David Cleevely CBE

Interviewed by

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Welcome to the Archives of Information Technology. It's the 24th of April 2018, and we're in the City of Cambridge. I am Jonathan Sinfield, an IT professional, and interviewer with Archives of IT. Today I'll be talking to Dr David Cleevely, a telecoms and wireless expert, a serial entrepreneur, and adviser to Government on both a national and local level. A businessman with strong links to academia, who vigorously promotes networking, collaboration and the City of Cambridge. David is a Fellow of the Institution of Engineering and Technology, and a Fellow of the Royal Academy of Engineering. In 2013 David was appointed Commander of the Order of the British Empire, CBE, for the services, for his services, to technology and innovation. Welcome David.

Thank you Jonathan.

[01:01]
David, I want you to take you way back.

Oh yes.

And perhaps you can tell us, when and where you were born.

Oh, well, I was born in 1953, in a little town called Rinteln, in Germany, where my father was stationed with the RAF.

Oh right. So, is that the city near Hanover?

Yes, it's near Hanover. We moved a bit further south. We moved down to Mönchengladbach a bit later on, where my sister was born. And then we returned to the UK when I was about two I think.

About two. So your father was in the, you say the RAF, yes?

Yes that's right.

Yes, OK, fine. And your mother, what…?

Oh she's a, she's a, she's still alive. My father has passed away unfortunately. My mother is, was a teacher, and, deputy head, primary school. She went back to teaching I think when, when I was about, six or seven I think, something like that. And, she's, she's a great teacher, and is great with the grandchildren.

[02:17]
Great, yeah. And, your parents' parents, were they in the military, or…?

No. I mean I have very vague recollections of, of, you know, my, my grandparents. My paternal grandparents had a flat, or, actually they owned a house, in Richmond, and when we came back from Germany I stayed, we stayed in the basement for a little bit before my parents managed to buy a house themselves. So I remember, I remember some of that. And my, my paternal grandfather, the main thing I remember about him was talking about Gallipoli, and, as an interesting anecdote, how he filled up the tin cans. So, I don't know if you know but, in the retreat from the Turks, they had two tin cans, one they filled with water with a hole in it, and the other one caught the water, and it was tied to the trigger of a gun. So the guns would go off at random, so the Turks would think there were still people there whilst they were doing the retreat. And he was doing the, he was doing the filling of the tin cans. So that, that's the bit that I most remember about my grandfather. My grandmother had been a waitress, I think, in a family hotel in Gloucestershire, when, when they met. Anyway, they had a bakery and they did all sorts of things in London, and then they, they bought this place in, in Richmond. A very big house, these days it would go for an absolute fortune, but in those days, there was, house prices were terribly low. So that, that was my real memory of my, those grandparents.
[03:56]
The other, my maternal grandparents lived up in Lytham St Annes, and he was a, a journalist and a, a bit of a financier, and did lots of bits of business and so on. Again, vague recollections, I don't think his wife did anything in particular other than, you know… Oh well, I mean, I mean she ran the household and so on. And, I think they passed away when I was, about ten or twelve or so. I mean, so, memories of them are a little bit feint as well.

[04:30]

Mm. Well thank you for sharing that with us. So you've come back to England. You said you initially went to your grandparents' house with your parents in Richmond.

Mhm.

And they, your parents settled in that area and you settled in?

Yes, settled in East Sheen, that's right.

So, and is that where you started your schooling?

Yes. Yeah, I went to East Sheen County Primary School, and then I went to the grammar school called Shene School. And, I then, was walking down the corridor of my grammar school in the lower, when I, I think it must have been the lower sixth, and I was thinking about what to do. And the careers master was a bit short of people to come to a presentation by somebody from Post Office Telecommunications. And so I, I went in, and, there was this opportunity to apply for sponsorship at university. So, I applied for that, and, they were very generous, they paid for you to do a year's training before you went to university, which involved some very very good stuff. I mean I, you know, learnt how to joint cables, and maintain telephone exchanges, and, rewire a coax and, climb up telegraph poles. I even did a thing with a divining rod, and discovered a 130 kVA cable that was buried. And, I, I'm a great sceptic about this stuff, but actually, that divining rod actually, it was just bent copper wire, bent copper wire, twitched as I went over it, and clearly laid out where the cable was. And the foreman, when we were putting in the pole, drilled down to show me that actually I had exactly spotted where the cable was. So, some people can do it. Whether it's reliable. I know they tried at Martlesham, the research thing, to see whether they could do it consistently, and you can't, so, they, they gave up on that one. But at least, at least I've done it. And didn't get ourselves blown up by going through a cable. So, that, that's by way, that's one thing that we did.

[06:31]

And the other thing that we did was, we did a whole load of maths and physics, and we built computers, and I built an analogue computer, and we did whole loads of bits

of electronics. The downside of that was when, after having done all that year's experience, arrive at university, and it's bit of a let-down, because there's, really, you know, I had been doing, I had been doing general relativity as, in the maths, and the stuff that we then did when I got to university was nothing like the standard that actually I had been taken through in the previous year.

Right. So in other words, a higher standard than your work experience?

No, the, the Reading, the Reading stuff, I went to Reading University, it was, it was really quite low. The advantage of it was, in the first year, [laughs] I came top in maths. But that was, [laughs] that's, that's just special coaching I think.

[07:24]
And, just briefly return to your, your grammar school, and, well perhaps even your primary school days. The subjects you either loved or excelled at at that time. You obviously mentioned maths subsequently, but was maths one of your favourite subjects at school?

Not really. I was really bad at maths. I mean when I was doing my O Level, I think in the mock O Levels I got about 28 per cent or something for my maths. Didn't really understand it, didn't… And I got a, I then got the maths teacher to give me a bit of extra coaching. In those days, you know, maths teachers had a little bit more spare time. And, after about three or four hours of that I began to see the light, began to understand what it was about. And went on to get a decent grade . So, that was, that's fine. I think that there's, there's a thing about, a thing about these things is that you, your performance sometimes in school, sometimes in the exams, doesn't necessarily reflect the way in which lights will eventually go on in your brain in the way that you will actually go. So I'm a, I'm a great believer in, like one of my sons, you know, a little bit of a late developer in many senses, but actually brilliant. So… I mean I, not that I'm necessarily very brilliant, but, but the… And we did all sorts of things at school, all sorts of crazy things, mostly with explosives. So, you know, I blew up an awful lot of stuff, and, we made rockets. I made one rocket that was about, twelve foot tall, made out of carpet tubing; took it into Richmond Park and set

it off. And as it took off, I remember thinking, I haven't thought this one through. [laughs] You know, if this succeeds, where is it going to come down? [laughing]

Right. Yes.

And I just hadn't thought it through. Hadn't thought it through.

I take it it has come down now?

It didn't go very far. Thank God we were very bad at making rockets. Very bad at making rockets. And on the biology field trip, just, just, give you some idea. I mean I didn't fall in line with the biology field trip, where we were supposed to take metre squares and count the number of bugs. So, all I did was, I built a camera attached to a kite that would be automatically fired, so that you would be able to take, what you would do with a drone these days, but you can take the photograph from the kite. So you would take photographs of the field, in order to be able to see what was actually going on without having to do all the survey work. That kind of thing. That didn't work terribly well when we actually got to the field. [laughs] There you go.

What an imagination, to come up with that though.

Well I, I don't know, I mean it was just, just the kind of crazy stuff you do when you're a teenager.

I wonder if this is the world's first drone then, I mean as you say.

Oh I, I don't know. I mean, I'm sure other people were, were better than me at putting cameras on kites.

[10:17]
But, from your schooling days, would you say there were, is there anyone that you felt influenced you in particular?

Oh well, in my school, the person who, I think who had the most influence, probably was my English master, and house tutor, and that was Brian Weedon. And, and up until the point where I had to choose A Levels I was, it wasn't really clear whether I was going to do arts or sciences, because of course, I mean, that's the problem with the English education system, you have to choose between them. But, in the end I went for the sciences.

Mhm. So you did the three sciences, did you, at A Levels, or…?

Yeah, I did maths, physics, chemistry. Hang on, no, what did I do? I did, physics, chemistry and biology I think. That's right. No, no, maths, physics and chemistry. Sorry. I dropped… No, what am I talking about? [laughs] I mean you can cut that if you want, because I'm just bonkers. The biology I didn't do, because I was actually, turned out to be really rubbish at this kind of, the stamp collecting mentality of, just remembering all the facts in biology. So I, I didn't do biology in the end. I did maths, physics and chemistry, which I, I really quite enjoyed. And I did of course the, the extra free A Level of general studies.

[11:38]
Mhm. And, and as you, you mentioned, you, perhaps we'll describe it as work experience with the Post Office Telecommunications.

Yah, I was, I was actually very lucky in a sense, because, when I took my A Levels I was ill with glandular fever, and I actually had the maths, which I then dropped a grade on, I went from an A to a B, I did in the exam hall, but I was really ill. And then I did my physics and chemistry, under supervision, at home, because I wasn't well enough. But fortunately it was, they were OK, but… And then, then, that was good enough to get me, I mean, get me the approval from the Post Office Telecoms guys. So I joined a group of eighteen, eighteen students, so I was one of eighteen, doing this, doing this particular thing.

Right, OK. And, and you opted to go to Reading University.

Yeah, because it did cybernetics.

Yes.

You see, I, I had been browsing in a bookshop, I was about sixteen or so, fifteen, and I picked up a copy of Norbert Wiener's *Cybernetics*. And, I was really interested in the idea of control systems. So, you know, [laughs] having tried to get a camera onto a kite, and, and the rocket, and how to control the rocket, and, I had built a robot out of Meccano, and I, I had done various other bits and pieces. And I was just really interested in control theory, and how you could make robots. So when I was looking at a university, I did go down to Kent as well, which was the other place that did cybernetics, and I looked at a couple of other places that did engineering. The school didn't think I was good enough to go to Cambridge. Because there was another guy who was brighter than me, and so they wanted to put all their effort into him. That's, that, you know, I mean that's, that's the way it goes. These days, of course, looking at this, I'm a bit passionate about making sure that everybody who is, who has the slightest glimmer, has a chance to go for some of these, go for Cambridge or Oxford or whatever. But in those days, I think it was a, it was a rather different thing. And, so I, I looked at those, that stuff. But Reading seemed to be the, the one that was most true to the, the kind of, I suppose what you would call tinkering these days, that I really wanted to do.

[14:04]
And for our listeners, perhaps the term cybernetics might not be that familiar. If you had to sum it up in one or two sentences, what…?

Yeah, well it's… Yeah, you're right Jonathan. Of course it's been hijacked, and it's been called cyberspace as… And of course that's largely to do with some of the, some of the things that have come out in science fiction books. But the, the cybernetics, Norbert Wiener defined cybernetics as the, the control and communication in the animal and machine. And his thesis was, and he did this way, way ahead of anybody else, was that, the important things about animals and machines, well not the mechanics, but actually the control system. So, why is it that you've got fine motor control in your fingers, and how do the nerves actually make that work, and, how do you use the feedback to be able to get yourself, and use your

eye and brain coordination to be able to do certain things, as well as doing it in mechanical systems where you might want a robot to do the same thing, recognise that that's a teacup and be able to pick it up?

[15:10]

So you were at Reading for, what, three years, '73, 1973 to '76.

That's right.

Did you enjoy your time there?

[hesitates] Yeah, more or less. I, I think, as I say, I was slightly frustrated, because some of the stuff was, to be honest, I mean, a number of us, I think three of us in a year of, fewer than eleven, I think, there were not very many people on the course, got Firsts. And think we were all slightly frustrated by the… Some of the course, particularly on the control side, was a bit too much of spoon-feeding. And it was noticeable that when I came to Cambridge to do my PhD, and started to supervise, and actually give lectures eventually in applied stats, that, the, the way of teaching was rather different. And so there's always been this thing, Jonathan, as to, you know, should I have actually gone to Cambridge rather than going to Reading first of all? And you can't really rewind the tape, because I've no idea where it would, would have landed me. But, in answer to the direct question, yeah, it was fine. I mean I got a lot involved in student politics, and, did various things like that. But overall I think it was… Oh, and, of course, being sponsored by Post Office Telecommunications, I had things prepared for me in the long vac, so in the long vac, one, for one of the long vacs I went off and, went to France, and spent four weeks touring round France with a couple of others, looking at how they were re-engineering their telecommunications network. Because at that time, France had something like ten telephones per head of population, right?

Mhm.

Unbelievably low. And that's fixed telephones, there were no mobile telephones at that point. Because General de Gaulle had referred to it as *le truc*, you know, that

thig, dismissed it, didn't think that telephones were important. And, and it was remarkable seeing how a state-controlled telecommunications entity could, in the space of a very short time, actually modernise an entire network and have a fantastic vision of where telecommunications were going to go. I'll give you an example of that. We went to, we went to, to the, their research station which was based out at Lannion in Brittany, and they had a wall in which they set out how their particular electronic switching system was going to evolve over the next 20 years, and they had it all planned out. And that kind of stuff had a real impact on me. So those four weeks in that long vac.

[18:11]

And the other long vac I did was with a thing called the Long Range Studies Division. So we're beginning to get a bit of a theme here, which is, you know, looking long-term into the future. The Long Range Studies Division, I started to look at, in particular, the project I had was the future of video conferencing. And, at that time, again it's hard to imagine, such a dim and distant past, the idea was to put in these video conference centres in cities, so people would travel to a video conference centre instead of having to travel the long distances between cities. And I did the map. I worked out where all these video conference centres ought to be. And I remember doing it at my then girlfriend's house, now wife, laying out this map and discussing with her [laughs] where I should put these video conference suites. And in fact, pretty well all of them got built in the end. And I found about that about ten years later when I found the person who had actually been responsible for implementing them. And there's another lesson in there by the way, which is, you, you sometimes find in these organisations extremely junior people providing the data, or making the decisions, that the management then implement, without the management actually understanding that this, what the actual, the original source was.

Right, OK.

But anyway, that was, that was an interesting thing.

[19:35]

So having gained your, gained your First Class Honours degree from Reading, and with the experience that the Post Office Telecommunications Long Range Studies Division offered you, you then chose to do a PhD.

Yah, well, in the Long Range Studies Division, I worked on a number of different projects, and one was about CB radio, and I wrote a report saying, this could be a mass-market product. [laughs] The person who was most senior, not in Long Range Studies but in the Marketing Division, loved it so much he claimed it as his own, and then, and then put the security classification that I wasn't to discuss it with anybody. [laughs] Which is flattering, that's fine. It was an introduction to the way that corporate management worked.

Mm.

I, I worked on the idea of a computer on your desk that could actually not only, could actually do word processing and communications as well as calculations, and what that would mean. And, I had a, a particularly, two particular things that happened there were, one, I was on a Delphi panel, where I projected the future costs of semiconductors and memory devices, and I got thrown off that Delphi panel for being too radical. I said memory prices would halve about every eighteen months in price. Of course I had read Moore's book at that point, it had come out only a few months before, and I had done the investigation on the physics. And I got chucked off for being too radical, for being too extreme, because everybody else said they would, the memory prices would fall at around about five per cent a year, and I said they'd fall at 50 or 60 per cent a year. Or, 30 to 60 per cent a year.

Mhm.

[21:28]
The other one was, a meeting down in London at University College with a professor, whose name escapes me for the moment, but he wanted Post Office Telecommunications to invest in a new packet switched network that the Americans had developed, which was currently running at about 2.4 kilobits a second, which is going to be upgraded to 64 kilobits per second, but across the Atlantic they were

going to experiment with running voice at 2.4 kilobits a second. And they were also going to do some video stuff. And my head of division turned to me and asked me, you know, should we fund this? It was about, about £100,000 I think, or £120,000. And, I said, 'Jim, we should fund this because some day all information will go by packets.' And, we funded it.

Mhm.

And I had at the time [laughs], because my mind had been prepared by doing all this work about the electronics, and I still believe that I was right, and, I probably was, unfortunately for the people who then decided to be less radical, and, my mind had been prepared by the fact that this stuff was going to get very cheap, and in the long run, if you took it ten or fifteen years in the future, there was no doubt that everything was going to go digital, and there was no point in having anything that was going to be circuit switch, which is a technical term for saying, I'm going to have a circuit that you can transmit across. Actually what I'm going to do is, I'm going to break it up at your end; you're going to transmit this stuff in packets; and then I can have a generalised network, because of the economies of scale and scope that that would then deliver. I, I can't pretend that, that I kind of thought it through in those kinds of ways, but I just knew that that was what was going to happen. And that leads me to one important conclusion that has guided me through a lot of my career, is that probably people in their twenties, probably have a better instinct for what is going to happen than anybody who is 40 or 50 or 60, and, and certainly anybody who's eminent, because anybody who's eminent has already run through all their ideas.

[23:44]
Right. Interesting thought. Your PhD at Cambridge.

Yup.

You talked about, in your vacations from Reading, seeing an international system, in other words going to France.

Yup.

Your PhD also centred on telecoms abroad, in Africa, yes?

Yah. That came across, that came, or, I came across that because, I did a little bit of work for a consultancy called the, called the centre for, Communication Studies and Planning, also called CSAP confusingly, because that's, that's what I founded as the Centre for Science and Policy, but, this is Communication Studies and Planning. And there I met a chap called Robert Saunders and another guy called Bjorn Wellenius who were with the World Bank, and I talked about the idea of doing something, partly, partly with my experience in France, about how you could transform a country using telecommunications. And originally I was going to do the World Bank mission to Tanzania whilst I was doing my PhD, in fact I did to Kenya, and then I did another one to Algeria, but the Kenya one was the, the basis of me being introduced to Kenya Posts and Telecommunications Corporation, KPTC, and getting the right introduction so that I then had the ability to go and do my fieldwork, which is what I wanted to do. And the PhD was, was very straightforward. It said, look, if you've got these kind of settlement patterns, those settlements patterns, the different sizes of towns and how they relate to each other, mean there's trade between them and there's distribution and so on going on, you probably would find that that pattern of settlement also was reflected in the pattern of communications, and that if that was the case, whilst you couldn't necessarily prove it, you could infer that in order to re-enforce or enable those settlements to work effectively, you had to have communications between all of them. Because they weren't, it wasn't just in Nairobi, it wasn't just in Mombasa, which is the big port, port city.

Yes.

And, I did, I approached it from various ways, produced a model, and did bits of fieldwork. And actually changed the World Bank's policy on that, because they, they started to realise that, whilst there was lots of demand inside, you know, the big major cities, actually if they didn't wire up the rest of the country, you were going to find that the rest of the country wasn't able to deliver the goods into the cities and you won't be able to get the, the development in those rural areas.

[26:22]

So, there are several themes that I've picked up in the interview thus far that we'll come on to throughout your career, but, things you've mentioned to me that seem to run through your, your career, normally I would ask an interviewee, how things affected their, their future career, or what things were carried forward. But you've mentioned, clearly research; you've talked about funding; you've talked about monitoring; you've talked about evidence-based decision-making; I'd say some blue sky research in there; and also policy change.

Yah.

So it seems in, very early in your, even during your academic years, i.e. when you were studying, this was going to form the basis of your, your future career.

Well I've always been interested in economics, I did economics as part of my first year at Reading, and the, [laughs] the economics department actually tried to persuade me to change to economics from doing cybernetics. And I, I dropped in there that I had been the economist on the World Bank mission, so the World Bank missions have a, a finance guy, an engineer and an economist.

Yes.

And, you know, I was dropped in the deep end in Kenya, and less so in Algeria, but, you know, I did the economic evaluation, the economic analysis. And, it's always struck me that the world, I mean the world works through all sorts of mechanisms, socio, political, economic, there's the engineering stuff. Unless you really understand all of it, or you, you're taking into account all of those things, you have a very, as the Kelvin doctrine has it, you have a very mean and limited view of actually what's going on.

[28:25]

Mhm. What do you think would be, if you had to describe the key lessons you learnt from education that you would attribute to your latter success, are there any specifics that you would highlight?

Education?

Mm.

Well, [laughs] I, I think you need to be, you need to be stretched to your limit with education, but I am very wary of the kind of formal handle-turning education. Because, certainly, I mean, you know, everybody is different, but in my case, nothing that was ever really formal or handle-turning ever did me tremendous benefit. The benefits that I got were, were from, generally from doing stuff that was slightly off-piste.

Mhm. And by that are you saying, that, rather than learning by rote as it were, when you are given freedom to experiment, is that what you are suggesting?

Yah. And I think, the older I get, the more important I think that is. Because when I look back on the experiences, there is, there is nothing like making a mistake with hydrochloric acid for giving you a feel for really how that stuff actually behaves. And you, you don't do that in, either in a completely controlled environment or one in which it is done, for example, using some kind of virtual reality. It's, it's not the same thing. So… Or… You know, I kept bees at school. I, you know, I built the rockets. I did a number of, you know, all these, all these kind of weird things, all of which, now I look back on it, made a big difference. You know, I directed a theatre play, and acted, played the lead role in it. Those kinds of things were extracurricular, they weren't really part, but they made a big difference to what I think I can now use in, after all these years, I, I draw on all those things, as much as I might do, if not more so perhaps, than learning how to do specific bits of maths or proving a theorem.

[30:54]
Mm. OK. Well thank you for sharing that. So, in '82 you're awarded your PhD. And, you return to the, to the Post Office.

No. No no, I… No, I, I… In my… Having got my PhD, and let's see, is it '82? Yes, it is '82, you're quite right on that one…

Yes. I beg your pardon, sorry.

No. [laughs] Having done that, I then decided I would go and work for the Economist Intelligence Unit.

Ah, my apologies.

As the, as the Americans, who I used to talk to, used to go, [with accent] 'The Communist *what*?' The… [laughs] The Economist Intelligence Unit, which was based down in St James's. And, a lovely neoclassical building we inhabited, with absolutely mind-bogglingly awful 1960s or 1970s furniture. And, I spent, two and a half years year there I suppose, learning the trade of being a consultant, and making lots and lots of mistakes, making some money for them, losing some money for them, before I set up my own consultancy called Analysys.

Right. So you were with the, EIU as it's sometimes referred to for, for three years, '82 to '85.

Yup.

And specialisation within that period of time?

Well I… Again, I mean, it's ridiculous really, given how inexperienced I was, I was… I became the Director of the Telecommunications Division, so I was responsible for, I don't know, five or six staff and, and actually running a, running a significant chunk of the consultancy in, in… They had a… What they had done was, they bought the, you remember I mentioned earlier, the Communication Studies and Planning group that I'd been touch with, the Economist Intelligence Unit bought part of that, and then used that to start off some stuff in information and communications technology. In the early Eighties, this was becoming a bit more trendy, you know, the Microsoft PC was coming out, and, and so on, doing all those things. So, I, I joined that, and then I, because of my expertise in telecommunications, I then did, I developed a telecommunications division. Managed to go out and sell lots of work,

write proposals, get money in, execute on the contract, quite often overrun [laughs], but there we go, and learnt how, learn the tricks and trade of consulting.

[33:27]
Mhm. But after a relatively short period of time, in other words, three years…

Seemed like a lifetime at the time.

Seemed like, seemed like a lifetime. You chose to, to go it alone.

Yeah, that, that…

I assume that wasn't necessarily an easy decision, or perhaps the decision was easy, but it in itself had its own challenges. Perhaps you would like to…

Oh. Oh, looking back on it, it was completely bonkers. I mean, the… I had established some relationships with people who seemed to trust me and, and like what I did. And, I, I got the thing off the ground, with our first kid. Well actually, we had the, I think we had had the second kid at that point. And, and the third kid arrived within about a year and a half after I had started. So, there's two boys and a girl. And, built up enough work to, to make it operational. Getting the thing off the ground was, is, is a terribly difficult process, because, what you have to do is, you have to go and sell the work and you have to execute it; you have to, also have to recruit. You have all sorts of costs and so on. And when you're, I was in my early thirties I suppose, it was, and I was inexperienced, I made all sorts of terrible blunders and errors. And I had a mortgage to pay as well. But, but somehow, somehow, I managed to scrape through that. One year I didn't pay myself any money, to actually make, to make the whole thing work. But, got through it and got, got through the depression at the end of the Eighties, because there was the Lawson boom, which then turned into a, a collapse, and collapse in house prices, and I remember squatters moving into one of the houses just up the road from us, in what is a very posh area these days of Cambridge, and, as, as people weren't able to pay their mortgages and went bankrupt. But we got through that, and got to the other side of it, largely on the basis of, of sticking to the knitting, and sticking to the knitting was, doing consulting

that was founded on strong intellectual foundations, not doing stuff that was, wiffly-waffly.

Right, good.

So there was modelling, there was a deep understanding of the economics, deep understanding of technology. And so informing people, I think on a much more sound basis, about, fundamentally the technical economics, tariff levels, where markets were going to go, how the technology was going to move, what the implication of that technology change was going to be for their businesses.

[36:22]
Seeing as this, correct me if I'm wrong, this was your first business as it were…

Yup, that's the first one. Apart from doing things like selling cheese straws when I was, or, selling my honey when I used to keep bees at school.

Right. [laughs] Well, your second business then in that case. Perhaps a few questions our listeners might well be interested in. How did you fund that first year?

Well, we… Looking back on it, I, I… One response is, I've almost no idea. The… There were a number of things that happened. One was, there was a chap called Mike Gardner[sp?], who sadly has passed away, was a friend of mine who had a company called Al Communications, or Al Systems, and he had a place up in the Science Park, Unit 128, and he let me stay there for free. And he also allowed, he also bought a computer and a printer for me, and I was able to repay him that money. And, extraordinary as it may seem, I think that computer and the printer together cost, something like two and a half, or maybe three thousand pounds, which in today's money would be close to £15,000, for something which you can now, you can now pick up at, I don't know, you'd probably, if you paid more than £1,000 for that, you'd be, you'd be paying too much. And, and of course would be a more powerful beast. So, with a bit of help, I got the thing off the ground like that. I was earning relatively well in London, so, you know, put aside a little bit of a buffer. But very quickly I got some money in from, as I say, the contacts that I had made, and some, in particular,

did quite a lot of work with the European Commission, on their new cross-border research programmes that were then turned into Horizon 2020, that kind of general research framework.

[38:42]

OK. So, when did you take on your first employee? Was it in that first year, or…?

Yeah, I took on my first employee in the first year. And, I think I got rid of my first employee within, about six weeks of taking them on I think.

Mhm.

Because they were… And, and there were various people floating round who were kind of stringers and, people like that. I, to be, to be absolutely honest Jonathan, I can't remember exactly, but it was, you know, one or two people at the end of the first year, and then…

Right, OK.

And, and one of the things that I do remember was that there was quite a high churn rate at the beginning. In other words, when you're a very small company, you are not necessarily going to be able to pick the right people who are going to stay for the long run, but gradually more and more spaghetti sticks to the wall as you throw it at it [laughs], and, and gradually I began to get people who were right for the environment and they stayed for, for a long period of time. One of the most important of those was a chap called Nick Gray, who did his PhD in English, on mediaeval English, and then joined as a freelance editor, and then came in full-time, because I realised that quite a lot of consulting, certainly at that time, before everybody moved to PowerPoint, quite a lot of consulting at that time was actually being able to craft decent prose, and if you had somebody who really knew how to write, they could do it much better than a consultant. So, so Nick took a lot of this stuff and turned it into stuff that people could, text that people could understand. And that was, that was a huge breakthrough. He went on to run, in fact, the editorial department, and then became, later on, the chief operating officer looking after, you know, 130, 150 people.

[40:35]

Mm. Actually, I think there's a definite lesson there, when you see some proposals et cetera, even today, in 2018, poorly written et cetera et cetera. You know, the, the presentation is so important, I think.

Yah. Well, we used to get, at Analysys, compliments, and people told me that they had heard other people talking about Analysys and how clearly and precisely we presented things. And of course, you know, when the client is getting this as a final product, I think it is worth putting a great deal of effort into it. And having an editorial department has an educational value as well. It's a training value for the consultants. Because, writing stuff out, you have to write it out logically, you have to say how this is going to work. It's not good enough to come out with, ungrammatical, emotional stuff. You're not conveying anything with that.

[41:38]

No. You've mentioned one of your clients being the European Commission at that juncture in time.

Yes.

So, a blue chip company – sorry, organisation, not a company.

Well blue, blue with yellow stars.

Yeah, blue… I'll get that right. [both laugh] Yes. How many stars is the question. Yes yes.

Well it's still twelve.

Indeed, yes, still twelve.

Still twelve. They're not going to change that.

No no, exactly. And, and your other clients at the time, also…

BT, local Cambridge City Council. Those kinds of things. But the, the transition was that the, the European Commission gave us a big contract, and it was a huge risk for them, a big modelling contract about the future of telecommunications over the next 20 years. So we looked at the period 1990 to 2010, and we did models of how the telecommunications was going to develop, and what that would mean for markets and revenue and importance in the economy and so on. And, we, that really was the breakthrough, because at that point we were then respectable, we had done all the work, we had done all the research across the whole of Europe, and then we could start to really work with some of the telecom operators across Europe, at a time when the monopolies were all being broken.

Mhm.

And, and so the 1990s for us was a, was a real boom time on the back of that, mostly on the back of that one contract.

[43:09]
Right. I appreciate it's a company that you, that you founded, you were Managing Director and chaired for a period of nineteen years before you, you sold it on. But, in that time, how did you, if you were speaking to an entrepreneur today, how would you say you went out and got your clients, what would you, any tips to success in that area?

Oh tips.

Mm.

Oh, I, just be nice to people. Take an interest in them. Talk to lots of people. I always had a innate urge to talk to people, note down their names, work out who they were, find out how they were connected. My chairman, who arrived in the early 1990s, John King, who used to be Marketing Director at BT, and on the board of BT, used to, used to get slightly, irritated? Well, slightly irritated with me, for being quite

so jumpy about getting hold of people and getting their business cards and knowing who they were. But it's something that's always driven me, and I think it's, it's very important, because, whilst it appears that everybody… Nobody… It appears that everybody sort of just comes along at random. In fact, they, they are, you are meeting them at random, and there's a, there's a huge bias, and there are lots of networks that tie everybody together. And therefore, you know, some 30 years later, I suppose it must be 30 years later, I now have, you know, I carry around, I think it's ten or twelve thousand contacts on my phone. And, those contacts are the network that help me do the things that I want to do. But I've invested a lot, and I think you have to invest in that network.

Right.

You have to demonstrate stuff, you have to listen to people. I don't know, just, just try to be a nice human being.

[45:27]
Mhm. Thank you for that. During that time – we'll come on to Analysys – you also got involved with other companies as well, in terms of, Abcam for example. So, whilst your, your own company was still growing in terms of turnover and people, you started also to diversify yourself, lend your expertise to other organisations.

Yah. Now, so, well, yes, Abcam's a very special case, but, it came out of a feeling that the, the IT systems and the Web in particular were going to be very important. We made a transition. I built internal systems to manage projects, to have a CRM system and so on, because nobody was producing this kind of stuff. So we built it ourselves. And I had a software department that did those things. And, the Web came along, and we moved very quickly over to a Web-based interface, for our internal and external – our internal systems as well as everything external, to the extent that we were out-pacing anybody else. I mean, even in the United States we were able to, we did an explosion with Analysys, we moved across the entire world, we had offices in San Francisco and Washington and Kuala Lumpur and Auckland and Paris and Munich and Milan, and we, we had done all of that based on using the

Web to get access to all our internal systems. So anybody in any of those locations was able to act as if they were in the office in Cambridge.

Mhm.

[47:08]
And that excited me a great… So, put in this perspective, that's more than 20 years ago.

Yes.

And, and that excited me a great deal, and I started to look at things like the second-hand car market, selling houses on the Web, doing all these, these bits and pieces. I got discouraged, not only by the people who were the incumbents in those sectors, but also by my fellow consultants who just really couldn't see the point of what I was trying to do sometimes. [laughs] But there we go. And then I bumped into Jonathan Milner, who was a research assistant doing work on breast cancer with a chap called Tony Kouzarides, and Jonathan was very angry about the quality of antibodies that were being sold in particular by a company called Santa Cruz. And, wanted to do, wanted to make antibodies and make them better. And I sat with… I met him by accident at dinner once with, through my wife and now Jonathan's wife, so, because they both worked together in an art gallery. And, I… So I quizzed him a little bit about this, and then started to talk to him about the economics of doing this across the Web. And, Jonathan knew nothing about the, the economics of making antibodies. But when I did the calculations, it turned out that you can make antibodies for around about £3 each, and these were antibodies that were being sold at £150. Now when I actually did the calculation a couple of days later, and I've got the original emails on all of this, I said, 'Well I think it'll end up at about £20-£25 by the time you finish doing this.' That was my consultancy training coming into play, knew how things work. But, nevertheless, there's a big enough margin between £150 and £25 to be able to sell these across the Web, let's… So I had all the technology sitting at Analysys with all the Web stuff; Jonathan had the expertise on the antibodies. We, you know, originally he wanted to do a goat farm in Wales to raise antibodies. You inject mammals with, well you can inject any, any creature, but, inject particularly

mammals with a peptide and then you produce the antibodies, roughly, something, 90 days later. And, then you extract the, you purify the, extract some blood and then you purify it to get the antibodies out. That's the general process. He, his focus was, was quite, mainly on that, because that was what he had learnt. Mine was coming at this from the systems point of view, and saying, actually, I can see how to do this, you know, end-to-end, and, how to get the scope and the scale, and I had the business. And of course I had a little bit of money at that point, because Analysys had been successful. So we, we started Abcam together.

Mhm. And, eventually, Abcam was floated of course, wasn't it.

Yah, I took Abcam through flotation. So, Abcam was floated in, 2006 I think. It's one of the few companies that, I remember the, [laughs] the people who took us, our advisers, through this flotation, said it's the only company that planned to do a float, started planning it over a year in advance, and floated within one day of the target date that it had gone for. I think Abcam's, yeah, Abcam's been fairly successful since then.

[50:45]
Right, yes. And your, going back to Analysys, your own company. 2004 you decided to sell.

Oh yes. Terrible. I should have sold in 2000, 2001, when people were queueing at the door to buy the company. Here's another lesson, if you want one, for anybody listening. Timing is everything.

Mhm.

Don't think that the world is going to go on always in the same way. If people are coming along offering you crazy money for your company, why don't you give it to them for crazy money?

Mhm. So, at the time you sold, just to give our listeners an idea of the size of the company, what, up to about 130 people?

Yeah. So, roughly £100,000 per head. So, roughly thirteen, fourteen million pound turnover. Something like ten, maybe a bit more, per cent profitable than that, it was probably fifteen. So, it was making a reasonable amount of money, but nothing like the, the money I could have, I didn't get anything like the money I could have got for it in the, in the ridiculous days of the dotcom boom. But, but the most important lesson out of this is, that having not sold when I should have done in 2000, and then, because we had the two fundamentals, one, we understood about all the, the nitty-gritty and fundamentals of telecommunications, so when the nuclear winter arrived, which it did in, and was, and killed off a lot of our rivals, we were left standing, because, we were the only ones who actually really understood what was going on. Everybody else had bloated up with people who could do slideware but didn't actually understand the subject.

Mhm.

And the, the second one was, that the systems that I had built, these Web systems that underpinned the whole of the consultancy business, meant that when I sold the company, the systems were the company, not me.

Mhm.

And so, I could walk away with cash. That's not normal in the consultancy business. Normally the founder is, is integral to the business.

Yes.

But I had made myself non-integral to the business. That took me the period between 2001 and 2004 to engineer the company so that I could walk away.

Mhm. So the company was sold to Datatec, a South African group.

That's right.

For, I mean, a very sizeable sum, 12.8 million. So…

Yeah, it's a little bit… Yes, something, something like that.

Yes.

That's, that's supposed to be secret. How did you find that one out?

I beg your pardon. [DC laughing] We, we can cut that.

No no, it's all right. It's some years since I signed that non-disclosure agreement, but…

Oh right.

I could, I could say something like, 'You may say that, I couldn't possibly comment.' [laughs]

Exactly. Well let's leave it like this.

I know where you got that from. You got that from the *Cambridge Evening News*. I remember that. I remember that.

Could well have been, could well have done. I couldn't possibly, couldn't possibly say.

It isn't the exact number, but there we go. That caused a great deal of… Thank God my kids were old, old enough, because, at that point, some of the kids were still at school, and, that headline on the front page of the *Cambridge Evening News* caused an awful lot of ripples for them.

Right, yeah yeah.

Yes, kind of one of the lessons you learn about these things.

[54:12]

Yes, yes. Well moving on from the local press, but staying in communications. You then got involved with 3WayNetworks.

Yah. So, so some guys came along to me with the idea that you could put a 3G base station into something that looked about the size of a, of, you know, a standard Wi-Fi router. And, I thought that was a good idea, I thought it would be great to get coverage inside houses and offices by plugging this thing into a broadband system. And we spent some time developing it. And, went through some fairly rough, rough bits and pieces. I, I've learnt a lot about hardware and how unpopular it is generally with VCs, for, for some very good reasons actually. And then, we flipped it, we, we… There was an American company called Airvana, who, whose main customer was Nortel, and they wanted to float on the Nasdaq, and they needed some baubles to stick on the side so that it would look attractive. And we were one, we were a bauble. And they bought us for a very respectable sum, which, I'm not going to tell you what it was, but it, it was, it was certainly one of the shortest, I mean, two and a half years, two and three-quarter years, of, of starting a company to flipping it, and selling it, and the biggest multiple in that, given the space of time, that I've ever done in my life.

Yes, unfortunately the Cambridge Evening News hasn't given me that information.

No no no. And that, that bid is still probably going.

Yes. So, two and a half years, again, sold to an overseas buyer, this case, as you say, well, a Massachusetts based company.

Yes.

[56:06]

So, changing slightly tack, and perhaps going on to, let's talk about education for a moment and your, your interest in education. And perhaps we can talk about your involvement with the Raspberry Pi Foundation, how that came about, and how you see the objectives of that organisation, indeed success of that organisation.

So, do you want to do Raspberry Pi first of all?

Or… Yes please, yes.

So, Cambridge Angels, I helped start a group called Cambridge Angels, which are, basically people who have sold their businesses, or sold at least one business, made some money, and now want to invest in new businesses. So, we started that around about 2001, again, great time to start [laughs], given what was happening in the rest of the world. And that, I, I… Robert Sansom was the first Chairman. I became Chairman when Robert stepped down after about nine years. Did that for about three years. But the, the Angels brought together a lot of people in Cambridge who otherwise would not be necessarily in contact with each other, which I think is a, is a lesson about networking. We may get back to that later.

Yes.

So Cambridge Angels brought those people together. And in particular it brought a chap called Jack Lang into contact with everybody else. And Jack was very keen on this idea of, he, he was at Computer Lab, looking at the falling numbers of applicants for computer science. So he wanted to do something about that. But the thing that they alighted on, must have been about 2008 I suppose, was the idea of doing a single-board computer that the kids could mess around with, and you could break, you could do all sorts of things with it. It would be cheap enough not to worry about it. And, by the time they got to 2012, they had got some loans from some of the Cambridge Angels, they set up the company, they had made the first stuff. They decided that they wanted to make it into a charitable foundation rather than a for-profit company, partly because they thought they, they, [laughs] they never thought they would sell very many, and it was an educational thing. And, as they got the thing off the ground, they decided, for the trading part of the company… So, Raspberry Pi Foundation is the foundation, is a charity and a subsidiary called Raspberry Pi (Trading) Limited, and Raspberry Pi (Trading) needed some directors. So, they invited Hermann Hauser, myself and Sherry Coutu to join the board. So I joined the board. We had a happy year or so there. And then, for some reason, I think it was

David Braben, who was delegated by the trustees to buy me lunch and to ask me if I would like to become chairman of both the foundation and the trading company. And I think when you're offered something like that, you've got… We're back in the days when, we'd been selling hundreds of thousands, but not the millions. We now sell six million a year and plus, right? And, it… I thought, well, you know, this looks like a worthwhile cause. I'll see what I can do. So I, I became Chairman of both entities.

[59:31]
Mhm. And you, you talk about size of the organisation. I think I read recently that it's the third most successful computer platform ever.

Oh yes, it is. I mean, you know, there's the PC, there's the Mac, and then there's the Raspberry Pi. I mean, in terms of numbers of units sold, per quarter now, we're getting close to, we're getting close to Apple.

Mhm. And, yeah, as of March '18, I read that sales have reached, the region of 90 million or something.

Yeah, that's right. So, as I say, in the last twelve months, trading twelve months, we've probably done more than six million. And the launch of the Pi 3+, without giving too much away, has been very good.

[1:00:16]
Yes. And the organisation won an award, the MacRobert Award. Perhaps you can tell us a little bit about…

The MacRobert Award was set up to, to talk about engineering as technological advancement. So, doing something that was technically difficult, doing something that was commercially successful, and doing something that actually had a, an impact on society.

Mhm.

And, to be frank, Raspberry Pi ticks all those boxes, and does so very well.

Mhm.

But… And it's, it's administered by the Royal Academy of Engineering, where I'm a Fellow. I waited a little bit, because I wanted to have the evidence that we were, we were actually doing what, when we went for it, that I hoped we would win. I didn't want to… I wanted to keep our powder dry.

Mhm.

But we went for it last year, and I did the application, and ran the process from Raspberry Pi's point of view. Very very pleased to be awarded it. And one of the children… One of the interesting things, just to show you how I think Raspberry Pi operates. The announcement was made in front of, I don't know, one of, the Duke of Kent or somebody was there, and, you know, all, all the bigwigs, and, they're on stage, and they said, 'And Raspberry Pi.' And they expected us to go up to go and collect the prize. Instead of which, everybody, because we were at two tables, everybody simply got up and hugged each other. Right?

Yes, yeah.

And, all the dignitaries and everybody was waiting, and everybody in the, in the dinner, were all just waiting for us to go and collect the prize. We weren't concerned about the prize. We were concerned about the team, and how well we had done.

Mm. I mean it, what amazes me is how Raspberry Pi has been used, its diversity, how people have…

Oh it's fantastic. If you go on the Underground system and look at all those screens on the, on the escalators, they've got Raspberry Pi's in them.

Mhm.

That's what's powering them. And factories. You know, people have put in Raspberry Pi's to control processes in… You know, you go into development places, you know, in larger companies, and they've got the, they've got vending machines in which you can then just, you can simply, I mean you're not[?] paying for it, but you get a Raspberry Pi for your development work. I talked to a chap called Tony Fish who's got a makerspace down in the east end of London, and he did a count, he had got over 1,000 Raspberry Pi's in his building.

Right. Mm. I mean, I wrote down in my notes, from skateboards to the Space Station.

We've got a couple up in the Space Station. Yeah, that's a fabulous project. So the, the… We had to design special cases for the Raspberry Pi. Because in zero gravity of course it's rather difficult to disperse heat, so you need very very big aluminium cases. And, we've got two of them, two of them up in the Space Station. And they used to run experiments for kids, so the kids write their code, the code goes up on SD cards in a Shuttle, and, then they're run, each one is run on the Raspberry Pi. And they have some fabulously creative ones. They've got an astronaut detection system one of the kids wrote which, which detects humidity changes and temperature changes in proximity to the Raspberry Pi, because as an astronaut comes by, they will change the temperature and humidity. So, they can… And there's another, there are various other ones for detecting cosmic rays, and… The kids have been fabulous in, in terms of thinking these things. And that's now run across, across Europe. And we may well do similar things with, with the United States. Just as a little bit of amusement, I had dinner with Tim Peake – well… Sorry. That's a bit, let's be careful about that. Cut that little bit OK, that's a bit too much. Tim Peake was our guest at the last Raspberry Pi dinner, and I had the, the honour and pleasure of sitting with him. But he gave a great speech in which he described these, these little SD cards arriving in a plastic bag. Now in zero gravity, you've got a real problem. You open that plastic bag, and those SD cards have minds of their own, they'll go wandering everywhere. [laughs] So he put a plastic bag, the biggest plastic bag he could, over his head, and body, and then opened the SD card plastic bag, inside the plastic bag, in order that he would be able to actually deploy them properly. So those are some of the, the difficulties of deploying Raspberry Pi's in space. But, honestly, the kids have come up with such fabulous, fabulous projects.

[1:05:08]

And, talking about education at that level or, how it was initially, shall we say for the younger generation to get them into coding and…

Yeah.

…understanding all about computers.

Yes.

You're also involved with the Cambridge Science Centre as well.

Yah. So the Cambridge Science Centre was a project that was started by Christopher Lennard and Katia Smith-Litiere, and they, they got together and thought about how science centres ought to run. If you go to the Science Museum, or go to Bristol, or Cardiff or Newcastle or Glasgow, you'll see big science centres with lots of exhibits and, and big spaces. That's not necessarily the only way to do it. It's a good way to do it, but it's not the only way. And in particular, if your starting point is, you want to reach the maximum number of kids, for the lowest possible price, then you might think about designing your science centre in a rather different way. And that's what Cambridge Science Centre has done.

Mhm.

It thought about it as a relatively small space, with exhibits that can be easily moved around, and transported in vans. And so, the result of that is that, from, from an engineering point of view, because an engineer is keen on doing things for half the cost that somebody else can do it for, we can get to kids for about £7.50, whereas the average for science and discovery centres in the UK is close to £16 or £17. So, we've got a way of doing this, flexible way of doing it, with a smaller space. Dwell time at the Cambridge Science Centre is about an hour and 55 minutes, which compares to the Science Museum of just over two hours. So we're pretty comparable in terms of, how much time people spend in the centre. And, and we do some great stuff. We

have some really great reviews. And we also reach an awful lot of kids, in particular, because we go on the road, and we've got the stats on this, we are far better at reaching the bottom disadvantaged 30 per cent of kids than even their distribution in the population. In other words, we reach proportionately more of those than there are in the population. And that demonstrates to me that the outreach, going on the road, doing the small science centre way of doing things, actually works. Whereas, when you have a big science centre, it's probably only the more advantaged kids who can afford to go, and do the travel to get to the big centres.

Mm.

Go to the kids. Make sure you reach the, the bottom 30 per cent.

[1:08:01]
Right. Monitoring comes, you've been involved in monitoring, analysing, throughout your career.

Yes. [laughs] I love data.

Yeah, you love data. Yes, yes.

I'm a bit of a freak. It was… It was freaky, I was freaky about data at Abcam you know, I did all the, did lots of the data analysis about which antibody sold and why and, you know, I… Yes, I, I'm a bit of, I'm a bit of a nerd in that respect.

And just thinking about measuring outputs. Highly successful Raspberry Pi in terms of, of sales, reach et cetera. And you've talked the Cambridge Science Centre. Are we seeing the fruits of that, as we sit here today, in terms of people coming through, into engineering, to the profession, or is it too early would you say?

It's a bit early. It's a bit early. Remember, you know, the, the, the real impact is probably going to start to be felt in, three, four, five years' time. There are people now applying to university, and that's going up, people who picked up a Pi in their early teens for example who are now applying to university as a result of doing that.

And there's anecdotal evidence that that's happening. The number of kids applying for Cambridge Computer Science now for example has gone up very substantially. So, I, we can see that. At Raspberry Pi Foundation, there's a, in charities you have a thing called the Theory of Change. Theory of Change is a bit of a, I didn't like the term when I first heard it, but, you get used to this stuff. What it says is, look, you want to have this impact. Now what are the chain of events that will lead to having that impact? And we have that mapped out, and we know where in those, where in that chain we need to intervene, and what we need to be doing.

Mhm.

But as you point out Jonathan, it takes time for that to flow through. I think we're beginning to see the beginnings of it. The next five years we'll see, I think, some big changes.

[1:10:08]
And Raspberry Pi international, you've talked about markets outside the UK. Do you see this as at all… One of the concerns I've heard, I don't know whether you subscribe to it, is, particularly with the evolution of AI, is that certain countries, perhaps developing countries, could get left behind in the digital revolution. Do you see that Raspberry Pi could possibly reverse that, or help avoid that potential situation?

Well, ever since I did my PhD on Kenya I've been interested in developing countries. I think Raspberry Pi actually does more for lower income, whether they're lower income within the UK or other advanced economies or whether it's the, the low income countries such as those in sub-Saharan Africa, you can get hold of this stuff much more cheaply. It doesn't mean to say that everybody can afford one, but it does mean to say that you are going further than you would otherwise do if somebody had to buy a tablet or a, a computer. And there are lots of examples now of people in those kinds of places using Raspberry Pi's, and people developing for example backpacks fitted with Raspberry Pi's and disk drives that can go off to villages and enable people then to gain access to bits of the World Wide Web for example and, and education material, that otherwise they would never have access to.

[1:11:50]

Mhm. Now, perhaps looking at a, a slightly older generation, but staying with academia, but moving on to a network front, perhaps you could tell me a little bit about the Cambridge University Centre for Science and Policy.

Ah. Well that's a, that's… [laughs] That again is a, that's another one of these things where you go slightly off-piste.

Mm.

So the, the university had something called the Cambridge University Government Policy Programme, which got the permanent secretaries up to Cambridge twice a year to talk to them about scientific things, and what they might mean. So they did migration and obesity, genetic engineering, satellites, all sorts of stuff. And I got involved in one of those. Thought no more of it. And then, I got a call in 2008 I think it was from an old friend of mine, Frank Kelly, who's an eminent statistician, was Master of Christ's, and he said, 'We're thinking about doing this new Centre for Science and Policy as an inheritor to CUGPOP, and I wondered if you would like to, like to do it?' And, so I looked at this thing, and said, 'Well yeah, I'll have a go.' And I was reviewing it recently, because I'm going to give a lecture in June about this. And at one point I said to them, reaching right back, 'I'm not sure you've got the right person for this. [laughs] Because, I don't think I want to do research and then tell policymakers what to do on the basis of that research. That's not, I don't think that works.'

Mm.

The reason for that is that, there's loads of research out there, policymakers can get hold of that research if they want to. What policymakers are, are lacking when it comes to interacting with academia is actually, is actually the, the chat, the explanation, the kind of thing we're doing here, you know, asking the questions, getting some answers. And, so I, I said, 'OK, I'll do this.' I was given about one and a half million pounds. Some of it came from Winton Capital, David Harding, that

was the majority, and some came from various other funds, the Newton Trust, and hive funding. And, so armed with that, I then set up shop. The academics wanted me to spend it on research, and I said no. So that made me very, very unpopular in some quarters. Everybody does research. That's not special. What was special was that I hired two people very early on. One was a lady called Jackie Ouchikh, who is the events and programme manager. So, what she was doing was running events, and making sure that we had systems that underpin things. And the other one was somebody I've mentioned earlier in this conversation, Nick Gray, who had been the chief operating officer at Analysys, and understood all the systems and processes and how that would work. He was brought in as a consultant. And, I, I faffed around for, a good six months I suppose, before, having done, talking to lots of people, I then finally worked out what the USP ought to be.

Mhm.

[1:15:18]
And the USP was to create a thing called the Policy Fellowship. And the Policy Fellowship is designed for policymakers who want to have contact with what is going on in academia, in a particular subject area.

Mhm.

They provide a list of questions. We then give them five days where they talk to 30 people. Now to give you some idea of the scale of this now, we have about one and a half thousand academics and other experts on one side of this process; we've put 350, maybe more, of these policymakers through that process, and we've had over 10,000 meeting between them. Which means that the policymakers now have a network that they can draw on if they ever want advice. They can talk to each other about their experiences; the academics also talk to each other but maybe not so much; but the academics are getting a chance to explain what they're doing and influence policy, they're also getting some interesting ideas that will influence their research. And on the policymakers' side, they're getting access to a rich network, which means that, if they've got a problem, they know who to phone up, or to send an email to.

[1:16:36]

Yes. I know that the, the Centre for Science and Policy, one of the questions, I believe, it asks of yourself, is, how does academia contribute to the work of Government?

Yah.

I, I'd be interested, if you can… You've talked about the 10,000 meetings et cetera, and you've explained very eloquently about what the organisation does. Can you think of one policy that, that perhaps sticks out that you can definitely attribute to this, this collaboration?

Well, do you know, there's a very short answer to that, and it's, no.

Right, OK.

And it's no for, for two reasons. One, one, you know the rule of Fight Club, that basically, if you're dealing between academics and policymakers, the last thing anybody wants to do, or, certainly from the policymaker's point of view, do you want to own your policy, or do you want somebody else claiming that they designed or influenced your policy for you? And, and I think, you know, probably it's better to stay schtum about these things.

Yes.

The, the other side of it that, that there's a, there's a slippery slope here, and it's, it's about management and control, and KPIs. Now KPIs have their place, management control has its place, blah blah blah. However, we have people queuing at the door to become Policy Fellows, and we have academics who are willing to talk to them. And we have lots and lots of activity going on. Why do I need to tell anybody anything else than that? In the market, if somebody has a successful product they sell lots of it.

Mhm.

What else do they need to tell anybody? They sell lots of it and they make a profit. Fine. You don't need to know anything else. You know that there's a demand for it. We have a demand for our product. What else do you need to know?

Mhm.

Why… If policymakers, who are busy people, want to spend their time doing this, they're probably the best decision makers about how best to spend their time. They're getting something out of it. Now, I'm not going to pry inside that system, because once I start to do that, I will pervert and distort everything that is going on. I will tell you one thing though, and it's, it's an example of, of how we change minds.

Mhm.

We did, about a year ago we did something for the permanent secretaries and director generals, and so we, we do that once a term, they come up to Cambridge and we run a, a workshop, and then a dinner afterwards, to discuss a topic that they have chosen. And they chose artificial intelligence.

Mhm.

The rule is, we go round the table first of all, and the policy, the policy leader fellows, these are very senior people, they're running their departments, say what they want out of it. And a large number of them said, 'Well I'm not really sure why I'm here. I'm not really sure why AI is important for my department. I'm not really sure what's going on.' At the end of the session, at least two of them said, 'On Monday morning…' this is on a Friday evening, 'On Monday morning I am calling a meeting first thing to discuss the implications of what I've learnt today. Because, I had not realised just how far-reaching all of this was going to be for my department.' Right?

Yes.

Now they knew about AI, they knew it was important, da-da-da-da. But I think it's that kind of reaction that you're looking for. You're looking for, people waking up to

things that are going to come across the horizon at them. And, that's good evidence I think of that.

Mm.

As I say, specific policies, no. The first rule of Fight Club, you know, don't talk about it.

[1:20:43]
But it, it just plays into your desire that, always people should be ideally making informed decisions, and that's what you're saying, you're giving them, or you're enabling them to, to be better informed, and hopefully they take that on board.

Yah. And, and of course, today, as opposed to, you know, 20 or 30 years ago, you can, you can use networking, and I mean networking between people, much more efficiently, much more effectively, than you could do it before. You know, before, you know, it was small groups who generally knew each other. We need to break that. I mean it's still, it's still dominated by that, it's still the same old same old, you know. But what you've got to do is, till the ground, turn the thing over, you know, expose fresh earth, fresh ideas, fresh thinking, to people. Because then they'll… You don't know what you don't know, in the immortal words of Donald Rumsfeld, though he said it rather long-windedly. You don't know what you don't know. So, so let's expose people to the things they don't know about, and, and something will happen as a result of that. Particularly if you've, if you've got it… It's, it's not random. [laughs] You allow a certain amount of randomness. But you have a structure, and the structure will then produce the effect that you want, and that's what the Centre for Science and Policy does.

[1:22:06]
And, leading on from that, and talking about networking, in 1997 you co-founded the Cambridge Network.

Yup. That's right.

A network of, a commercial business network organisation. Very famous today. Perhaps you could talk about that, and, and the objectives and the success of that particular network as you see it.

Yeah, well that, that came out of a, as many of these things do, from a dinner meeting. It was, it was actually a, a thing called the Local Industry, Academic, Local Industry and Academic Links dinner? I can't remember the name of it. Which used to run. And, Alec Broers, who was then the Vice Chancellor, Hermann Hauser and I, sat at the end of a table, and, it just turned out that, that I had organised a group of Malaysians to visit Cambridge and find out what was going on. And people were very exercised, because, these Malaysians, the Malaysian group had been talking about their new Cyberjaya and how they were going to produce a new cluster, and, the new capital was moving out of Kuala Lumpur, and, all these things. And, and people got very exercised, because they said, 'We've got this stuff here. What are these guys doing?'

Mhm.

So we decided, I think Hermann, Hermann stood up and proposed the name Cambridge Too, which was a little bit Me Too, and we recognised that. But, but we, we had a discussion. Out of that came a dinner that Hermann organised at New College, now Murray Edwards, at which a chap called Fred Hallsworth stood up and said, 'What we need is a marketing tsar for Cambridge.'

Mhm.

And I came out of that dinner saying, 'Look, I'll build the website.' Right? Because, back, this is back in the days, if you remember, when I was talking about Abcam and what I was doing with technology there, I was looking for applications for this Web stuff. And I said, 'I'll build a website.' [laughs] Actually, I could see a business model for something which didn't actually work, but that's, there's another, that's another matter. 'I can build the website. Here's a way which we're going to do it.' And then Hermann and… And then I, I, Hermann and I and Alec and Fred Hallsworth, Nigel Brown, Anthony Ross, and one other who's probably going to be,

I'll be killed for not remembering their name, all got together, and decided that we would put up £20,000 each as guarantee, and as a result of putting up £20,000 each as guarantee, everybody said, 'Well, they're clearly committing to this. We'll join.'

Mhm.

And we never had to use the £20,000 guarantee.

Right, OK.

And it was, it was… It transformed things. I mean, about two years later I was at a party to which I had been invited by a rival consultancy company in Cambridge, and I met one of the old grandees, a chap called Richard King, who said to me, 'The place has been transformed.' You know, we used to have fights between people, there was a fight between Chris Curry and Clive Sinclair in the Baron of Beef.

Mhm.

And Richard said, 'The place is transformed. I never thought I would see companies collaborating like this.'

Yes. So, things have moved on in a very positive manner.

Yes. Yes, I, I… There's… Look, there's all the competition in the world out there. There's no need to go punching people in the face in – well, allegedly, hitting people in the, in pubs. That's a, that's, that's a silly way to behave.

[1:25:51]
I mean the turnover of Cambridge these days, well, I'm not sure what it is today, but I mean, in 2016 it was what, 33 billion; I'm sure it's grown since then.

We're growing at around about seven per cent per year.

Right. Mhm.

No city in Cambridge, including… I just did the calculations last night about Bradford, which is supposed to have grown at a similar rate. We are growing faster than Bradford ever did in the nineteenth century. And that was supposed to be the fastest growing town.

Yes. Yes, in saying that, I've read, as you say, the fastest growing town. And you're passionate about Cambridge, I say, for obvious reasons, but…

Well it's a fantastic place. I mean… And going back to this point about networking. You know, the point is that, [coughing] that, that Cambridge is, is, I suspect, I have no real facts to justify this, but, when I go to other places, and, and get the feeling they're like deserts, compared to Cambridge, Cambridge is rich in this, in this networking. Everybody knows everybody else. Everybody is willing to collaborate. Everybody wants to give their time. You know, there's a, there's a, there's not a, that won't work, kind of mentality. It's, how can we make this work? kind of approach to things. And, and I think that, that, going back to what Richard King said, you know, that's a positive thing that's come out over the last 20 years. You know, I've played a role in doing that with Cambridge Angels, with Cambridge Wireless that I helped set up on, on the radio and mobile, mobile technology, and Cambridge Ahead, which is about the business, businesses helping look forward about 20 or 30 years. All of these things, all of these things make a difference to the quality of life and the economic prosperity of a city.

[1:27:42]
Mhm. And you mention Cambridge Ahead, which I believe you are Vice-Chairman of?

Yah. Yes, that's right. It's, it's a fairly honorary title.

Uh-huh.

I sit on the board and, help.

[1:27:53]

I was interested to see, a previous interview you've given talking about looking in the future, was it, was it 2065 or something.

That's right. [laughs]

Along those lines. And, and saying, espousing the need for an underground system in Cambridge.

Well… Yes, so this is, this is a very straightforward thing, and it's a technique which I learnt, and I've applied in many different places, and that is, you, you take the rates of, you take the current state, and you take the rates of growth, and then you just push those forward into the future. Don't worry about whether you're predicting what's going on; just project. And if you project those numbers, then what are the consequences of that? I did this with Abcam. We had a problem with, with fridges. You store antibodies in fridges. And, so, I, we put together a ten-year model for Abcam, with the rates of growth slowing up, because we knew we weren't going to grow so fast, and it led us to all sorts of consequential decisions, one of which, about the fridges, was, we had our own robot fridges designed, because otherwise, we were going to be occupying football pitches of fridges, containing all these antibodies. And the logistics were not of scale. So, it's, it's a great pointer to how to do things. And as far as Cambridge is concerned, exactly the same thing, I took the rates of growth. Actually, I slowed them up hugely, because when you are projecting forward fifty years, you, exponential growth can do some very weird and wonderful things. So slowing up the growth. Even so, even so, with relatively slow growth, you ended up with a metro area of more than half a million people – sorry, a metro area of more than a million people, and a city of, maybe 500,000. I mean, you know, it's, it could be enormous. Now if that's going to be the case, and I'm not saying that it will be, but if that's going to be the case, you had better build an underground system.

Mhm.

Because, there's no other way of dealing with it. And, you can pretend that, OK, the growth is going to stop, which, in which case you wouldn't need the underground

system, but the evidence of the last 20 years is, that growth doesn't stop. I was looking at the comparable figures for Silicon Valley. Silicon Valley was growing at that seven per cent. From, from the, from, roughly from 1950 to the, through the Sixties into the early Seventies, was growing at around about seven, six or seven per cent per year. It's the same kind of process that's going on here. Now I don't want freeways everywhere. I don't want the kind of… We haven't got the space that the, that the Americans have over there. I was over in San Francisco three or four weeks ago, it's a very nice place, but boy, it's lots of freeways and lots of cars. No. Even with the BART, the Bay Area transit system, it's still, it's still got a problem.

Mhm.

We need to make sure that we don't fall into that trap. So… Fortunately, technology's going to deliver some wonderful answers to us, with autonomous vehicles.

Yes.

Let's not worry… The Victorian solved autonomous vehicles by sticking things on rails, right?

Yes.

That's their idea about an autonomous vehicle, because it can steer itself. We don't need that any more. And actually, we could do with the flexibility of having rubber tyres on tarmac, and maybe a robot that's doing it rather than a human being. It also means that you can have separate ways, tunnels, or separate ways above ground, which will mean that this stuff has a guaranteed service level, which is the most important thing for public transport. Yah, we, we could do some great things. But we, we are going to need something like this if we are going to grow at anything like the rate we've been growing in the last ten years.

[1:31:47]

So it's clearly, I say the, the evidence there in a compelling case for, for governments to, to react to what's known today. Do you, do you feel that local and central Government are reacting, or perhaps not reacting in a timely manner, or…?

Oh well, I, I think they are. I think they're beginning to… Again, it's, these are slow processes. If you, if you had asked me this question five years ago, I would have been deeply sceptical. But we've got the, the Cambridgeshire and Peterborough Independent Economic Review off the ground, of which I'm one of the commissioners and Vice Chair, and Dame Kate Barker is the Chair, and we have a fabulous set of people who really know their stuff. We have produced, as Cambridge Ahead, some, or we've, we've collated, data on what is actually going on, so I can talk authoritatively about it, more authoritatively than, than we used to be able to do, because that data wasn't being collected.

Mhm.

And, and so now we know what's going on, and the local authorities recognise that, that now we have proper data evidence-based on which we can build things, they're, they're not daft. They, they know what, they know if, if that is the case, then, certain things are going to need to happen. So, now we're in the process of writing, we'll have an interim report coming out in a couple of weeks, we'll have a final report in September, and that will form the basis of what infrastructure investment is going to be made in order to meet this. And all the councils, everybody is now coming together, collaborating, going over to my, my point earlier, collaborating on all of this, based on the fact that, well here's the evidence. Now, now, you, you might not like where that evidence is pointing, and you may say, 'Right, well we need to have a different kind of growth,' or, whatever else it is, but that's a political decision. In the meantime, here's what's happening, and you, the politicians, now need to decide what you're going to do about it, because we're now telling you, you know, how fast and how far we are likely to go.

[1:34:03]

Yes. Thank you. David, thinking about Government. From 2001 to 2008 you were a member of the Ministry of Defence Board overseeing information systems and services. Perhaps you can tell us about your experience in that role.

Yah. So, we were responsible for all the in-theatre and all the back office systems for the Ministry of Defence, so that's a budget of, I mean at the time it was about 1.6, 1.7 billion a year. So, so fairly respectable. And, you know, you have to think about what was going on. I was, I was brought in from the outside, clearly an outsider, and, I was the man who asked the awkward questions. I asked, you know, what products and services have we got? And got them to try and produce a catalogue of actually, what it was we were providing everybody.

Mhm.

I was trying to work towards how much it would cost to provide, which is, is always a difficult thing to do. And I asked various things about network topology, and, and how the systems worked, and so on, those kinds of things. I also talked a bit about cyber security, because I was on the, the Cyber Crime and Trust Foresight Panel, and so I, I came with some of those thoughts, and, talked to them about that. But, one thing stands out I think which plays to some of the, the long run view that I have on things, goes back to my experience with the Long Range Studies Division of Post Office Telecommunications, and, all my, my obsession with how things are going to turn out in the long future. And, and it's this, that when you are in procurement with Defence, some of the things you're having to do go out to 25 years. You know, if you're going to procure a destroyer, or, even a telecommunications system, some of those things, certainly telecoms, are at least fifteen years. And the problem was that we were negotiating with contractors who would write, who would write contracts for now, rather than fifteen years' time, or even five years' time.

Mhm.

[1:36:16]
So, I thought long and hard about this, and so I got my colleagues to ask the people who were bidding on telecommunications contracts, what happens if the demand for

our bandwidth went up by a factor of ten, or even by a factor of 100, what would they do? And the problem here is, that, that when you write a contract, the way that the other side will do it, the provider, will often make their money from saying, 'Oh that's a bit extra, and I'm going to charge you for that.' Everybody's been a victim of that. If what you do is, you say, I'm going to, 'I'm going to need 100 times as much bandwidth as you are providing at the moment; how much is that going to cost?' they've got nowhere to go, because they've now told you how much it's going to cost to get 100.

Mm.

It also changes their view about how they're going to design the network, because if you're going to put those demands on them, then, they're going to put in a different kind of network that can accommodate that kind of scale. Now I've no idea what effect that had, but I did get told by the brigadier general at one point afterwards that that had made an enormous difference to the cost of procurement, and the way in which we wrote contracts with Defence.

Mhm.

So I think, there's a lesson in there which is, you know, think forward into the future, and try and understand what it is that the other side is thinking about, and try and solve their problem for them. Because, you know, BT for example bidding to us, also had this problem, they didn't know what our demand was.

Mhm.

Well give them, give them a huge figure. Because, at the margin, the extra cost of bandwidth is actually quite small; that means that we could have 100 times as much bandwidth, and raise our prices, raise our costs by ten per cent. Right?

Mhm.

If we could that, then that opens up an awful lot of other things that we could do more efficiently and effectively. It's a, it's, it's thinking about the entire system and how it works.

Mm. And, and that's something that individuals should carry across all industries basically.

Oh yeah. Yes. It's always a good question, what happens if we're, we're ten times the size that we are at the moment? That's the same question with Abcam for example.

[1:38:25]
And talking about industries, I, I know, I think, I read that you had invested in 55-plus businesses, or even more.

Yup. Yup.

One interesting one that caught my eye, it must be approaching lunchtime now, was your, your interest in the, in, I say the restaurant trade, I hope I haven't…

Yes, the restaurant trade, is fine.

Yup. So, perhaps you can tell us how you got involved in that.

Well it's, that's a restaurant called Bocca di Lupo, which is, also has a gelateria called Gelupo. And Bocca di Lupo is a, Italian restaurant, it's won a lot of prizes, in the *Financial Times*, *Evening Standard*, *Time Out* restaurant of the year and so on. And it's, it's, it's a great restaurant, but, I can't claim… I can… The claim, credit I can claim for it is financing it. The actual idea came from our nephew, and that's my wife's side of the family rather than, than me, so, there you go, I can't even claim credit for that. And he's, he did natural sciences at St John's, was very interested in doing cooking and so on. And, cut his teeth opening restaurants for people and helping. And then, we discussed various ideas for restaurants. Dismissed most of them. And then he came along with a menu for Bocca di Lupo, and I went, 'You

know what, that's investable.' And we, the bit that I did was, buy the restaurant [laughs], buy the actual premises, because, renting restaurants is, if you don't own the underlying asset, it's always a problem. It was an old casino and money laundering den in Soho. Since then the, the street has greatly improved, largely because we came in there. And, it's been a fantastic success, because, because Jacob and his partner Victor have been really good, Victor on the finance and accounting and management side, and Jacob on the, on the, he's just a genius when it comes to food, absolute genius.

[1:40:37]

Right. Well, thanks for sharing that with us. Coming towards the end of our interview now. If I were to ask you what you would say the biggest challenges and opportunity of the IT industry, dare I say, in the next ten years, perhaps there are a few things that would spring to mind.

Yeah. I… I think… Partly… I think the biggest challenge is, is the emergence of these monopolies. That things… What we're seeing with Facebook, and we will probably see with Google and others, is that they, they have occupied quasi monopoly positions in their particular areas. Going back to my experience being an economist, the economists have ways of testing whether there is significant market power, but the trouble is that the markets that they look at, a bit like an industrial policy, is to think of industry as aeroplanes, or, agriculture, or, something like that. I mean, to be frank, those kinds of divisions about the way in which the economy works are going to be blown away. They are already vanishing before our eyes. Because it's the IT and information processing that is actually the economy. It's not… It's not actually the physical goods. Part of the problems that we have I think over this debate about free trade and where things are going to go is a fundamental misunderstanding about a modern economy. A modern economy is the information; it isn't the goods.

Mhm.

And, we are making a, a massive mistake at the moment in our political relations with the rest of the world, and the direction of travel that we're going in, because, in the long run, we have looked back at the nineteenth century and physical goods; we have

not looked forward into the twenty-first century, about where things are really going. It's a, it's strategic mistake of a massive, massive scale.

[1:42:50]

But going back to this point about the, the way in which this now needs to be thought about. Because the economists think about these things in terms of sectors, then they have tests that they apply, and the significant market power is very difficult to, to nail down. In a world in which you think that all that matters in the economy are cars and aeroplanes and the food you eat, what is the significant market power when somebody has your data, and can target stuff at you in a particular way? And they are the only ones that are doing it, because they, they have two billion customers. And I think that's, that's a big challenge facing the IT industry.

Mm.

[1:43:35]

The second one is, the… Just a minute, I'm going to pause, I need to, just think. [pause in recording] The second one is that IT is simply getting buried in everything else, which is kind of the opposite of IT being everything. It's, it's also nothing. You pick up your iPhone or your computer or iPad or, Galaxy or whatever it is; you don't, you don't… or, the Internet of things stuff, you're not thinking about these thing as actual bits of IT. They're appliances. A part of what Raspberry Pi is trying to do is go back to basics, right? This is what this stuff does, this is how it works, this is how you should understand it, and this is how you can contribute to the modern world. And I think that, the IT device as an appliance, which I first heard said in Oxford I think back in the early 2000s, and it struck me as odd at that point, and I didn't really realise the implications of it, but it is coming home to roost. That, that if IT is just an appliance, then, people don't really understand what it's about, and we, we don't get it. Cam we pause for a second. [pause in recording]

[1:44:49]

And then finally, I think it's the challenge of, of AI. And, AI is bigger and will go further than we think, and will emerge in a different way. It's not going to be straightforward, it's not going to be the, you know, the, the robot's eyes turn red and that indicates they're evil and they're going to kill you. But our relationship with the machines is going to define the future. It's a bit more like Iain Banks's *Consider*

Phlebas, those kinds of, that kind of science fiction. That, that's the, that's possibly one way in which it will go. But in the shorter run, the most important thing, you know, for, for people over the next 20, 30, 40, 50 years, is that AI will make that transition from being something which is an interesting experiment, and, you know, you can play games with it, to being something which is running our lives, and, I think that that, the ethics of that and what we're allowing AI to do, and what systems we put it into, and how it, how it then interacts with us, is going to be an enormous challenge.

Mhm.

And, and, [laughs] big enough, big enough a challenge to be an existential threat. In other words, an existential threat, and it's something that could either wipe out or permanently alter the human race. And, and so, I think those are the three big things.

[1:46:20]
At least two of them, well, involving governance really, governance of AI, governance…

Well, I think, you know, this is one of the curses of getting old, you know, you, you start, you start your life, your career, thinking everything is technology and that's the way it's, that's, that's the future. As you get older and older and older you, you realise that actually, it's the, the governance structures, it's the way in which you have the rule of law, it's the way in which society organises itself, which actually determines all those outcomes. And so, the technology is important, and has a huge effect, I mean vast effect on our society, but in the end it's the way in which human beings decide to organise themselves that's the most important.

[1:47:04]
Mm. And finally, can I ask you what advice you would give to someone entering the IT industry today?

Mix with young people, find out… [laughs] Pursue some crazy ideas. Don't, don't… Don't take what somebody in their fifties or forties tells you, or sixties. Take

all that kind of advice with a pinch of salt. Because you are the guys who are going to make it. I got told, I, I would discuss with them, back at Reading, I discussed with somebody, I wanted to do a PhD, and I said, 'I've got this idea.' You know, integrated circuits are very difficult to design. So, why don't you just do this at random, and then you select which integrated circuits work, and then you breed from those integrated circuits and breed new integrated circuits that would then actually work. And, and the answer came, completely incorrectly, 'That will never work. Do you realise how many billions and billions and billions of possibilities there are? You could never explore that space.' Right? I mean they didn't say explore that space in those terms. But of course, they were completely wrong. You know, you can use genetic algorithms, which is what I've just described, for doing all sorts of design. There's a wonderful design of an antenna. You would never design an antenna using, in the way that this genetic algorithm produced this antenna, and yet it is fabulously efficient at doing its job. It's a bit of a regret of mine that I never pursued that idea, and I took at face value what somebody had told me. In the same way, [laughs] you know, sorry to go on, but, but, when I was doing my PhD, the breakthrough in my PhD was, I went to see a professor of geography, he said, 'Loads of people have tried to do that, and nobody's succeeded.' And at that point I went, OK, right, that's, that's where I'm going to do my PhD. That's, that's the thing that I'm going to crack. [1:48:59]

And I think that if you, the advice I give is, just, people will tell you things are impossible, that they won't work, or they're, they're useless, or whatever else it is. Just think why they might be wrong, and pursue, pursue what you want to do.

OK. Well, on that very sound note of advice, I would like to thank you very much for agreeing to speak to Archives of IT today. Thank you very much for your time, thoroughly enjoyed it, and, wish you continued success.

Thank you Jonathan. It's been a real pleasure, thank you.

[End of Interview]