

**Sue Nelson**

Hello and welcome to Create the Future, a podcast brought to you by the Queen Elizabeth Prize for Engineering. My guest on the podcast this week is an author and broadcaster well known to TV for presenting documentaries and to radio for his life scientific series GML. Clearly his main job, however, is as professor of physics at the University of Surrey. Having said that, he's also co-director of the Leverhulme Doctoral Training Centre for Quantum Biology. And, here's a connection to Create the Future: a judge for the Queen Elizabeth Prize for Engineering. So naturally, I have to begin, Jim, by asking how as a physicist, you became one of the judges?

**Jim Al-Khalili**

Well, my ex-Vice Chancellor, Christopher Snowden – Professor Sir Christopher Snowden – became the chair of the judging panel. I knew him very well, we'd worked together, and he'd invited me onto the panel as, I guess, the only non-engineer.

**Sue Nelson**

How did that feel then? Did you feel a little bit of a fraud? Or did you think “well, no, actually, I've got something to contribute”.

**Jim Al-Khalili**

Well, no, I didn't feel like a fraud. I knew that my good friend, Brian Cox, was a judge on the panel when the prize was first set up a few years ago. So, I knew I wasn't unique in this sense. But also, I think it's encouraging that, you know, science, physics in particular, and engineering, overlap in so many ways that I felt I could maybe bring a slightly different or less applied perspective when judging some of the great contributions of engineering.

**Sue Nelson**

I mean, that's true. It's probably a bit cruel calling you a fraud.

**Jim Al-Khalili**

No, no, no offence taken.

**Sue Nelson**

Okay, just as well. And, you know, you mentioned this connection between, particularly physics, but between a lot of science and engineering. It seems as though that's been one of the benefits of having this prize - is that people are seeing engineering in a different light, that they're seeing it encompasses, or is attached to, or works with, far more areas than previously thought.

**Jim Al-Khalili**

I think science certainly has its prizes – there's the Nobel and there's plenty of other prizes. Engineering has suffered from sort of an image problem. You know, people often say “where are the superstars of engineering?”. If your average person thinks of an engineer as the guy who comes to fit their boiler, or someone with a hard hat on a building site – and it's always white, it's always a male and so on and so forth. So I think engineering really needed something to boost its profile to celebrate the superstars. But also, to show that all these great scientific discoveries that we might make – scientists are essentially people who want to know the hows and whys to understand how the world works. Engineers put that knowledge into practice. It's the next step, and it's no less valuable. So, I think it's hugely important that some of these great minds in engineering, who've applied science, are being celebrated in some way. This prize is doing exactly that.

**Sue Nelson**

Now, the most recent prize was awarded to those who had played crucial roles within GPS. This is an area that nicely overlaps with physics because it encompasses both physics and engineering.

**Jim Al-Khalili**

Yes, for me, what was fascinating isn't so much the software computing developments or the technical know how to get these satellites up there or how they communicate. It's a rather sort of nerdy point about how they

maintain very accurate timekeeping. Because that's where the great physics innovation comes in, these satellites that help us locate our position on the ground. You know, everyone who has a smartphone uses GPS on it to find their way around, which I'm sure you did in finding your way here to this office on Surrey campus.

**Sue Nelson**

Sorry, took a while.

**Jim Al-Khalili**

But we take it for granted. You know how it works, and some people say "I don't like using GPS because I'm sending signals to tell everyone where I am". No, it doesn't work like that. It works the other way around. It's satellites sending signals to your phone and you use that to trilaterate. But the physics comes in because all these satellites have highly accurate timekeepers, atomic clocks, which are accurate at tiny, tiny fractions of a second. But because of Einstein's theory of relativity, which as you know, is how I got all enthusiastic about this development. Time runs at different rates. Satellites, because they're further away from the earth – they're in freefall in orbit around the Earth – their clocks run faster than clocks on the surface of the earth. So, the engineers, learning this lesson from physics that time runs at different rates, have to deliberately slow down the clocks on GPS satellites in order for them to synchronise with time on Earth. Because you need the time to be synchronised to work out how far away they are, otherwise we wouldn't find our position.

**Sue Nelson**

And I noticed on the way up to your office here, that reception said there was an engineering department so you've, you've sort of got your physics and your engineering in the same building part here?

**Jim Al-Khalili**

Absolutely. I mean, physics and in particular, you know, electrical mechanical engineering, really, really overlap and an undergraduate student in the physics department or the electronic engineering department would pretty much do be doing very similar modules. So you know, they've got to do sort of the mechanics and the maths and the computing and electromagnetism - all the things that I think of as physics subjects, an engineer has to study as well. So we are part of one faculty, the physical sciences, together with chemistry, aeronautical engineering and so on. And it's quite remarkable just how much these subjects overlap, and the boundaries are blurred. And then when you graduate from university, very often a physicist will go and work in an engineering job or an engineer will be doing a physics job.

**Sue Nelson**

And you are next door to Surrey Space Centre as well, which is you know, what a success story for the university.

**Jim Al-Khalili**

Yes, Surrey Space Centre, Surrey satellites is a spin off company. And it's, I guess it's one of the things that the University of Surrey is best known for. For years, along with then-Marconi's, we were the only institution in the UK building its own microsatellites, these washing machine size satellites that companies put in orbit for all sorts of telecommunication applications. And so successful was the research here at Surrey that there was the spinoff company, my colleague Sir Martin Sweeting was very successful and we still have this connection now with this company Surrey Satellites and the Surrey Space Centre, which is part again of our faculty. It shows how a lot of these ideas being developed in a university, then apply in industry and benefit humanity rather than just learning more.

**Sue Nelson**

And this is an important part as well of the prize is it's beneficial impact, it's not just about innovation. It's also about how it's changed the world. I mean, is that a deliberate approach so that people can see this connection between something that may seem very other to people that actually no, it's made your life better?

**Jim Al-Khalili**

Yeah, I think that is vitally important. It's highlighting the fact that what many people would just take for granted is based on innovative ideas, very clever people thinking very hard and working very hard, that has

completely transformed society, transformed our world. When we're going through as judges looking at the different applications and nominations for the prize, you know, we are blown away by oh my god, yes, billions of people wouldn't be able to do such and such were it not for this development. So it is very much about highlighting just how useful a lot of these applications are. A story which I've told many times, my son David, who's now in his late 20s, 10 years ago when he was thinking about what degree to do. He's very smart – maths and physics A Levels and so on, and I sort of assumed he'd follow my footsteps into physics. But he said in the end, no, he was going to do electronic engineering, and that's what he did. He went to Southampton to do electronic engineering. And his rationale was that "Dad, you can do the deep thinking I want to do something useful". It is sort of a quite a sweet distinction between physics, which is about wanting to know the hows and whys, and engineering, which is putting that knowledge to some use in society.

**Sue Nelson**

That's so funny because I studied physics and my son is now studying engineering. And we maybe thought it's because his father did biology that he chose something in between, but actually, I am the least practical person. I can understand easily how the machine we're recording on is working, that's not a problem for me. But actually, well, we're lucky we're recording this quite frankly.

**Jim Al-Khalili**

[Laughs] It's on record.

**Sue Nelson**

Yes, and it's lovely to celebrate the way engineers think because, you're right, it's a huge with math and physics, or it could be biology if you want to be a bio-bioengineer. But there is that ability to create something and to make something and I know the problem-solving aspect is the same as science because obviously you work in theoretical physics.

**Jim Al-Khalili**

Yeah, I mean, it is all about problem solving in the end. It's a puzzle, how do I get this to work. For me it's how do I get this equation to work, how do I solve this integral, how to do calculus, how do I get this computer programme to model a particular system. But it's really no different in terms of an engineer faced with an instrument or piece of hardware and how do I get this to do this? It's about logic, thinking logically, and solving problems. So, in that sense, it's very, very overlapping skills.

**Sue Nelson**

I mean, this is partly why I do broadcasting and my first job actually was as the equivalent of a sound engineer for the BBC, and it was soon became apparent that again, the theory yes, the practical maybe not so much.

**Jim Al-Khalili**

I decided to pursue theoretical physics rather than experimental physics when, as an undergraduate student I almost electrocuted myself. I was cleaning some vacuum chamber in an experiment in a lab and I had to clean these electrodes and then realised after I'd finished, that I hadn't unplugged it. I could have been frazzled with several thousand volts. I could almost imagine at that point thinking, you know what, this isn't, I'm not cut out for this. I'm much safer on a blackboard with equations or in front of a computer screen.

**Sue Nelson**

So what are you most interested in working on at the moment? I know that you've written a lot about quantum mechanics, which is actually quite a difficult subject to get most people's heads around.

**Jim Al-Khalili**

It is difficult and I guess that's why I love it. You know, it's a constant puzzle. Yes, my main research area has been, throughout my career, nuclear physics and of course, that doesn't mean nuclear power or nuclear weapons, but understanding how the atomic nucleus is built up of subatomic particles, protons and neutrons. So that all uses the maths of quantum mechanics. But of course, quantum mechanics is this weird counter intuitive idea of things being in two places at once, you know, cats in boxes dead and alive at the same time, the Popular Science popularised version of it is well known. I've recently moved into an area where I'm applying

quantum mechanics to biology. So we've now got a research centre here at Surrey on quantum biology, which is a new research area, it brings physicists, chemists and biologists together. And it's based on this idea that inside living cells, there seem to be certain things that go on that you cannot explain without appealing to the counter intuitive world of quantum mechanics. It's still controversial, you know, that's big, and mainly because physicists find biology difficult and messy. Biologists, find quantum mechanics and the maths too complicated. And the chemists who are sort of stuck in the middle say what is all the fuss about? Don't go around inventing new fields which are basically just doing chemistry. But it is exciting and it's really allowed me now to move sideways in my research and actually develop some of my ideas that I've had a passion for throughout my career on the on the basic foundational questions of quantum mechanics. What does it all mean? How does it happen? So, I guess I'm more research active now than that then I've been for about 15 or 20 years, which is nice.

**Sue Nelson**

Quantum biology is obviously very theoretical at the moment, but do you envisage a future where that could involve engineering?

**Jim Al-Khalili**

Absolutely. I think even if the more speculative ideas that we're pursuing in our research in quantum biology don't come to fruition, there is going to be a convergence, I think, of several areas that are of interest now. So on the one hand you have nanotechnology, developing mechanical devices down to the nanoscale, a billionths of a metre, manipulating molecules. You also have synthetic biology, developing instrumentation, which relies on the machinery of life itself. You also have quantum technologies, people who are working on developing quantum sensors, quantum computers and so on. You can imagine a convergence of all these coming together as some sort of, I'm trying to think of the right name for it, I don't have a name that trips off the tongue, but how about something like quantum-bio-engineering, right? QBE, let's say, if I put it on record now, if that does become a name I'm going to trademark it, I invented it. But something like that, that doing engineering down at the tiniest microscopic scales and engineering down at the level of molecules is absolutely, I'm convinced, going to transform our lives in the coming decades.

**Sue Nelson**

So it's a good example, I suppose of how the profession is sort of changing and evolving to incorporate everything new that we're discovering.

**Jim Al-Khalili**

I think that's something we're seeing a lot in research, both within industry and academia at universities, where we're much more comfortable crossing discipline boundaries and coming up with these interdisciplinary, multidisciplinary research centres. So, you're basically bringing people in with expertise from different areas, breaking down these silos and looking at solving problems from different perspectives. I mean, it's easy to say and it sounds really logical and sensible, but it is actually happening. And in our quantum biology centre, for example, we have PhD students who have backgrounds in biology who are teaching the physicist genetics, and the physicists are teaching the biologists about quantum mechanics. It's exciting because you're starting to look at problems from a different perspective. I think that that is only going to get stronger and more prevalent within research.

**Sue Nelson**

And it must be nice as well, when you're crossing disciplines like that, to see all the different entries that come in for the Queen Elizabeth prize. It's pretty impressive.

**Jim Al-Khalili**

Yeah, I mean, looking at them, any one of the topics could so easily be the winner and you could make a case for it. And sometimes it's down to whether the time is right. You know, it's not about how many billions of pounds or dollars is this industry worth based on this innovation. It's more about how the judges come to a conclusion that this, now the time is right to celebrate this particular innovation, this particular technology. I wish we could give the prize much more regularly because there's a whole backlog of innovations and inventions and discoveries that somehow need to be celebrated in some way.

**Sue Nelson**

Now the window for the launch of nominations takes place in April, what would you do to encourage people to apply, or now that it's been up and running, do people just submit entries fairly easily.

**Jim Al-Khalili**

I think the prize now has developed a very high profile in terms of the coverage that it's received so far, people are aware of it. People are now talking about the Queen Elizabeth Prize as the for engineering. Depending on whether people say "we are our own prize, we don't want to be sort of be compared with the Nobel", but in terms of the wider society, everyone's heard of the Nobel Prize, but that doesn't cover all disciplines in science and engineering. This is the equivalent of that in terms of prestige. I think the profile is such that people are aware that this is something that they would love to be able to win. I can't imagine there's going to be any shortage of nominations put forward, going into the future. But sometimes, you know, there are innovations that we so take for granted because they are so part of our everyday life, it doesn't occur to us to dig back and find out what actually made them possible in the first place, because they are so ubiquitous. I think somehow that's where a lot of engineering innovation suffer. We so take them for granted that don't realise the geniuses that actually allowed that to happen in the first place.

**Sue Nelson**

I've just realised, of course, that the comparison that does happen between the Nobel and Queen Elizabeth Prize for Engineering in that there has been an overlap with one of the previous judges, Frances Arnold who won the Nobel Prize for chemistry.

**Jim Al-Khalili**

That's right Frances was one of the judges. In fact, she was a judge on the prize the year before I joined so I met her briefly and it was just before she won the Nobel Prize, otherwise I would have been even more in awe of her, she is an absolutely remarkable woman. What makes it even more remarkable is that she had submitted some research recently, which she then had to retract because some issues showing the honesty in science that, you can make mistakes, and that's fine, and that's how you learn. So yes, she is and she's an absolutely remarkable woman.

**Sue Nelson**

Now, this is not necessarily an easy question to get people to answer on the spot. But for you, which engineering innovation has probably had the biggest impact on your life, be it professional or personal?

**Jim Al-Khalili**

Wow, that's really, really hard to say. I mean, in computer science, I guess computers are so ubiquitous that we don't know how we would live without them and the Internet and the World Wide Web. I don't really go there because of course, the World Wide Web was invented by physicist and we're celebrating engineering.

**Sue Nelson**

But they did win the Queen Elizabeth Prize for Engineering because of all the computer engineering and software engineering that went on.

**Jim Al-Khalili**

Exactly, absolutely. So software engineering certainly is something that has transformed society in my lifetime. But this is the problem, you look at all the different technological aspects that surround us in our everyday life and you can pick any one of them and dig back and realise that that wouldn't have been possible were it not for this engineer here, or that engineer there. So, it's really hard to disentangle that I can just look around just pick up my smartphone and look at the technology that goes into that - whether it's material science, whether it's electronics, computer science - so many innovations, in a sense, because engineering tends to sort of span a lot of disciplines it is quite hard. It's harder than the Nobel where you can go and say, so and so discovered this enzyme or so and so developed this equation in physics. In engineering, because it brings together so much expertise, it's really hard to draw boundaries or encapsulate a prize for one thing, we just keep on trying to celebrate the best that we can.

**Sue Nelson**

Jim Al-Khalili thank you very much indeed.