SDS PODCAST EPISODE 719: COMPUTATIONAL MATHEMATICS AND FLUID DYNAMICS, WITH PROF. MARGOT GERRITSEN

Show Notes: http://www.superdatascience.com/719

Jon Krohn:	00:00:00	This is episode number 719 with Dr. Margot Gerritsen, Professor Emerita at Stanford University and Executive Director of Women in Data Science. Today's episode is brought to you by the Zerve data science dev environment, by Gurobi, the Decision Intelligence Leader, and by ODSC, the Open Data Science Conference.
	00:00:23	Welcome to the Super Data Science Podcast, the most listened-to podcast in the data science industry. Each week we bring you inspiring people and ideas to help you build a successful career in data science. I'm your host, Jon Krohn. Thanks for joining me today. And now let's make the complex simple.
	00:00:55	Welcome back to the Super Data Science Podcast. Today we've got the extremely intelligent and super delightful Dr. Margot Gerritsen on the show. Margot has been faculty at Stanford University for more than 20 years, including eight years as director of the Institute for Computational and Mathematical Engineering. In 2015, she co-founded Women in Data Science or WIDS for short. It's an organization that supports, inspires and lowers barriers to entry for women across over 200 chapters in over 160 countries worldwide. She hosts the corresponding Women in Data Science podcast and she holds a PhD from Stanford in which she focused on computational fluid dynamics, a passion she has retained throughout her academic career.
	00:01:35	Today's episode should appeal to anyone. In it, Margot details what computational mathematics is and how computational math is used to study fluid dynamics with fascinating in-depth examples across traffic, water, oil, sailing, F1 racing, the flight of pterodactyls and more. She also talks about Synaesthesia, a rare perceptual phenomenon, which in her case means she sees numbers in specific colors and how this relates to her lifelong interest in math. And she fills us in on the genesis of her

		women in data science organization and the impressive breadth of its global impact today. All right, you ready for this breathtaking episode? Let's go.
	00:02:17	Margot, welcome back to the Super Data Science Podcast. It's my first time with you as a guest on the show. You were last on the show just before I became host, so welcome back. Where in the world are you calling in from today?
Margot Gerritsen:	00:02:31	I'm in Oregon right now, so I'm moved up from the Bay Area where I spent how many years? 26 years of my life and I've now been in Oregon for three years. It's wonderful. We're just east of the Cascades in beautiful Bend.
Jon Krohn:	00:02:48	Yeah, I used to have Intel as a client, so I was in Oregon frequently, and wow, it is a beautiful part of the United States, of the world. I can see why you picked that as a place to live. Let's dive right into our topics here. So you're a Professor Emerita at Stanford University where you have fascinating research, the confluence of computational mathematics and environmental health and many other exciting applications. So first off, what is computational mathematics and how is that related to data science?
Margot Gerritsen:	00:03:25	Yeah, computational mathematics is my big love after my husband and my son and my dogs. So I was always fascinated when I was a kid and then later as a student on how I can use mathematics to better understand the world around me, and particularly physical processes. I was a huge, huge fan of fluid, fluid dynamics ever since I was a kid. How do you see currents flow? What drives them? Can we predict them? What about air flows? What happens underneath the ground? You name it, I wanted to understand and explain.

00:04:11 Now, in computational mathematics, we do that translation and we allow that exploration. So think about, for me anyway, this is just one side of computational mathematics, it's simulation. And in simulation what we do is we take what we know to be the laws governing physical phenomenon, like for example, a flow, and we translate that into a computer code that we can then use to build a virtual laboratory of that same process. So computational, because we're doing tons and tons of computations, we're working on the computer and mathematics because that translation step requires a lot of mathematical tools.

00:05:02 The field of numerical analysis comes in, the field of linear algebra comes in, and then of course once we've done a translation, you become both a data scientist and a computer scientist, a computer scientist, because you have to run those models and those models can be very large. We ran models, for example of Monterey Bay. Monterey Bay is a large bay in California. And to run a model that can really help predict relatively small scale flow phenomena, we needed to run for weeks and weeks on end on a very, very large computer. So obviously you need to be a pretty decent coder because if you're not a very experienced coder, then the programs that you're running will not be very efficient. So computer science comes in, you need to understand the systems on which you're running it as well. And then data comes in for two reasons.

00:05:59 One is a lot of these models are really data driven, meaning that you need data in order to run the models. Think about simulating a part of the ocean. Well, when you simulate a part of the ocean, clearly you're creating boundaries. You cut the ocean off somewhere, and of course you need to understand what's happening at these boundaries to drive your model. Otherwise nothing interesting will happen. So there's a lot of data there. You need data to validate your code as well. And then you generate a lot of data. So I always say that I came into data science, not so much because I was using tons and tons of data to help drive my models. Data came in for sure, but because I was producing, I don't know how many bytes, whether I should think about terabytes or petabytes or even more of data in the simulation itself.

Jon Krohn: 00:06:58 Makes perfect sense. Yeah. So in computational mathematics, what other kinds of, I mean maybe it would help me kind of understand the area if you also explain some applications other than fluid dynamics, but let's stick with the fluid dynamics application for a moment. So I can kind of say back to you my understanding of what computational math means. So with fluid dynamics, you want to be modeling how some fluid is flowing. And I think that could mean not just liquids, but air system, like how air can-

Margot Gerritsen: 00:07:27 Yeah, absolutely. Anything that flows. In fact, of course computational mathematics is used a lot for solid mechanics as well. So for any substance that may move or break or fracture. So computational mathematics plays a massive role in earthquake dynamics. For example, earthquake prediction modeling. But computational mathematics is used to help understand any physical process and also engineering processes and also human decisions. Here's another example. Computational mathematics is used to simulate the stock market to help predict the stock market, when to buy, when to sell, what sort of put options to put on, you name it. So they sometimes call people like that Quants that are looking at financial, quantitative finance, and those are also computational mathematicians. There's a lot of math behind it. There are computational mathematicians looking at behavior of people. So behavioral analysis, anything that is done in the world that, in which you are using mathematics to translate or describe a behavior, a system, computational mathematics comes in.

00:08:56 There are models where people just say, here are the beautiful mathematical equations that you can use to represent this phenomenon. And then they leave it at that and they start analyzing just the pure mathematics and they do not try to put that then on a computer. But as soon as you start putting it on a computer and you're using the computer to help gain more insights, to optimize, to simulate, to predict, and that's done through a code, a computer code, it becomes computational mathematics. And then everything you do to prepare for that is also under computational mathematics.

00:09:39 So the translation of the physics to the math of the math to the computer code and every single step in that last process as well, how you do that translation from mathematics to computer code and then how you implement it on the computer. We all see that to be part of computational mathematics. In fact, computational mathematics claims a lot because I would say that computational mathematics or computational science and engineering as some people like to refer to it as well, includes data science, includes AI because in data science and AI, we're doing exactly that. We're interested in solving a problem, we're interested in predicting something out, we're interested in making a decision, and we're using computer algorithms in order to help us in this. Well, that's computational mathematics. There's always a ton of mathematics behind that.

Jon Krohn: 00:10:36 Yeah, so it sounds like I was kind of trying to think of computational mathematics as something relatively constrained where I was trying to think about, okay, maybe this is a field where that idea of translation is something that's obviously very important. You mentioned that several times where this idea of translating mathematical equations, maybe a physical processes or behavioral processes into computer code. And then it sounds like something very frequently in computational mathematics is that you can end up generating a ton of data.

Margot Gerritsen: 00:11:08 Yes, yes, we do. In fact, there is a treasure trove out there, Jon, of data. There's a treasure trove of data that was observed, has been observed over the past and it has never been looked at. So that's interesting part of it. And sometimes colleagues discover and then gain more insights from it. I remember one of my colleagues at Stanford finding these old aerial photographs of Antarctica and now having the digital tools to really look at them and digest them.

00:11:45 But there is this enormous treasure trove of data that has been generated over the last decades by computational mathematics that we haven't looked at yet. And I've certainly put some of that data in that treasure trove I mentioned earlier, Monterey Bay in these simulations. Well, these simulations really generate four dimensional data, three dimensions in space, one dimensions in time. But at the time we generated this, and this is now nearly 20 years ago, over 20 years ago, I think, we did not have the data analysis tools nor the compute power or the memory to easily get into the data, get our hands dirty, so to say, and really understand what the data was telling us.

00:12:30 So use the data to actually visualize what was happening. So we would look at the data just in slices to say, hey, let's put a vertical slice in this Monterey Bay and look at what's happening in that slice or horizontal slice. But all that data is still there to be explored, and I'm sure there are many, many things that we could discover. Now if we went back and looked at this, the same with the, I don't know how many bites produced by companies like Boeing or by institutes like NASA or national laboratories that are sitting there in massive memory storage systems and have never really been fully assessed. But now with data mining tools, data analysis tools, we could. So it's kind of exciting when you think it's like, wow, there's all this unexplored, it's like a frontier that we can still go and explore.

Jon Krohn: 00:13:28 That's fascinating. And you're also a delight to listen to speak about these things. Yeah, I don't know. Between your Dutch accent and your beautiful visualizations of everything you're saying, I am completely in rapture.

Margot Gerritsen: 00:13:51 Oh, that is not how I look at the Dutch accent. Oh this is very funny. I moved away from Holland when I was 24 and I had high school English at the time, but it is really too late to sort of reshape your jaw and reshape the way you speak. It's sort of baked in by this Dutch accent. We do so much from the throat and in the back of our mouth and so little at the front end. Of course, American English particularly is so much is in the front of your mouth. So that accent I could never get rid of. But most of the time when I hear myself I think, oh, that darn Dutch accent.

Jon Krohn: 00:14:25 No, I wouldn't change it at all. I think it's great. But yeah, and even more so for this field of data science that obviously I am really into, and our listeners are really into the way that you describe it with such color and excitement and opportunity, which yeah, I think a lot of us see that all the time, but we can get so down in the nitty gritty sometimes that we kind of lose sight of the beauty of the whole thing. And we do have some more on the beauty that you see in math coming later in the episode. But for now, let's dig into some of your research projects. So our understanding from our research is that things like traffic congestion and emissions simulation are something that are pretty big for you right now.

Margot Gerritsen: 00:15:12 Yeah, I went into that area in the last few years, got really fascinated by traffic flow. Again, it's things that flow and there were so many interesting decisions and optimization problems around traffic flow in the Bay Area where I was spending all my time. As you probably can imagine, there is tremendous traffic congestion. There's also, of course, traffic related emissions and pollution and questions come up is how to design a system in a really heavily populated area like the Bay Area that alleviates traffic congestion for everyone, not just for the people who can afford to use fast lanes or who can afford to have electric cars so they can have access to carpool lanes or those people that can actually afford to have a carpool period. Because that's not always there for everyone. That can only happen if you can be slightly flexible with the time that you leave or arrive or if you have colleagues that leave from the same place and go to the same office or the same work location.

00:16:31 And that's just really not available to everyone. So I got really interested in that and I mentioned earlier that I'm interested in this translation from mathematical equations that describe a phenomena to the computer where with traffic flow you can do this also. You can look at equations, we call them partial differential equations for traffic flow and then translate. And then when I started looking at this and saying, oh, what's the state of the art in this? Every time you start digging into an area, there are some questions that you have for yourself. Say, oh, could I do that faster? Could I do this better? Could I add a little complexity? Could I make it more realistic? And so a student of mine, Nadim Saad and I got very excited and we started digging into that. Now the ultimate motivation was because of work that we've been doing for Sonoma County.

00:17:27 Sonoma County is a county just north of San Francisco, and it's a really interesting county to look at. It's got wealthy people. It also has some pretty poor people. It has a lot of people that, immigrants who came into the country to help with construction, to help in the wine industry, for example, very low income. Also a lot of what we call illegal immigrants then. And they tend to live also in the areas where there is most of the traffic pollution and they tend to be excluded from some of these traffic mitigation measures that are being put in. So we wanted to see where was the equity in what people were doing there, could we help out? Would it be a really good maybe example, for example, county, for other counties. We got interested in clean car for all programs around United States, including clean cars for all in California, and looked at equity in that space. So again, it started with this fascination for things that flow.

00:18:38 That's probably the theme of my research lies. And it started to include so much more and we built a little team around it. It was also really fascinating for me to end up doing that because I really started my career at Stanford. Not before that. I was in New Zealand for five years before coming back to Stanford as a professor.

00:19:03 But at Stanford I started my career in a department that was then called petroleum engineering. And I looked at flows too, but sub-service for oil and gas flows. And a lot of people listening to this may think, oh, what? You did what? You worked in oil and gas and may think that going full circle and actually end up thinking about emissions is an interesting trajectory. By the way again, it was mostly because I was interested in flow. And over time as I was working as a computational mathematician and as a Stanford professor, I got very, very interested in the human impact of the work that we do and the human impact of engineering and the impact on societies of data science and all of computational mathematics. And so it's been a fascinating transition.

Jon Krohn: 00:20:11 Tired of hearing about citizen data scientists? Fed up with enterprise salespeople peddling overpriced, mouse-driven data science tools? Have you ever wanted an application that lets you explore your data with code without having to switch environments from notebooks to IDEs? Want to use the cloud without having to become a Dev/Ops engineer? Now you can have it all with Zerve, the world's first data-science development environment that was designed for coders to do visual, interactive data analysis and produce production-stable code. Start building in Zerve for free at zerve.ai. That's Z-E-R-V-E dot A-I.

00:20:49 And I can see how people might get a knee-jerk reaction that's negative when you hear about oil and gas research. But I mean it's historically and even still today, this is where the vast majority of our energy comes from. And I'm sure I, a lot of our listeners and you as well, we are excited about a future where that is no longer the case and we're moving in that direction. But still today that we have energy needs.

Margot Gerritsen: 00:21:22 Oil and gas has made us here in the United States, in Europe, the developed world as we are. Without oil and gas and the very high density of energy that it gives us, we wouldn't have been able to develop so much that we have in transportation, in healthcare, in education, you name it. So we've definitely built our modern society on it, and I'm very grateful that we had this because otherwise I think we would have been not as far. But, and there's a very large but, we've had the technology to transition a long time ago and we haven't put a priority on that and that's not good.

00:22:11 When I was working in oil and gas and transitioned from ocean flows, air flows to flows below the subsurface, I was attracted for several reasons. One was because the department at Stanford that offered me this new position has and certainly had there, a fantastic team of professors and students. Really incredible place to work, very supportive place. And that's always, of course, wonderful to find an academic home that can truly be a home. So that was great. The science questions that were still open and are, a lot of them are still open and outstanding for sub-service flow, which is not just oil and gas, but it's for example, also water. So you can apply a lot of what I did to subsurface water reservoirs, aquifers, and so on, are fascinating, very, very complex mathematics, very non-linear. So part of my math brain was drawn into this saying, oh, I thought turbulent flow in the ocean was as complicated as it would get.

00:23:30 But then I discovered subsurface flow and particularly flow that involves different phases, liquids, gases, solids, and they're all interacting with each other, in rock with super, super, super small pores. I mean, fascinating stuff, really interesting math, really interesting translation from math to the computer. And then the third thing was that I immediately started working in areas of oil and gas that I really hoped and thought would help mitigate some of the most harmful impacts of oil and gas production. And that was with enhanced oil recovery that was in situ. So a lot of the oil recovery, particularly of sticky oil, we call it heavy oil that is a little bit hard to get out, is done by what we call thermal stimulation. So what you do is you heat up the oil and that makes sense, right? I mean if you have a really sticky substance, say cold honey that you want to pour on your pancake, what do you do to make it run easy, right? You heat it up a little bit, right? You put it above a steam or your, some people now put it in the microwave. I wouldn't do that, but anyway, you try to heat it up.

00:24:51 So the same with the sticky oil, but the way that it was in the past and still heated was by burning fossil fuels at the surface, creating steam, for example, and putting that steam in the reservoir to heat and make this gooey stuff flow more easily. So I started working on systems where you can create that steam in situ. So not at the service. You don't have to burn fossil fuels at the service, you can do it underground. Everything, the products that you're creating because of the combustion can stay underground and it's much better for the environment. So I thought that was very useful and with some of those technologies you can compute how many Prius equivalents. That is something that we looked at saying if we can change this reservoir production from the traditional way to this other way, this is the equivalent in terms of combustion savings in previous units as we call it now. Probably maybe it's Tesla units.

Jon Krohn: 00:26:09 I was going to make that joke. That's funny that you actually... Yeah, super cool. I actually wasn't aware of subterranean oil and gas flows existing. In my mind, I imagine them as static, but of course, yeah, they're liquids and so-

Margot Gerritsen: 00:26:29 Yeah, you got to get that stuff out, right? That is the whole thing. And so you do that, but as if you're sucking on a big straw, you're pumping it up. But the thing is that the well from which you're pumping is of course only very local. These wells are not very big. They're maybe six or eight inches across, and so you're only touching a little part of that reservoir. So you start sucking, if I'm allowed to say that, sucking the oil and gas out. And of course then oil and gas from elsewhere, we start flowing to the well, right? You're creating a flow within that reservoir. Now it's a very slow flow. It doesn't go very fast. The volumes are very large, so that's why you can produce quite a bit. But these oil and the gases, and often there's also water in these reservoirs, all start flowing towards these production wells in the most fascinating ways because they interact with each other. They have to flow through these minute pores in the rock. Most people,

		when they think about a reservoir, I think the visual they have in their head is some underground lake a big-
Jon Krohn:	00:27:43	Yeah, that's exactly-
Margot Gerritsen:	00:27:47	[crosstalk 00:27:46] but it's not. I don't have a rock here with me. But imagine a rock that you pick up in your garden and look at the open space in that rock. That's pore space, and that is where this oil and gas sits. So it flows through there. And these pores are microns, right? If you're lucky, you get bigger pores, maybe a millimeter or more than a millimeter, but most of it is really small pore space. So that stuff starts to flow through there. Like I said, it's very complex.
Jon Krohn:	00:28:18	Wow. Yeah. I had no idea. I just had this idea of an underground lake and you just put a straw on it and [inaudible 00:28:27].
Margot Gerritsen:	00:28:26	Nope, that is what a lot of people think also for aquifers, of course, with aquifers, that's also not the case. It also lives in rocks, right? We don't have massive caverns underneath the earth filled with this stuff. It's mostly really small.
Jon Krohn:	00:28:47	I had no idea.
Margot Gerritsen:	00:28:49	Yeah.
Jon Krohn:	00:28:50	Yeah. So that's really interesting. So these liquids, these subterranean liquids, oil, gas, water, they're not typically moving around, is that right? They're only moving when we apply some pressure to them, or...?
Margot Gerritsen:	00:29:06	Yeah, they're moving anytime there is some sort of pressure. So a lot of these fluids are moving because there are forces on them. So there may be pressure changes in the earth around them. You may be producing

from a reservoir further away, but that can be affecting oil and gas and water at huge distances, slowly, very slowly. But it happens. You have gravity acting on them too. So if you have heavier and lighter fluids mixed in together, that over time again very, very slowly, the heavier stuff will sink through those pores and the lighter stuff will rise just like we have in the atmosphere, but many, many, many times slower. So these processes are going on, absolutely. And pressure changes in reservoirs may be human induced. It may be because of earth movements. I mean, there's many, many ways to imagine.

00:30:20 There are some places, for example, where you can see this in action at the surface too. Those are seepage places. So I used to take my students to a beach in Santa Barbara in California where oil was visibly seeping out of the ground. Not a human caused process, just the natural process. We have leakage through fractures in the earth as well. Again, fractures can be human induced and people talk about fracking as a bad thing that can introduce fractures and can cause leakage into valuable parts of the subsurface, for example aquifers, and also leakage to the surface.

00:31:09 But there are a lot and a lot of natural fractures that are created by earth movements, and humans have absolutely no impact on it, that cause leakage and seepage. We have gases escaping the earth at times, and this is well known as well. So it's not static. There's movement all the time, be it very slow most of the time, and sometimes a little faster. And then that's not always good. Think about volcanoes. When you think about volcanic eruptions with lava, ash, gases escaping from volcano, these gases, this lava, all this stuff comes from the subsurface and magma flows are just one example of subterranean flows.

Jon Krohn: 00:32:05 What if you, as a data scientist, could not only inform decision-making but also drive it? As a leader within your organization, imagine confidently harnessing provably optimal decisions. Gurobi Optimization — the leader in decision intelligence technology — equips you to unlock the power of mathematical optimization and transform your organization. Trusted by 80% of the world's leading enterprises, Gurobi's cutting-edge optimization solver, lightweight APIs, and flexible deployment ease the transition from data to decision. Visit gurobi.com/sds to get exclusive access to a competition showcasing optimization's importance, with prizes for top performers. That's G-U-R-O-B-I.com/sds.

00:32:53 Wow, this is super wide opening for me. I'm realizing as we're talking that my knowledge of geology and any of these kinds of processes of these subterranean liquid flows, I didn't know any of this. And so hopefully this is also really interesting news for our listeners as well. So something that's occurred to me a number of times as we've been talking here as you talk about fluid dynamics is how when we model weather, this is also the similar fluid process. And I particularly started thinking about this when you were talking about supercomputers running for weeks. And I was thinking about how, it's my understanding, that a lot of our world's supercomputers are tied up with this weather simulation problem. That in order to be accurately able to predict weather changes up to even just a few days, that the amount of complexity of the fluid flows is so great that you have some of the world's biggest supercomputers doing those computations.

Margot Gerritsen: 00:34:01 Well, let me rephrase this a little bit. I think a lot of really large computer systems were designed just to do that. So yes, it's not as if the weather modelers come in and say, "Let me steal your computing time." A lot of these systems were designed particularly to solve these really complex problems. So you're absolutely right. Weather prediction is one of them. Of course, weather prediction has enormous impacts on societies. I mean, if we can improve that, that's why we're constantly chasing improved weather prediction, it can make an enormous difference on people's livelihoods and people's comfort. Just imagine if we were better at predicting tornadoes, formation of tornadoes even better than we are now, predicting hurricane pathways and so on. And it's not just air weather. I always talk also about ocean weather because we can certainly add coastlines be impacted by ocean weather. Is there a storm surge coming, right? Is there a tsunami traveling through? Are there extra big waves? Is the swell enormous? Should we worry about impacts of wave erosion?

00:35:23 So all those things, ocean weather and atmospheric weather are both really important for us. It impacts on agriculture, impacts on safety, you name it, comfort. Yes, we use enormous computer resources for that. There used to be a time where I, and I can't remember how long ago, where it was still more accurate to say in the weather prediction, "Oh, the weather tomorrow is going to be the same as today." You had a higher chance of being right than believing the actual weather prediction. But I think we are past this now, weather prediction is notoriously difficult in some areas of the world, particularly around big mountain ranges, at the confluence of places where there's often this confluence of high pressure, low pressure systems. It's tough work this prediction, but we are much better than we were when I first started in this field.

00:36:27 The other area that of course requires a tremendous amount of compute power too, is climate modeling. So this is weather in the long run, sort of averaged weather patterns. And so you can imagine that if weather forecasting requires a lot of compute power, climate forecasting requires even more. Now, the scale at which you do climate modeling and the scale at which you do weather modeling is a little different. In weather modeling we want much more resolution, in climate modeling we cannot afford that resolution just yet because then we would really be extraordinarily expensive. So now other areas, computational mathematics that take an enormous amount of compute power is of course social media related data science. It's searching on internet engines, it's recommending systems. It's things like large natural language processing, large language models take a lot of work. It's optimization and running of our electricity systems, our grid systems, it's optimizing and running stock predictions, stock market analysis. You know about Bitcoin, which is a variant of that. I mean, there are many, many systems that require a lot of time. It's design of certain products. Think about the compute power that is needed to help optimize the design of new airplanes, of cars. There are many -

Jon Krohn: 00:38:11 And of yachts.

Margot Gerritsen: 00:38:14 Yachts, of course.

Jon Krohn: 00:38:15 That's of particular interest to you, isn't it?

Margot Gerritsen: 00:38:17 It used to be, yeah. When I lived in New Zealand after my PhD, I went to the United States for graduate school, and then after my PhD I moved to New Zealand, which by the way was a natural progression for me because I grew up in Zealand, the old New Zealand.

Jon Krohn: 00:38:36 The Old Zealand.

Margot Gerritsen: 00:38:39 The Old Zealand. And Abel Tasman, who named New Zealand was from that same area back in Holland. So hence the name New Zealand. So I always told my parents there's a national progression, I'm moving to New

Zealand. But when I was in New Zealand, I ended up working on coastal ocean flow because New Zealand is an island and has I think 14,000 kilometers of coastline. So coastal ocean flow, super interesting, estuary flow, really important. Auckland by far, the largest city in New Zealand is right in between two coastal ocean systems, a large estuary and then the Pacific side also, which creates lots of interesting shallow water flows on the continental shelf, pretty shallow. And on the other end is an estuary. And then the Tasman sea, which is also pretty wild.

00:39:38 So worked on coastal ocean flows for a bit, because that's what the interest was in New Zealand and also on yachting. Because New Zealand is pretty darn amazing as a country in sailing, A lot of very, very good sailors come from there. And there is this race called the Americas Cup that New Zealand has won several times, Australia too, United States also, I must admit. But I got really interested with some of my students in the flow past sails. So how would you design sails on a competitive yacht used in the Americas Cup so that you could go faster? And that was fascinating. I did in my PhD, a little work on airflows, particularly for wing design. I didn't do wing design myself, but I worked on codes that could be used by wing designers. And sails are a bit like wings, but much more interesting because at that time, sails were pretty elastic, pretty flexible. And of course, we're moving around a lot nowadays in the Americas Cup, for those of you listening who have watched the races over time, the sails have really been replaced by vertical wings, and there's much more rigidity to them than before. So the aerodynamics involved for that, the computational mathematics involved for that is much closer to what I used to know.

00:41:17 But I started working on sails for a while, and one of my former students, Stephen Collie, is still a member of Team New Zealand. He also worked for a couple of other challenges, but he's been back at Team New Zealand for a long time and he's one of the main designers there. And it's terrific. I don't know if you saw this, but the sail design that I worked on for a while also led me to the craziest project I've ever worked on in my whole life. And that was designing a wing, but the wing of a pterodactyl, pterosaur, which funnily enough looked a bit like a sail. So anyway, yeah, that was a very interesting sort of segue for me in my research.

Jon Krohn: 00:42:09 What was the practical application of designing a pterodactyl wing?

Margot Gerritsen: 00:42:14 Well, seemingly very little. When you think about this, why would you try to create, and that was what this project was about, a flying replica of a pterosaur that lived 150 million years ago. Now, from a science point of view, it's fascinating. Can we understand the way that these pterosaurs and the pterodactyl in particular that we were looking at, can we understand the ways that it flew, that it hunted, that it fed itself using the fossil record and using knowledge that we have about bird flight, bat flight, and also human flight.

00:43:02 So that was a fascinating question. And the interesting thing for me was to really think about the wings of these pterosaurs that were a little different than birds. They don't have feathers. They have a membrane. So it's a membrane wing, which is a little bit like a sail on a sailing boat, but of course horizontal most of the time instead of vertical. And though these pterosaurs were really, and I'm quoting an aero astro professor that helped me on this project, pterosaurs were really badly designed airplanes so it seemed. They must have been very unstable flyers. They had massive heads, big bulky things sticking out in front of the wings. That is not how you design an airplane for a nice stable flight.

00:44:02 And so what that meant that if they really did fly, as we think they did, they must have been able to control their flight very, very fast responding to instabilities. A gust would come and push that big head of their sideways, they're going to wobble. They need to be able to correct themselves very fast. And we found evidence, I'm using we now for paleontologists that study this, or we for humans as a whole, not our research team, but evidence was found of blood flow to the wings, which seemed to indicate that there were muscular abilities in that wing for maybe very fast wing shape control. And that was fascinating because then of course you start asking yourself the question, can we learn something from that? Can we mimic that now? And could it perhaps have insights that we could apply to remote control airplanes, that we could maybe apply to smart wings in the design of airplanes, maybe things that could make wings more energy efficient so that we wouldn't need as much thrust in order to stay up in the air or to move fast?

00:45:32 So all these questions came up. But it's a slow process. Sometimes people think that new insights happen instantaneously or very fast, but often it takes many, many years to derive insights that are practical. So I would say that maybe we contributed a little bit, but we certainly didn't contribute as much as that we've seen any changes in the way that we are designing. But it was fascinating nevertheless. And we worked on this with National Geographic. They created the documentary called Sky Monsters that features our engineering team. So if anyone listening want to buy a now very cheap DVD on Amazon, Sky Monsters is the name and you can see the efforts of the engineering team and the paleontologists also involved with us in creating this replica. And you can see plenty failures, which is great. And you can see me in 2005.

Jon Krohn: 00:46:44 So cool.

Margot Gerritsen: 00:46:45 It's interesting. Yeah.

Jon Krohn: 00:46:48 Be where our data-centric future comes to life, at ODSC West 2023 from October 30th to November 2nd. Join thousands of experts and professionals, in-person or virtually, as they all converge and learn the latest in Deep Learning, Large Language Models, Natural Language Processing, Generative AI, and other topics driving our dynamic field. Network with fellow AI pros, invest in yourself in their wide range of training, talks, and workshops, and unleash your potential at the leading machine learning conference. Open Data Science Conferences are often the highlight of my year. I always have an incredible time, we've filmed many SuperDataScience episodes there and now you can use the code SUPER at check out and you'll get an additional 15% off your pass at O D S C .com.

00:47:36 Yeah. I'm so glad that I asked the pterodactyl question. I didn't know that it was going to lead to such a fascinating answer and to a documentary that I'll be sure to include in the show notes so people can dig into that more and see more of that story. So cool, Margot. So with all of these advances in computational methods, does it mean that we don't need real-world wind tunnels as much as before?

Margot Gerritsen: 00:48:04 No, we still need those because I hope we'll, well maybe, we'll, no, let me rephrase this. I don't think we'll ever get to a phase where we can truly 100% trust the computer simulations to reflect reality completely. So I think in design of airplanes, in design of cars or anything else that we're designing, design of bridges, things for which we need to be very safe, ultimately you want to test in the wind tunnel, you want to test prototypes of course as well and not just rely on the computer model to say, oh, this design will work great. Just go and take off with a bunch of people in it. Who needs wind tunnel testing? Who needs prototype testing? But what it has enabled us to do and will maybe do more so in the future also is significantly reduce the number of prototypes that we have to test.

00:49:09 So see computational simulation as a way to sift through all these different designs that you may have and come up with the most likely to succeed designs before you then test them in the wind tunnels. Before that, if you had different design ideas, you wanted to test them all because you couldn't test them any other way. Now we can say, oh, here are a gazillion different design ideas. Let's test them first in a computer simulation, find out which ones are most likely to be the best, the optimal designs, pick a number of them and do wind tunnel testing on that.

00:49:56 So we've definitely seen a replacement in that sense from many tests to fewer, more tailored. And it's interesting how experimental work and computational work can interplay, so we can use simulations to help understand what we really should be testing experimentally. Experiments are used to help us write better simulators. So there is a two-way flow, and sometimes computations can be used to design better experimental systems. So it's a really interesting interplay, and I've been very lucky to have worked a bit on that interface too, doing experiments as well as doing simulations and finding the interaction between them.

Jon Krohn: 00:50:51 That's so cool. Do you follow F1 racing at all by chance?

Margot Gerritsen: 00:50:53 I'm not a fan. My sister is a big fan. Of course, I have to, as a Dutch person, I have to really follow it with such a great Dutch rider or driver. What do you say? Driver, I suppose.

Jon Krohn: 00:51:09 Driver. Yeah. Max Verstappen.

Margot Gerritsen: 00:51:11 Yeah, Max Verstappen. So yeah, he is great. I do know, and I have worked with people who are now in F1 racing and in design. At Stanford we built at some point a massive visualization wall of high resolution terminals, all sort of coupled together. And one of my colleagues who did work on Formula One Racing used the wall that we designed to look at improvements in the design of the car shape. And that was phenomenal to watch that. I worked with a postdoctoral student who later started working for Formula One Racing team, and I'm really excited that several very big name designers and data analysts for F1 teams are women. McLaren and Mercedes teams both have women. Yeah.

Jon Krohn: 00:52:14 Oh, that's really cool.

Margot Gerritsen: 00:52:15 You should have them on your podcast. Yeah.

Jon Krohn: 00:52:18 I would love to. Do you know them?

Margot Gerritsen: 00:52:22 Not personally. We've been in touch because we've invited them to Women in Data Science, but they're all connected in this fascinating sister organization of Women in Sports Analytics. And so there are F1 folks there. There are people looking at baseball statistics, basketball, soccer, you name it. American football also.

Jon Krohn: 00:52:52 Yeah. Well, I'll follow up with you after the episode to get those names. I would love to have a representative from F1. I've started to really get into it recently, like many people through the Netflix series, Drive to Survive, but now I follow it as well. And it's been a [inaudible 00:53:08]

Margot Gerritsen: 00:53:07 Amazing series, right? Amazing series at Netflix. So who's your favorite driver?

Jon Krohn: 00:53:13 Yeah, Lewis Hamilton.

Margot Gerritsen: 00:53:16 Okay, okay.

Jon Krohn: 00:53:18 Yeah, actually, I don't like Max Verstappen very much. I mean, obviously you're Dutch and I see all the Dutch flags at his races. I see that. I don't know. He drives so aggressively and dangerously. So it's interesting, he has this fearless way of driving that's one part of his success. But then the other part of his success, and this is kind of what I wanted to get into with respect to flow dynamics and airflow, is that, so there were many years in a row, I can't remember exactly now how many, but something like six years in a row, Lewis Hamilton and Mercedes won the F1 championship, except for there was one year where Lewis Hamilton didn't win because his teammate won by just a couple of points. And so Mercedes had this in the modern, there was some major car change 10 years ago, and Mercedes had won every single year until three seasons ago.

00:54:24 And there was a season where it was very close. So Max Verstappen and Red Bull, they were able to be very close to Mercedes and just kind of very controversially in the final race Max Verstappen won the Driver's Championship, but Mercedes still retained two seasons ago, the Constructors' Championship. But then this season and last season, Mercedes has really been struggling, and it's related to it's this flow dynamics thing, the car, the way that they did this overhaul. So for people who don't watch F1, periodically F1 releases vastly different rules for how the car needs to be designed. So every constructor, so whether you're a Red Bull or Mercedes or McLaren, every season you design a brand new car, and sometimes season over season, the regulations don't change that much. But between last season and the season before, there was this major change. And you don't actually get to test the cars on a track until just before the season starts, and everyone gets the same amount of time to do it. Even for wind tunnel simulators, there's strict limitations on exactly how much time you get to spend in a wind tunnel. And so you have to take big calculated risks.

00:55:52 I'm suspecting now after this conversation we had that it's this modeling, this computational mathematics is critical because that there's no limitation on. So you can, I imagine, I'm just guessing all this now, and you can probably corroborate, but you spend tons of time designing the core in a computer simulation and then having the flows run over it to try to assimilate how it would work. And so the big thing that has allowed, well, that has brought Mercedes down and has allowed Red Bull to dominate now this current season as well as the preceding season, is that Mercedes had something, they did a design that according to the simulations, and I think maybe even in the wind tunnels, looked incredible and it was something that had never been done before. But in practice on the track, Lewis Hamilton's car as well as his teammate's car did this porpoising. So it's bouncing up and down and it's not going over bumps, but it's related to the way that the air flows are. And obviously this is super inefficient if your car is bouncing up and down. Lewis Hamilton was having back problems from how much this car was shaking. And obviously it slows your forward motion if so much of your energy's [inaudible 00:57:01].

Margot Gerritsen: 00:57:01 Exactly. It saps your energy. Yeah, it's unfortunate for them. And at the same time, it's a great example of why it is so tricky to design those systems. Those are very complex flows and there are many phenomenon that take place around these cars in the flow that are not easy to predict at all and are very sensitive to small perturbations. We call it non-linear flows, that if there's a small little change somewhere, a new behavior or a different behavior, modified behavior can be created that can have these impacts. And so I remember my colleague looking at the design of a mirror. They found some drag on the car in a new design that they were working on, and they couldn't explain this increased drag and they started running all these simulations to try to understand it. So a lot of data to visualize and people are so much better at seeing things and noticing things and identifying things when they look at it rather than when they stare at the spreadsheets and tables of numbers.

00:58:24 You got to see it to really understand it. And so in this visualization that was much more detailed on that very large system that we had built, they could actually find the reason for this. And it was a different mirror placement that caused this. And they had not seen that before. They could actually look at that detailed flow. So there is so much to it. Maybe these computer simulations had some signature of this bouncing effect in it, but clearly they didn't spot it well enough. And it could also very well be that you can never set up a system that is exactly the way it is on a racetrack because putting something in the wind tunnel, it is not the same as racing the actual thing. You don't get the same temperature profiles around the car. When you're actually racing and you have that friction of the wheels with the road.

00:59:24 Everything changes also because of that. So there are always going to be differences between your wind tunnel testing, your numerical, or sorry, I should say computational simulations and reality. And this is unfortunate and also not really surprising in these very complex systems, changing rules like this and expecting teams with these very complex systems and very sensitive systems to respond to this well is in my opinion, a little crazy and shouldn't really necessarily be done. Because you can imagine that if you don't give them enough time and such changes are put in, could be very dangerous to drivers too. So they do the same in the America's Cup by the way. Every challenge, there are new rules and there is this whole rule book around which you have to design. So it's not just Formula One that does this.

Jon Krohn: 01:00:22 Cool, I didn't know that about the America's Cup and yeah, that's really fascinating. I hadn't thought about the safety concern. To me, I was thinking, well, this is obviously very challenging for the constructors that are designing the F1 cars every year, especially if you don't have the big budgets. So there's a few teams like Ferrari, McLaren, Mercedes, Red Bull, they have much bigger budgets than other teams. Some of the teams probably can't afford computational mathematics.

Margot Gerritsen: 01:00:57 It's a rich person's sport. You need incredible capital in F1. You need incredible capital also in the Americas Cup for those same reasons, very expensive campaigns. And sometimes it is interesting. It's fascinating because every single time they're pushing the boundaries of what they can and cannot do. And so from an engineering perspective, a science perspective, it's fascinating. And you see some of these design changes of course then penetrate in systems built for us, normal people, you can see this with seal design. So a lot of the America's Cup designs over time found themselves into the design of regular boats if you like. The way that seals were molded the shape of the seals, you see that trickle through. You see the same with the Hydrofoils at the America's Cup. Now you can start seeing Hydrofoils everywhere because this whole knowledge about Hydrofoils and how to behave grew so much.

01:02:09 And of course with Formula One racing, you have a lot of designs over time that have trickled into designs of regular passenger cars. But yeah, I think what you see in those systems is that they're now at a point those cars where these systems are so complex and so narrowly optimized that even a relatively benign looking design change can really throw people off. And since these cars are driving so incredibly fast and these drivers are exposed to so many forces, it may not be super safe, but I'm sure they're thinking about this. I'm glad that nothing bad happened with that bouncing, that bouncing wasn't resonating out of control. Maybe it could never happen because I don't understand what causes it. And I'm sorry that there are injuries involved with it. It's not great.

Jon Krohn: 01:03:16 Yeah. So I hadn't thought about the safety component of it, but it does make it interesting, these constant rule changes. It means that because the constructing teams need to take big gambles. And so yeah, so Mercedes was dominant for a long time and it's nice to see now some competition, Ferrari, McLaren and Red Bull. But Red Bull in particular, Red Bull it's crazy how dominant they are this season in particular. Max Verstappen, at the time of recording, he had just crossed the most consecutive F1 races won of all time.

Margot Gerritsen: 01:03:49 Yeah.

Jon Krohn: 01:03:49 Think he's on [inaudible 01:03:50].

Margot Gerritsen: 01:03:50 I should have have worn some orange today. Do I have any orange? I don't have any orange.

Jon Krohn: 01:03:58 And I do love Dutch sports. I was in Amsterdam for the World Cup final against Spain, however many years ago that is now, 12 years ago, something like that. So fascinating. And it's also the design element that you talked about there with these changes to America's Cup boats, to F1 cars coming into the real world, a cool thing that's happening that I'm aware of in F1 is that they are also dealing with these climate issues. Because obviously F1 cars... There is formula E, which I don't really watch, but it is something you watch. That's the electric equivalent of F1 racing. But even in F1 racing, they're moving towards having the sources of fuel be sustainable or renewable, which is interesting. So that's coming, some of the rule changes coming in the upcoming years.

Margot Gerritsen: 01:05:07 And if they can design really efficient engines with better fuels, that can really help. Of course, we're really now at the cusp of the era of the electric car and looking at changes in solid state batteries and so on. I'm quite optimistic.

Jon Krohn: 01:05:30 Yeah. Very cool time. So amongst your research projects, is there anything else that we haven't discussed that you're really excited about, upcoming projects or collaborations that you'd like to tell us about? Or have we covered a lot of what's going on?

Margot Gerritsen: 01:05:46 I think we're good. We talked about the craziest project. We talked about my love for fluids. I think we're probably saturated.

Jon Krohn: 01:05:57 Nice. Yeah. Great. So then let's move on to your passion for math in general and teaching. So you have videos on YouTube that have millions of views. So you have a TEDx talk called The Beauty I See in Algebra as well as a video called Mathematics Gives You Wings. I mean these are unbelievably popular. I'm looking up at the time of recording the Mathematics Gives You Wings lecture, which was published by Stanford, it has 1.2 million views. And The Beauty I See in Algebra talk, yeah, quarter of a million views. So I mean exceptionally popular videos, you're obviously very gifted as our listeners are I'm sure are already aware, having listened to you for the last hour, that you are amazing at being able to articulate mathematics, data science in such a beautiful way. But what is it in particular about algebra and linear algebra that you find so fascinating?

Margot Gerritsen: 01:07:06 My love for math really started really early on, even as a kid in elementary school, I liked manipulating numbers.

I'm one of these people that mix numbers with colors and there's a main name for it and it always escapes me. But that made me the fact that numbers and colors in my mind were combined as a young girl, really interested in manipulation of them. It was just a fun game for me to play.

Jon Krohn: 01:07:41 Yeah, that's synesthesia.

Margot Gerritsen: 01:07:45 Synesthesia, that's it. That's the word. And I think that really drove my fascination when I was young with math manipulation. To me, there seems to be this other language out there, and that was the language of numbers and the language of colors for me. And I tried to understand it. But as I was growing up and being exposed to more and more math, I started seeing mathematics as this fantastic language. Really, the way I studied English and French and a little bit of German was no different in my mind than the way I studied mathematics. There are all these concepts in mathematics, they're numbers, they're matrices, they're vectors, they're entities that you can manipulate according to certain laws. So it's like words and grammar. You've got concepts and mathematical algebra.

01:08:51 There's this thing called multiplication. You can manipulate two numbers by multiplying them. It's a rule that opens up in my mind, at the time anyway, this language or game if you like, of playing with mathematical entities. And I just found it entirely fascinating. As I was continuing in my math education, I started realizing that some parts of mathematics were really everywhere. Like I say in my linear algebra talk, linear algebra is at the base of almost everything that we do in computational mathematics. Is at the base of much of data science, is at the base of all simulation. And so I really wanted to understand those connections. And it was incredible to me that so many different applications that I've worked in also from airflow to sub-service flow, to traffic flow modeling to other aspects of data science that I've worked on, the [inaudible 01:10:04], a replication that they all had that common base language of linear algebra.

01:10:14 And when I first came to United States and started studying at Stanford University under an amazing professor called Gene Gallup, he used to say this, he said, ultimately all engineering is linear algebra. And I've become to believe that. So it's like having this universal language for so much in science and engineering and then being able to translate physics and engineering processes and human processes into that language, just mind-boggling to me. And then of course you see that I had some natural ability, not a huge amount, I don't think I'm a genius at all, not at all when it comes to mathematics, but I had some innate ability and then worked on improving my skills in that area. And as I was doing that, I saw so many people around me give up on mathematics or saying, we just don't get it. And I started realizing that it has much more to do with the way that we were teaching and the way that we were explaining than with people's ability to actually grow to understand this.

01:11:29 Most people can learn a new language. You don't see many people say, I just cannot do another language. They may say I'm not as good at it or it takes me a long time. But people tend to accept and know that if you apply yourself enough, you can speak, okay, you may have a strong accent, like a Dutch accent, but you can make yourself understood. You can read, you can comprehend the spoken word. But with math, there's still so many people who believe that is really one of those things you just have or you don't have. And I've never believed it, and I've always been on a quest to show this and help people really discover their ability to learn and improve over time in this beautiful language that also opens up so many doors. So I ended up studying mathematics ultimately because as a teenager I started thinking in high school about what I would like to be and I was fascinated with weather.

01:12:40 So I thought, oh, maybe I should be a weather forecaster. But I was fascinated with bird flight as well. So I thought maybe I should be an ornithologist. And then I was fascinated by the earth, and so maybe I should be a geophysicist. And then other friends of mine were starting to get interested in finance and I thought, oh, that sounds pretty fun too. And I was interested in biology and there were so many different things and I thought, wait a second, I don't really want to choose. How can I keep doors open to all these areas? And I found this math as this base language of so much of what we do in science and engineering to be the ticket. So I thought if I study mathematics and then computational mathematics, I can go and work on whatever I like. And when I look back on my career, that's exactly what I've done.

01:13:33 But I've gone through so many of those doors and so it's been fascinating. So clearly I love it. I think it is fascinating. I think it allows access to so much other work. It's very empowering to scientists and engineers to understand math. And we see a lot of people struggle with this. And I believe a lot of that has to do with some myths about really needing that innate ability. And if you don't have it, just forget about it. So people give up early. And also about teaching that is really not very optimal. So I've enjoyed over time in my career to try to explain concepts in a way that's more intuitive that explains the usability, the power of the mathematics. And I'm happy if that has resonated with some people that Mathematics Gives You Wings talk, by the way, that was an interesting story.

	01:14:37	It was almost an impromptu talk at Stanford. I didn't even realize at the time they were taping it. They were going to put it out on video. I'd almost forgotten about it. It was reunion weekend, homecoming weekend at Stanford, and the football game was starting. Big football game. I was going to go to this football game, but just before the game, I checked my email and there was this reminder say, hey Margot, you're supposed to give a lecture for homecoming weekend. This was a homecoming weekend lecture called A Class Without a Quiz. And I almost forgot. And so I went in a little bit unprepared and I literally winged that talk.
	01:15:23	But then they taped it and I didn't even realize they taped it. And then my son, I think it was a year later, he was looking for something online for his math class, he was in middle school I think at the time. And he says, "Mom, we needed to find a video in math and I found you." And I said, "What video did you find?" And he said, "I found Mathematics Gives You Wings, you have 250,000 views." I said, "What?" So that was a surprise. So that's an older video. And the responses to that video have also been very interesting. Hey, and now I'm joined by my little doggy here, so if you can hear. Hello. Hi, Millie. I know she's getting very impatient with me, I'm sure.
Jon Krohn:	01:16:12	Well, we're getting near the end of the interview, so Millie will be able to have her walk soon. So yeah, so really fascinating section there on your math and teaching passion. Of course, we'll link to both those videos. The Beauty I See in Algebra and Mathematics Gives You Wings in the show notes. And yeah, the synesthesia thing is fascinating to me. I don't know if I've ever had a conversation with someone who is a synesthete. And so just to give us a taste to make this crystal clear for people. And you actually do often see that people who are synesthetes are especially good at math because it's easier for you to see numbers, to distinguish them. Some

people can even do the operations. You just think, oh, yellow and blue makes red.

Margot Gerritsen: 01:17:01 So I used to do math like this, and I think what has helped me having this affliction or whatever you call it, is when I was really young and first started being introduced to numbers. So first grade, second grade, it helped me get better at math because I could see the numbers in colors. And I did indeed do manipulations like this. Four times five was 20. That was a color combination that was just ingrained in me. And I remember times tables based on colors. Fascinating things, there's some numbers I really dislike because they're associated with colors I really don't like. There's some numbers associated with brownish colors. They're very unattractive. And so I avoid them in my life. I don't really want to ever to live at a place with number 17, for example, that's just brown.

Jon Krohn: 01:18:02 Oh my goodness.

Margot Gerritsen: 01:18:03 It's a brown number.

Jon Krohn: 01:18:05 I was imagining that it was always individual number, a single digit that was associated with a specific color. But you just said 17.

Margot Gerritsen: 01:18:14 Yeah, for me, yeah. So of course there are patterns. I tend to have a preference for even numbers. I also associate them with roundness. If you look at them visually, a lot of even numbers are roundish, an eight, a two, where some of the odd numbers are much sharper in presence. A seven, a one. A nine of course is also around, but a nine happens to be ochre color for me and I don't like it as much. But anyway, so the color combinations, I really like numbers that are powers. For example, even though it's odd, I absolutely love the number 27. That's three times, three times three. So that's just fascinating. And three is a nice number to me, and it's associated with colors. I also associated, I'm sorry to say numbers with people. So I have favorites people in my life and I would say that person is a 27. My husband is a 27. It's a really good number. So it's a little weird and I don't talk about it all that often.

01:19:37 So it doesn't help me now. And it hasn't helped me much apart from having this weird association. It hasn't helped me much probably since third grade. But it helped me in the very first starts to be better at number manipulations at my times tables. I felt good about this. I was one of the better kids in class. I was a little competitive. And it got me on that math train, because I never felt as a young kid, I cannot do this. I have a hard time with number manipulations. I never felt it because up to say manipulations of two digit numbers as you do maybe up to third grade or second grade, it was easy for me. It was just a color spectrum. And sometimes people, with timetables, I would associate the people. So I would say say, oh, four times five, that is Pete times Jane. Because I had associated four and five with particular people, and I could imagine they would produce something called the 20.

Jon Krohn: 01:20:50 That's so interesting. Yes, I've learned a lot about synesthesia here today. So just out of curiosity, how about just three and 27, what colors do you associate with those numbers?

Margot Gerritsen: 01:21:07 So three is a spectrum. Three is one of the colors that for me-

Jon Krohn: 01:21:11 It's a spectrum.

Margot Gerritsen: 01:21:13 That has more of a rainbow. Some of the nicer numbers, when I first started noticing this, there were some numbers that I loved so much. They didn't have just one flavor. They had this whole spectrum, very bright primary colors. So three is one of those. 27 as a result is also that very bright, very vivid. And then like I said, there were some other numbers. Four is a red, five is a blue. And don't ask me why there is no rhyme or reason to this. And also everyone that has this thinks about it differently. There are different color associations. Sometimes people think that all of us in this group have the same color associations with the same numbers. It's completely varied. And some people associate people with colors and like I do not just numbers or numbers with people, or some people pull in smells as well and they have some visual connections too. For me, visual connections have always been very important. When I teach, I'm very well aware that there are students that are very visual learners. They really need to see some picture, some sort of representation before they can understand it. Other people are very comfortable just being verbal so they can see a formula, they can see words, and they can associate with that just fine. I've always been very visual in everything, and that probably also stems from this, because early on it was all about what I saw in my mind.

Jon Krohn: 01:23:01 Yeah. And so the key thing here for our listeners, to make crystal clear, is that this isn't something that Margot taught herself. This isn't an association where you say, "Oh, I'm going to learn that four is red and three is this brilliant multicolor." It's that you, from I guess as long as you can remember from childhood, it's printed in black on the page, but you always saw that four is red.

Margot Gerritsen: 01:23:29 Yeah. And I think it came up with numbers so much because numbers are so visible. It is just this one thing. Words are a little bit more confusing at times. There are many letters, there are so many different combinations. But I also have these associations with some words, the early words that I used to learn. So the words that you start reading for the first time, these little kid's books, I don't know, in French it was [French 01:24:01] "Dad smokes a pipe." That was the first sentence I learned. In English, the first sentence I learned was, "Keith is in the garden." So in Dutch you of course have this too. And all those words, the first words you learn, maybe a couple of hundred words, they have color associations for me. Because at the time I was doing that with those words too, they tend to be smaller words, shorter words. So it wasn't as confusing. Of course, as my vocabulary increased and my reading ability increased, I had to give up because I can do that with the millions of combinations that you have with words. At least I couldn't. I know people that can associate colors with language as well, yeah.

Jon Krohn: 01:24:46 Yeah, fascinating. And I would love to keep going on and on about that, but we have a very important topic that we need to get into before Millie can get outside. So this is the Women in Data Science group that you started eight years ago. So you co-founded this and as impressive as your academic career is, and that's obviously what we've focused on in this episode, it's Women in Data Science, WiDS, which has grown now into a huge global movement. So you now serve as the executive director of WiDS?

Margot Gerritsen: 01:25:16 Yes.

Jon Krohn: 01:25:17 And yeah, so what sparked the idea and what have been your big learnings from this initiative?

Margot Gerritsen: 01:25:24 Oh, what sparked the idea was frustration. It's a great incentive. It's a great driver often. So I've been in this field of computational mathematics and in STEM for many decades now. And data science, which has become very recognized and very important and critical field because it's penetrating so much in our societies, had as it started and certainly at the time we started WiDS, had just like other STEM fields, very low percentage of women represented in the people asking the questions, the people finding the solutions, the people designing the algorithms. And also very, very few people, very, very few women were made visible in data science. Very few women on the podium at the big conferences, very few women on podcasts. Very few women instructors online, very few women experts asked to chime in on panels and so on. So not only were women underrepresented, but the amazing women that were in the field were really not made visible.

01:26:45 And when in 2015 there was yet another conference, in fact one in the Bay Area, that only had male speakers. And the reason they gave me when I asked them about this was that they had asked me to come and I couldn't make it, so what was I expecting? And they just couldn't find out any other women. I thought, together with two colleagues at Stanford, that this was just not acceptable for a critical field like data science. In particularly unacceptable and really bad for everyone to not have women in there and not have women visible, and to have this culture where women are really also not included as easily as men. And of course we are now talking binary women and men, but there are other genders that are of course even more excluded than women.

01:27:45 And so, we decided on a whim that one morning after I heard about this conference not having any women speakers because I couldn't be there, we decided just put on a conference. This was 2015, we said, "Let's just put on a conference. Let's call it Women in Data Science. Let's do it on Stanford campus." And we're just going to create a podium for these amazing women that we do know, to give them more visibility and start what I still refer to as project visibility. Let's make the outstanding women doing all this amazing work and making all these contributions visible. Let's normalize the presence of women in this field so that girls and women feel that they belong, so that boys and men don't question the presence of women. Of course women do this stuff. Of course I can collaborate with women absolutely equal in all regards. So we started that just as this one conference and then we hit a nerve at that time, other people started saying, "Hey, we'd like to do something like that too." We decided to organize an umbrella of Women in Data Science, under which other people in their own region with their own local role models, their own women they wanted to highlight, their own voices they wanted to emphasize, could organize under our umbrella as a Women in Data Science ambassador and a Women in Data Science event.

01:29:18 And then before we realized it, by 2017, 2018, '19, we had a lot of those events around the world and we started topographically creating this community of women through that. But we were only doing events. And so we decided, and we is myself, I was at Stanford at the time running an institute under which WiDS was organized and I had a fantastic staff member, Karen Matthys, and another staff member that we hired to help out with this distributed model, with the ambassadors and the regional events events. So the three of us as co-leads of WiDS decided to add year-round programming.

01:30:00 So we gradually started growing. We added a podcast, so we're now in our sixth season of our WiDS podcast. So wonderful women that we interview there, and you get to meet the women behind the science in those podcasts. So a lot of the conversations are personal, like in your podcast. We added an annual datathon, which is a global datathon, which is a low barrier for a lot of people's first experience with data. And we work on fascinating problems around social good topics. So our new datathon, by the way, is going to be launched pretty soon.

01:30:40 We added workshops as skill sharing for women in the field. A lot of women saying, "Hey, we love this

		community. We want to share our skills." Said, "Come in, give a workshop." So now we have Wednesday Workshops, we like the W in WiDS. We ended up having a next generation program for outreach. Because when you think about the barriers that women experience or the reason why so many women do not enter the field, there's a plethora of those reasons. But certainly a lot of those come up and rear their ugly heads early on, in elementary school, in middle school and high school. So we really wanted to go back down to these levels of education and see if we can remove some of these myths, get people interested in this field, do advocacy for raise awareness and see if we can get students to consider this and to not say, "Oh, that's just not for me."
	01:31:39	So yeah, here we are. Last year, we decided to spin off WiDS from Stanford. So we'd been under Stanford for a long time and we became so large that it was time for us to spin off. It was the natural thing to do. And with great support from Stanford and with Stanford remaining as partner, we are now a nonprofit. We just launched our brand new website with a new logo and everything, with hundreds and hundreds of videos that are nicely curated, lots of events that people can explore and lots of interesting information, and that's at widsworldwide.org widsworldwide, one word, W-I-D-S worldwide.org. So I hope people will check it out.
Jon Krohn:	01:32:23	Oh yeah, we'll be sure to include that in the show notes. It's fantastic. And so eight years ago that you co-founded WiDS, the conference is now enormous. So you co-chair the conference and you have the conference going on globally around filming today's episode?
Margot Gerritsen:	01:32:45	Yeah, as we speak. And right now, four minutes from now, we're starting our third broadcast of our five-hour program. And that's in the Americas. So we had three, I was up with several of my team members through the

		night. I did get a little nap in, but through the night in APAC and EMEA. We pre-taped our five-hour conference and so that made it a little bit easier. And no, I don't have to rush now, Jon, because we've got-
Jon Krohn:	01:33:15	[inaudible 01:33:16].
Margot Gerritsen:	01:33:15	No, no.
Jon Krohn:	01:33:15	Been up all night almost.
Margot Gerritsen:	01:33:21	It's all been pre-taped. I'm MCing the conference, but everything was taped a while ago so I can join a little bit later. Yeah, that's just fine.
Jon Krohn:	01:33:30	Well, we won't want to hold you in really too much longer. But I mean the conference is enormous, so it has over 100,000 participants worldwide from 175 countries, hence the long hours because people are in all different time zones. Attendees from Oregon, where you are now, to Tokyo, to Saudi Arabia. So fascinating and amazing to have this success. But yeah, clearly you tapped into something that was badly needed. And I agree, I mean it's wild to think that you could go to a conference and there'd be only male speakers, this kind of thing.
Margot Gerritsen:	01:34:13	It's getting better. It's getting better. And we have to do a big shout-out to so many fantastic sister organizations that around that same time or afterwards, or just before, started up as well. We have PyLadies, R-Ladies, Women in Data USA, Women in Big Data, Women in Analytics, Black Women in AI. We have DAIR, a fantastic organization set up by Timnit Gebru and some of her friends. And I'm missing out and I'm sorry if you're listening and you're running another sister organization and I miss out on you. But we have Sisters of SAR, we have the Ladies of Lancet, we've got Sisters in Sport Analytics. There are so many and they're all doing

fabulous jobs and we want to collaborate with everyone. So it raises the visibility of women, which is super helpful. It raises awareness in women that this is a fascinating field and yes, they do belong. And no, you don't need to be a computer nerd with a massive innate ability. Absolutely not. Most people that contribute to this field and everywhere in STEM by the way, are pretty ordinary learners. We just learn and make mistakes and get better over time, and we just love working in this field and love learning something new with every mistake we make.

Jon Krohn: 01:35:47 Yeah, it's amazing to me, Margot, that you're able to recite all of those different organizations. That kind of wrote listing of things is something that I'm really terrible at. So yeah, it's amazing that there are so many organizations and that you're able to reel so many of them off.

Margot Gerritsen: 01:36:05 And the one I forgot and I have to mention, AnitaB is another organization, [inaudible 01:36:11], Girls Who Code. I mean, there are so many and they're all fabulous. So anyone listening who wants to help get women and other underrepresented minorities in this field to the table and get them successful, there is a place for you, there's an organization that you can associate yourself with, you can help out with. Certainly, you're welcome in WiDS, very welcome. WiDS, a lot of our programming, all of our programming is done by women. There's women on the podium, women behind the mic, women on video, but it is for everyone. So all our programming is available to everyone at no cost. It just so happens that the content is delivered by women, and why not? Because women are a part of this.

Jon Krohn: 01:37:03 Yeah, yeah, yeah. And in addition to the conference, there is of course something that's probably going to be particularly of interest to our podcast listeners, is there's a WiDS, a Women in Data Science podcast of course as well.

Margot Gerritsen: 01:37:17 Yes.

Jon Krohn: 01:37:18 And so you host that show, I think as of recently you co-host that show?

Margot Gerritsen: 01:37:23 Yeah, we have Chisoo Lyons who is a team member, a core team member with Worldwide. She's our chief program director and she has joined as a host. She's wonderful. She will do most of the conversations with industry professionals, and I will do everything else. That will allow us to have more regularity. As you know, Jon, with a podcast it's great to do it regular, to do it often. And with which so far we've had seasons, every year we'd have a season with 10 to 12 podcasts. But you're going to see a lot more regular broadcasting of WiDS podcasts going forward, which we are really excited about.

Jon Krohn: 01:38:07 Nice. Yeah, and I'm sure our listeners are as well. Well, Margot, this has been such a fascinating episode. I've been gripped by your content and your beautiful accent, in my opinion, this entire time. Yeah, it's just such an incredible episode. I've learned so much. I mean obviously I learn a ton with guests on the show all the time. But with you today, it was almost everything. Almost every topic we covered, it was completely new ground for me. And so thank you so much. I'm sure it's the same case for a lot of our listeners as well. And as I've already said a couple of times on the show, the way you communicated it is masterful. So thank you. Before I let you go, and I know you're already aware of this because you've been on the show before, we always ask for a book recommendation. So I understand you might have a few for us.

Margot Gerritsen: 01:39:05 Yes, I can't resist. There's a few on different aspects of data science and also some are women in data science. But the first book I wanted to highlight, and we had the authors of the book, Ivy Ross and Susan Magsamen actually at the conference now, so people can see the video and that's this book here, Your Brain on Art, and it may be mirrored so you have to read it differently. Your Brain on Art by Ivy Ross and Susan Magsamen who give a lot of fantastic data-based evidence of how engaging in the arts, even if it's just 10 minutes a day, a little bit can really help your brain function better also in STEM and in data science. It's fascinating. It's been proven. And like I said, they give plenty data, very scientific book in that sense and it blew me away. And this is one reason why I'm determined to spend more time on my banjo. The other-

Jon Krohn: 01:40:13 Only a small portion of our listeners are doing it with the YouTube version. So there there's a banjo and a music stand right over Margot's shoulder, which nicely compliments the guitar over my shoulder.

Margot Gerritsen: 01:40:24 Yes.

Jon Krohn: 01:40:25 And there was a brief period where both of us, we were both getting ready before the episode but we both had our streams going and it was kind of funny, a banjo interviewing a guitar.

Margot Gerritsen: 01:40:38 Yeah. Anyway, the other book that I wanted to mention is this book called The XX Edge, and that's written by Patience Marime-Ball and Ruth Shaber, also-

Jon Krohn: 01:40:50 As in XX being of course the two chromosomes that lead to a women.

Margot Gerritsen: 01:40:55 That's right, it's a chromosome. Yeah, that's right. And they provide a lot of really interesting data and discussion of the impact that women can have on the financial sector, in investing and risk management, and how diverse teams tend to do much better. What I like about this book also is that it's very scientific and very data-driven, so interesting. And then the last book I just wanted to highlight is a book on teaching of data science. There is a part of data science that sounds very esoteric, it's topological data science. It uses topology, which for a lot of people is even more scary than algebra, and certainly was for me. But Colleen Farrelly and her co-author Yaé Gaba wrote this wonderful book called The Shape of Data, that explains how to use topology and network theory to do data science differently and for I'm sure many people more intuitively. It's a lovely book. So anyway, those are my three shout-outs.

Jon Krohn: 01:42:13 Those are fabulous recommendations and I am going to immediately, after we finish recording, go and order The XX Edge for my younger sister, who was a trader for many years at a bank and now does ESG fund management type of work. And that sounds like just the perfect book for her.

Margot Gerritsen: 01:42:36 Yes.

Jon Krohn: 01:42:36 So yeah, these are exciting recommendations. Thank you. And yeah, very last thing before I let you go, obviously we know about the WiDS conference, the WiDS podcast, are there other ways that our audience should be following you to keep up to the latest on your thoughts?

Margot Gerritsen: 01:42:55 Yeah, well check out our website widsworldwide.org. And we are very active on LinkedIn as well. We have a very large group on LinkedIn and so people can come in and connect and we post a lot of stuff there, so that's a great way. If you're really interested in joining us and helping, send me an email. I'm very easy to find. Just go to the website, you can find me. We love new ambassadors, we love new connections to corporations. Corporations can become corporate sponsors. We love donations, we love it all, but we particularly like your active participation. Check out our datathon, check out some of those podcasts, get familiar with the women in this field and incredible work they do. Just at this conference, by the way, that we are streaming right now as we speak, we're 10 minutes in in the Americas, they're amazing women.

Jon Krohn: 01:44:01 At the time of recording.

Margot Gerritsen: 01:44:04 At the time of recording, yeah. So what that means is that you can now find it really easily. You can go to our YouTube channel, find out Women in Data Science YouTube channel, where we have hundreds and hundreds and hundreds of videos, including all the videos of this conference. The conference is opened, but just to give one example, I'm so excited about everyone, but to give one example, it's opened by the head of data science of the World Bank. So that's something your sister would probably also find fascinating. Her name is Haishan Fu, she's dynamite and she gives a wonderful opening address.

Jon Krohn: 01:44:42 Awesome. Check it out for sure. Regardless of your gender, it's going to be a fascinating conference, no doubt, to check out. Margot, thank you so much again. I've already profusely expressed how amazing an episode this was, so I'll just end it here. Thank you so much again, and maybe in a few years we can check in again and see how your journey's going on?

Margot Gerritsen: 01:45:06 Yes, yes. Yeah, and if you change your name to Joanna, we can have you on our WiDS podcast too.

Jon Krohn: 01:45:13 Yeah, yeah.

Margot Gerritsen: 01:45:15 Thanks, Jon. It was wonderful to chat.

Jon Krohn: 01:45:18 I think I'd go with Joan so that I have a rhyming name. I'd be Joan Krohn.

Margot Gerritsen: 01:45:27 Oh, look at that. That's it. Okay. All right. Well, thanks again, Jon. It was wonderful.

Jon Krohn: 01:45:31 Wow. What an eye-opening and fun conversation. In today's episode, Margot filled us in on how computational mathematics involves the translation of physics and math into computer code, typically resulting in terabytes or petabytes of data being generated in four dimensions. She talked about how fluid dynamics is a common application area for computational math, but it can also be applied to solids like earthquakes and tons of other phenomena including human behavior, electrical grids, and engineering processes. She filled us in on how underground fluids are typically found within tiny micron-sized pores in rock, how Pterodactyls had big heads so they were not well suited to flying, but the quick reacting wing muscles they had to compensate for this have implications for airplane wing design. And she talked about how she co-founded WiDS as a reaction to a conference with only male speakers, and now their annual conference has over 100,000 participants in over 170 countries.

01:46:30 As always, you can get all the show notes including the transcript for this episode, the video recording, any materials mentioned on the show, the URLs from Margo's social media profiles, as well as my own at superdatascience.com/719. Beyond social media, another way we can interact is coming up on November 8th, when I'll be hosting a virtual half-day conference on building commercially successful large language model applications. It'll be interactive, practical, and it'll feature some of the most influential people in the large natural language model space as speakers. It'll be live in the O'Reilly platform, which many employers and universities provide access to. Otherwise, you can get a free 30-day trial of O'Reilly using our special code SDSPOD23. We've got a link to that code ready for you in the show notes.

01:47:14 All right, thanks to my colleagues at Nebula for supporting me while I create content like this Super Data Science episode for you. And thanks of course to Ivana, Mario, Natalie, Serg, Sylvia, Zara, and Kirill on the Super Data Science team for producing another breathtaking episode for us today. You can support us by checking out our sponsors links, by sharing, by reviewing, by subscribing. But most of all, I just hope you keep on tuning in. I'm so grateful to have you listening and I hope I can continue to make episodes you love for years and years to come. Until next time, keep on rocking it out there and I'm looking forward to enjoying another round of the Super Data Science Podcast with you very soon.