome. Well thank you so much to the both of you, who advance science every day but also really empower us all to dream big and to really articulate what our own dreams are and to go out and achieve them. Thank you so much on behalf of everyone.

**Chris:** Congratulations, Farah. I'm just so proud of what you folks are doing. Please tell your whole team, if anybody knows my name, but tell them I'm just so fascinated and excited and proud of what everybody's doing. And you especially, nice to talk to you with you today.

**Farah:** Thank you, and it was a great pleasure to talk with you as well.