**Sue Nelson**
Hello, I'm Sue Nelson and thanks for joining me on Create the Future, a podcast brought to you by the Queen Elizabeth Prize for Engineering. It's not just scientists who can combine academia with a career in the media. And while Danielle George began her career as a scientist and an astrophysicist in this case, she quickly discovered the allure of engineering. Today, she's as likely to be hosting TV programmes and podcasts, as she is to be at the University of Manchester as Professor of Microwave Communication Engineering. In 2016, she was honoured with an MBE and the Royal Academy of Engineering and Rooke Award for the Public Promotion of Engineering. And in October, she'll become president of the Institute of Engineering and Technology during its 150th anniversary year. She's also the founder of the world's first recycled robot orchestra, so I'll have to start with this Danielle, how did this come about?

**Danielle George**
The Manchester Recycled Robot Orchestra came about as an idea when Manchester was named European City of Science back in 2016. And there was lots of great ideas and initiatives to engage people with science. But I wanted to do something slightly different. So, you know, there had been citizen science projects out there, but I'd never heard of a citizen engineering project. So, I wanted to try and engage the public and especially young children with engineering. And so, I thought, well, what would sort of capture people's imagination and so I thought, well, robots because everybody loves robots, don't they?

**Sue Nelson**
Absolutely!

**Danielle George**
And also music, you know, people love lots of different types of music. So, you know, what can we do with that? And so we sort of thought, right, well, we'll put those two things together, a robot orchestra. But then we thought, right, what else would quite like to do with it? Could we use upcycled materials or recycled materials to do it? So, things that you might never have thought would create music, could you make them into a robot and then create some music from them? And we put this sort of call out, we had some sort of hackathons and makeathons where we had loads of different types of people, sort of engineers, professional engineers, students, and then children as young as about five. We all got together and said, right, let's create a robot orchestra out of everything. I mean, seriously, just whatever you could think of we created, or the children created robots from. So, we had an amazing one working with engineers on old floppy drives, remember floppy drives from computers?

**Sue Nelson**
Oh yes.

**Danielle George**
So the motors that are inside of a floppy drive, we got 16 old floppy drives together. And we fed them a MIDI file, so a Musical Instrument Digital Interface file and they played music. And so we had this floppy drive orchestra. We then had children of as young as five with tins of like a Pringles crisp can. [Music from the orchestra plays]. And we'd given the children a sort of a bag of bits if you like, so, a little electronic board, which was sort of the brain of the robot, and then some little bits, wires, crocodile clips, you know, things like that, little motors to play with. And then just said, create whatever you want. And so, they came back with so many different things and like I said, it was everything from Pringle crisp cans with, if you imagine a Pringles crisp can and then on this side of them, two chopsticks as arms, and then sitting in front of the crisp can was like a tin of beans. And so, the chopsticks would hit the top of the tin of beans like a drummer. And so we had like drummers like that, we had hexapod spiders that would normally go into nuclear reactors, would play a piano

for us instead. You know, we just had absolutely everything and everybody started donating materials that we could use. So, we had things from the Women's Institute, we had Manchester transport network, so many different things. And then they played with the Hallé Orchestra in Manchester at the opening of the Science Festival. It was just incredible to see the enthusiasm on the children's faces when their robots that they have created are playing with this amazing orchestra, the Hallé Orchestra, to an audience of hundreds of famous scientists from around the world. It was incredible. And it's just gone from strength to strength.

**Sue Nelson**
It sounds brilliant. Where are your robot musicians now? Are they retired?

**Danielle George**
Yes, some are retired because they don't make the journeys very well when we take them around places. So, they're all they're all sitting in one room in the University of Manchester at the moment, but we do try and take different bits of it to different festivals. If I go maybe do some talks to the public or in schools I try and take at least little bits with me as well. So yeah, they're all still around, but just in different phases of health.

**Sue Nelson**
Now, what is your home like? Because I've now got this vision that it might be filled with all sorts of unusual pieces of electronics and instruments lying around the house, or does your house give no inclination in terms of what you do? I mean engineers are often like that, aren't they? They just keep things just in case they're useful.

**Danielle George**
Yes, yeah, I'm very much like that. So, there'll be different parts of the house where the things that might be useful are kept. So, in the utility room, or in the garage, or in one of our spare rooms. But I do have I have one of the robots that we use, they're called Nu Robots and they're used as teaching robots for undergrad students at university and I have one of them and my five-year-old daughter just loves it. She's called it Natalie, which is the name of my younger sister. And she walks around with it and she talks to it and of course, the robot talks back to her and she finds that fascinating. So yeah, you see Natalie the robot around the house quite often.

**Sue Nelson**
That's great. Now your title at the University of Manchester, Professor of Microwave Communication Engineering, that's sort of unlike any title I've read before. What does it actually involve?

**Danielle George**
I'll tell you what it doesn't involve is creating microwave ovens, which is what I'm sure my friends still think I do. In the electromagnetic spectrum, there is an area just next to the radio waves, if you like, called microwaves and they are slightly higher in energy, slightly smaller wavelengths, higher in frequency. And so, I work on radio telescopes and trying to capture the naturally occurring radiation that is emitted in both the radio and the microwave regions of the spectrum. And that radiation is emitted all over the universe and so I work with lots of other engineers and scientists to create new instruments for radio telescopes to try and capture that really distant cosmic light.

**Sue Nelson**
And this is quite a good combination. In terms of how you got to do this because you didn't start off as an engineer and studying engineering. You started off studying astrophysics?

**Danielle George**

Yeah, that's right. Yeah. So, I really enjoyed the astronomy side and, you know, I loved maths, I loved physics and so it just seemed really the right thing to study at university and all throughout my undergrad degree I hadn't really realised at the time, it was just quite organic, but I was always choosing the very practical subjects. You know, when you had options for the units that you were taught, I was always choosing the practical ones because I wanted to help build an instrument, or design a different part of a telescope, or you know, something like that rather than take the data and crunch that data or work on the theoretical side.

**Sue Nelson**
So the clues were there?

**Danielle George**
Yes, indeed. Yeah. And it wasn't really until after my MSc, which I went to Jodrell Bank for, Jodrell Bank Observatory, which is part of the University of Manchester. And again, I wanted to do my dissertation for my master's as a practical thing and so I worked with the engineers there. And I was just so lucky, that I was in the right place at the right time. And this amazing project came across the books, so to speak, and it was to work on the Planck satellite. So, Planck was an unmanned spacecraft to go and look at the remnants of the Big Bang, the sort of oldest cosmic light in the universe, the cosmic microwave background. And so, engineers and scientists at Jodrell Bank Observatory were going to work on this and so I got to work as a junior engineer. So that was my sort of very first job as a junior engineer, was to work on the Planck satellite. It was then I moved, it was so good to have that background of astrophysics and give me that grounding from a physics point of view. And then I moved and used that in the application of engineering.

**Sue Nelson**
So, were are you actually based at the University of Manchester in the city centre or were you at that fabulous dish in the middle of the countryside surrounded by some flowers sometimes?

**Danielle George**
Yes, I was. I was out there in the in the fabulous countryside for a number of years, yeah, I worked there from 1999 until 2006.

**Sue Nelson**
I've been there several times, which is why I know even about the flowers, you know, it's such a fabulous place. So, it's a telescope, and particularly now with the Bluedot Festival that brings together scientists and engineers and musicians and plays beneath that huge dish. It's memorable.

**Danielle George**
It's it is inspiring.

**Sue Nelson**
It is inspiring. And so, working there as an engineer, working for the Planck spacecraft satellite. Did you contribute then to the design and development of instruments as well?

**Danielle George**
Yes. So, you know, you've mentioned the really big dish that's out at Jodrell Bank, the Lovell Telescope, 76 metres in diameter, so it's a beautiful big dish. And within it there are several different receivers. And the reason there are different ones is because we want to try and capture the different frequencies or the different wavelengths of the radiation from all different parts of the universe. So, they emit at different frequencies, so we want to try and capture all of the information. So, we have that on the Lovell telescope. And then there's

also what we call the Mark II telescope out at Jodrell. And then there's a linkup across the UK, which is called a MERLIN and that sort of links up the different radio telescopes across the UK. And then they also link with sometimes ones in the US and sometimes ones in Europe, as well. And so, I got to work on several of those telescopes as well as the satellite spacecrafts.

**Sue Nelson**
So, do you do industrial collaborations then as well as part of your work?

**Danielle George**
Yeah, so not as much now, I've sort of concentrated a bit more back into the astronomy side of things and working on two fabulous, big projects for radio astronomy. But, um, but there was a time where I wanted to take the technology that I had done from within radio astronomy and apply it to different areas, so, I worked with farmers for agriculture. So precision agriculture, so trying to bury small nodes in the ground and wirelessly gather information from those nodes about the soil. So, the nutrients, how much it needed to be irrigated, etc. And the idea about that was trying to save that precious resource of water, and only use it in areas of the field that need irrigating and not just to go and you know, water the whole field because that's what you think is needed. And so these nodes would be sort of peppered all the way around the field, and then they'd be able talk in real time to the tractor that was going across and then the tractor or the farmer would then make a decision based on real time information, whether to irrigate that part of the field.

**Sue Nelson**
So, what made you decide, you know, after working as an engineer, you're working in astronomy, to do a PhD in electronic engineering, what was it that that sort of made you decide to take your studies further?

**Danielle George**
So, it was when I was working out at Jodrell Bank Observatory, again on the Planck spacecraft mission. And, you know, I was working with these amazing engineers and scientists and Jodrell Bank is part of the Department of Physics and Astronomy within the University of Manchester. And I was just chatting to one of the lecturers one day and they said, Oh, hey, you know, all that work you're doing, maybe you should just write it up as a PhD. I was like, oh yeah, that sounds really good, you know, I'd really quite like to do that. And so, my boss at the time was very supportive. Scientists out at Jodrell Bank Observatory, were very supportive as well. And so, I wrote up my research work on a couple of different projects for my PhD. So, it was characterising low noise devices for radio astronomy applications.

**Sue Nelson**
That's pretty comprehensive and understandable because most people's PhD titles take about two minutes to read. I'd say that's possibly an early indication that you would end up involved in communication.

**Danielle George**
Maybe, yes.

**Sue Nelson**
And since then you've been involved with a telescope called SCA, the Square Kilometre Array. Can you explain how it works?

**Danielle George**
Yes, so the Square Kilometre Array is still being built at the moment, but it is a network of hundreds and thousands of antennas of different types. So you might have like the dipoles, you know, like the old antennas

that we had, aerials that we had on top of our houses, and then dishes as well and it is effectively once square kilometres worth of collecting area, but it's spread across Western Australia and in remote areas in South Africa. And so when you join them all up, you know, there's hundreds of thousands of these things all dotted around, when you join them up, it's effectively like having a massive dish that would have a collecting area of one square kilometre, and it will be 50 times more sensitive than any other radio instrument in the world. And it is a tremendous project to work on because there are so many engineering challenges to work on. It will be a fabulous science instrument when it's all built and whilst it's being built, it is a fabulous engineering instrument to work on, so many great challenges. So, I work on some of the front-end receivers. So, the amplification, you know, you need to amplify the cosmic signals that are being observed. And you just want to amplify the signal. You don't want to amplify any of the noise that comes with it, so anything to do with atmosphere or anything like that, you don't want to have any of that amplified, just this, you know, beautiful cosmic signal that you're trying to observe. And so that's the part I work on, which is a huge challenge, because normally we just, we'd be building, you know, 10s of, sometimes maybe one or two, but you know, maybe 10s or 20 of these amplifiers, and the SKA has just turned it on its head because we're now having to think about how you have the same performance from the amplifiers, but now you need to build them in a much more sort of commercial way, if you like, so industry standard ways, because you need hundreds of thousands, possibly millions of them. And so, it's a fabulous challenge to work on. And it means that that academia and industry are working a lot closer together. Which I think is a really positive thing as well.

**Sue Nelson**
And what do you think you bring to it? What qualities do you think you have from your career so far that you think really help you when it comes to your work?

**Danielle George**
I really love challenges. And I think that's probably true of any engineer and scientist. I love the challenges and I love the fact that they get me out of my comfort zone. And so, I embrace the fact that it gets me out of my comfort zone, and I find that really helps me. I also dealt with failure quite a long time ago in a positive way. You know, at the beginning of my career I was a lot more upset when things didn't work. And now I embrace failure because it's such a huge part of being an engineer or a scientist, is all of the failures you have along the way to get to your success and that so I've very much adopted the fail fast and learn approach and want to celebrate the failures as well. So, part of when I have amazing opportunities to go out and chat to other people outside of my field, I always want to make sure that especially children and young children know that failing is a part of being an engineer or a scientist. And not only is it a part of it, it's essential to be a good engineer or scientist, you do need to fail along the way.

**Sue Nelson**
Do you think engineers are better at that and scientists?

**Danielle George**
That's a good question. We probably have more of it in a way because of the practicalities, you know, the practical elements of things. It's sometimes harder because if you're an engineer in a big company, there is a financial risk to that as well. So, you can't fail too many times because of the sort of financial side of it. But I think scientists and engineers, you know, I think both people, if you're a scientist or an engineer, I think you do embrace failure. But I think the scientists who are on the more sort of practical side if you like, they probably get to deal with it more than the theoretical side.

**Sue Nelson**

And you have always been keen to communicate what you do, you know, the robot orchestra wasn't the first, you know, you've presented a TV series: Nation of Inventors, you've delivered the Royal Institution's Christmas lectures. So, obviously, you must think the communication of engineering and science is important.

**Danielle George**
It's so important. It is so important. And it's essential on so many levels that people outside of your field understand what you're doing, not just on a personal level, but you know, to try and communicate the fabulous engineering and science that goes on, we need people to understand what it is because fundamentally, we need people to be enthused about it as well, to carry on the great work of scientists and engineers in the future. And if young children aren't enthused and inspired, you know, they're going to choose a different path. And so, we need to make sure that there are enough people out there communicating the great work that engineers and scientists do in a hopefully compelling way and exciting way that appeals to that young audience, which are the next generation of scientists and engineers.

**Sue Nelson**
Is this partly because obviously, you didn't come to engineering until you had done your degree that wasn't an engineering and it was through, you know, being at Manchester and being at Jodrell Bank that you got into it, and isn't engineering perhaps missing out a lot of people in the same way, it just never actually catches them, that it's too late, they've gone off to study other subjects.

**Danielle George**
Yeah, I mean hopefully, you know, people do follow a similar career path to me. And hopefully it shows that it's never too late, you know, to change and to move to a different sector. But I think, you know, there are, there are so many similarities between science and engineering. You know, you have to understand the fundamentals of science to be an engineer. And I think, perhaps some of the issue with engineering, and you know, people being turned off by it or not turned on by it at all, is the perception that some people have of engineering and so there are lots of people trying to change that perception, and that sort of image of the hardhat and the boiler suit. Some engineers wear hard hats and boiler suits and that's great, but quite a lot of people don't as well. You know, it's like the image of a scientist wearing a white lab coat. You know, lots of them do and that's great, but quite a lot of them don't. So it's trying to get that sort of image of the different types of engineers that you have. And hopefully I help a little bit doing that.

**Sue Nelson**
Do you think there's, you know, a medium that works better than the other when it comes to engineering? Because obviously, people do podcasts, they write about it, they might do TV or radio and talks, obviously, TED Talks or whatever. What do you think is the best way to communicate or get people to really get engineering?

**Danielle George**
I think it's probably all of those things, really. And the more you can get it into the mainstream media, if you like, the better. And then all of those sorts of things can be amazing supporting materials if you want to go learn more things. So, you know, we need to have books about engineers and engineering right alongside, you know, other books on science, you know, mainstream engineering in the way we have mainstream science as well. And on the television, you know, documentaries or programmes about technology and engineering, and we do now, we certainly have a lot more than we used to. So, I think it is changing, for sure. And you do see a lot more younger people, you know, when I go into schools, and you know, just chat when I'm doing maybe public talks and things when you chat to the children. They're much more clued up about engineering now than was true maybe even just five years ago, but certainly 10 years ago. So, I think it's really positive you know, we're moving in the right direction.

**Sue Nelson**
That's good. That's really nice to hear. And do you come up with as is often the case whenever I've interviewed not just women engineers, but women scientists as well. They still have to overcome the perception that it's a profession for men first and foremost. And for unusual women.

**Danielle George**
Yes. Yeah. I mean, I think there is that perception sometimes. But it's quite interesting. I think the perception comes from the older generation. And I include myself in that. And what I mean by that is when you're talking to really enthusiastic girls who want to go into engineering technology and then I might say, you know, well I was the only girl in my class when I was at university doing astrophysics, would that be a problem? You know, if you were the only girl how would you feel about that? And a lot of young girls are sort of like, I haven't really thought about that. Like, that would be sad if I was the only person, but if I was, you know, we are still just all humans, so they don't have the stigma attached in the same way that maybe the older generation do. Again, I think that's a positive and if we can keep the mantra out there that there have always been fabulous women scientists and engineers, it's just we don't hear about them and that's the thing. It isn't that there haven't been them and so, you know, [it's not that] we are the first engineer or the first female engineer. They've always been there. It's just they're hidden a bit more. And so, I think we have to get that across you know, why have they been hidden and let's pull their stories out and get those stories told so people do know that female scientists and engineers have always been a part of history.

**Sue Nelson**
Oh, absolutely preaching to the converted with me. With the International Women in Engineering Day coming up, what have you got planned for this or has the pandemic slightly changed things a little?

**Danielle George**
It's slightly changed things. Yes. I mean, I'll be doing a bit more chats over on podcasts and chats over video conferencing and things like that. My thing about engineering, you know, women in engineering and International Women Engineering Day is that I really want to get to a point quite quickly where we don't have these sort of days, where we don't have to celebrate it because it's just the norm so why would you celebrate it? You know, it's quite normal to have lots of women engineers around the world, but we're not there yet. And I think that's why we need to continue at the moment, to have a specific day in which we will celebrate it. But I'd really like to get, in the next decade, get to the point where, you know, having one day that celebrates female engineers is just a thing of the past because they're everywhere and why would you want to have one day that you celebrate?

**Sue Nelson**
And how are you finding locked down at the moment? Has it brought out your inner - let's see what bits I've got around the house and just put things together, or are you more routine and obviously said you have a child? It's affecting people in very different ways depending on their family circumstances and where they live. What's it been like for you?

**Danielle George**
Yeah, so um, so there have been a number of meetings, quite a lot of meetings every day for work. And that's completely understandable. You know, I'm the Vice-Dean for Teaching, Learning and Student Experience for the Faculty of Science and Engineering so I need to make sure we are doing the best for our students at this time, and to make sure that we can deliver our content online and assess people online, etc. So, there's a number of meetings about that. But as you say, I have my daughter here as well. She's five years old and the

amount of cereal boxes and cartons and things that we're now storing up because every day we're trying to build something. She does like building robots, so that's good. We build robots, we build palaces, we built a robot dog, you know, just different things like that. So, um, so I think she's a budding engineer as well.

**Sue Nelson**
She'll have to be really wont she? Has there been any engineering work for you relating to COVID-19, that has stood out where you thought, whether it's related to incubators or new devices or any form that you've thought, "oh, that's really clever'?

**Danielle George**
The 3D printing aspects of what's been happening I think, are really good. And it's showing how sort of rapid prototyping has its place in something that's extremely serious as well. So yeah, all of the 3D printing that you've seen going on, I think is amazing. But I think just generally, you know, the way, we've all got together, you know, the scientists and engineers collaborating so much around the world, trying to, whether that's trying to find the vaccine or whether that's trying to develop new protective clothing or you know, whatever it is, many people are all trying to work together for that common good. And I think that's a real positive that we should take from this crisis.

**Sue Nelson**
Now, when you start as president of the Institution of Engineering and Technology, I know you've been deputy up until now. So, it's not a massive change, but you know, now you have that power when you get there are there any things that you think, if I was president, I'd really like to do this?

**Danielle George**
Yes. So, when presidents come in for a year, we all tend to have, you know, one specific topic that we'd really like to try and drive forward and mine is very much about inspiring that next generation, making sure that the next generation are still curious, they know that they can fail and that's okay, and that they are using their imagination and using their creativity and becoming engineers and getting across that you can be really creative. I mean, that was the other thing about the robot orchestra what that brought out was the common thing, whether the people were musicians or budding engineers was that creativity side and so it's absolutely key. If you are creative, you can be an engineer. And so, trying to get that across to the next generation and make sure they're inspired globally with it will be my sort of mantra for my presidency. Yeah.

**Sue Nelson**
They sound very worthy aims. And if you could look back, I know we heard hints there of how there was an engineer inside you about choosing your modules at university. When you were a kid, was there anything that you did that looking back on your thought, "aha", or is there anything you would like kids to get involved in like, you know, making robot orchestras or something? Is there something that you think actually, this is what we could encourage people to do and it might just set something alight give a spark?

**Danielle George**
Yeah, I think it's that curiosity and, you know, the taking things apart and putting them back together. And that doesn't matter what it is, you know, it could be electronics, which is sort of my bag. That's what I really love doing. But it could be absolutely anything, whether that, you know, you could be in the garden and be constructing or deconstructing something, and just making sure that people are curious, and they want to do something with that curiosity. And I mean, that was the key for me looking back on my childhood, so my parents were not engineers or scientists.

**Sue Nelson**
That's not unusual.

**Danielle George**
Yeah. So I mean, my dad was a car mechanic but not a qualified engineer. But I mean, he did love taking things apart so there's that side of it and I did used to help him 'help' I guess is in inverted commas at his garage at the weekends, you know, trying to help him. You know, while he was under the bonnet, I'm sure I was a huge help to him. But, but no, so they weren't sort of qualified engineers or scientists. But what they did do was every time I asked that sort of 'why?' question, which, of course, pretty much all children do, which is brilliant. You know, 'Why is the sky blue? Why is the grass green?' If they didn't know the answer, they didn't just say "oh, for goodness sake, Danielle, just go away and ask someone else or ask your teacher or something". They said "I don't know. Let's find out together" and so we would find things out together and so my curiosity was always a positive thing. You know, it was never crushed in any way. Every time I asked something, we'd go and find something out. So yeah, I think as parents or carers or teachers, making sure you help children with their curiosity, I think is the key thing.

**Sue Nelson**
And that's so interesting as well, because one of the positive things that's come out of lockdown, and I know it's, you know, it's mostly negative, has been a creativity of people. And particularly, because so many parents have had to home-school their children. It's been that coming together to do those sorts of activities, where you create things, make things work together. And I think actually, probably the parents have got as much out of that as the children.

**Danielle George**
Yes. Yeah, I agree. Yes. I think there are a lot of positives like you say of the of the lockdown. I mean, for sure. I feel like I'm spending more quality time with Elizabeth my daughter during the week than I would normally do, because you know, she's been at school all day, and then maybe an after-school club or something. By the time she gets home, and I get home, you know it is pretty much bath and bedtime for her so we have a lot more quality time. And it's, it's been really good for myself and my husband even though we find it challenging, you know, trying to work full time and home-school. But to have that time with Elizabeth and to change our working day so that we might just stop work during the day and then start again when Elizabeth has gone to bed and having that flexibility so you can spend some quality time and go out and dig worms or you know, create a latest masterpiece with, you know, loo rolls and cereal packets or something. I think it's really good.

**Sue Nelson**
Yeah, so do I, I must add though, that I found an empty bottle or Fairy Liquid by the washing machine the other day and I said "What's this, it's empty?" and I was told "No, no, keep it because I'm going to build a rocket". But that wasn't from my 19-year-old son that was actually from my husband, so.

**Danielle George**
[Laughs] Brilliant. We're all curious.

**Sue Nelson**
Exactly. Well, Danielle George, thank you very much for joining me and sharing your really fascinating career.

**Danielle George**
Thank you so much.