Doron Swade MBE

Interviewed by

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Welcome to the Archives of Information and Technology. It is the eighth of May two thousand and nineteen and we are in London at the British Computer Society. I am Elisabetta Mori, an interviewer with the Archives of IT. Today I'll be talking to Doron Swade. He is an engineer, historian, museum professional and scholar who publishes and lectures widely on the history of computing, curatorship and museology. He is the author of more than eighty articles and four books. At the Science Museum in London he was curator of computing and responsible for the national computing collection. He is a leading authority on the works and life of Charles Babbage. During his tenure at the London Science Museum he directed, managed, fund-raised and publicised the construction of the first mechanical calculating engine from original nineteenth century designs by [Charles] Babbage. In 1989 he founded the Computer Conservation Society and in 2009 was awarded an MBE for his services to the history of computing in the New Year's Honours List. In 2017 he [received] the Computer Conservation Society Lifetime Achievement Award. In 2018 he was awarded an Honorary Fellowship of the Royal Holloway University of London and in 2018 he became an Honorary Fellow of the British Computer Society.

Welcome, Doron. Let's start with where and when you were born.

00:01:30

I was born on the fourteenth of October 1946 in Cape Town in South Africa.

Can you describe your parents, what were their occupations?

My father was a doctor, a GP, a general practitioner, who had his own practice so he had private clients, and the legacy of that experience was that I cannot leave the telephone ringing and not answer it because our house landline was the practice landline so being on the telephone, even as a teenager, was always rationed until I had enough money to actually get my own line, and telephone, and that was a huge liberation. My mother was a music teacher, she taught students after school, and then later in life, in mid-life actually, retrained, went back to university and studied librarianship and became a librarian.

Did she want you to play instruments?

Well, I learnt the piano as everyone did, my sister actually was a concert pianist and my other sister is a flautist and the other one is a fine pianist and also a doctor, and I also studied the violin and, rather extraordinarily, and I don't expect anyone to believe me but it's true, my violin teacher was Italian and his name was Paganini, so I was taught by Paganini. [laughs] I was never a great musician, the instrument I really took to and discovered quite late was classical guitar but, at that stage, in the fifties, sixties, classical guitar was not recognised as a legitimate serious instrument and our house was very legitimate and serious in terms of music and culture, but I persisted and became quite – I won't say obsessed – but I really loved it, I loved the intimacy, the craft of producing a sound on a classical guitar I just think is exquisite and I played for many years.

Can you describe your grandparents.

I have a very faint recollection of my grandparents. I met three out of four of them, my maternal grandmother – sorry, my paternal grandmother, my father's mother died when he [my father] was very young so I never met her. My father was sixteen when she died. I remember very clearly my maternal grandfather, very austere, very warm but quite austere and formal, and I remember my father's father when he was already quite old, he was in a home and he was almost blind at that stage. I'm very, very clear, I must have been four or five at the time, and I have very clear recollections of them. They were part of the culture because all that grandparental generation came from Lithuania and Central Europe. My parents were first generation South Africans and most of their contemporaries were first [generation] South Africans, so it was a family and a culture with European connection, with a European allegiance. I won't say allegiance but it was a European connection, it was a European consciousness about them because of that big immigration from central Europe to various places, South Africa included.

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What was your family life like?

Family life was chaotic. It's difficult to describe. I had three sisters. My elder sister by eighteen months was an extraordinary prodigy, she was a phenomenal musician. My mother was a music teacher so in the house there were two pianos going at the same time and my room where I studied was actually between [them] – one was downstairs, it was a baby grand and there was an upright piano in my sister's bedroom. So I grew up with two pianos, totally unsynchronised, in this – call it chaotic if you like – complete babble of conflicting sounds. So my primary memory is my mother being excluded from my attention because she was giving attention to schoolkids after school, and two pianos going almost all the time. It was an extraordinary place, we lived in a Victorian house in the centre of town, my father's surgery was in the house, it was a beautiful three-storey house with a huge garden and fruit trees, and it was a kind of cultural centre because there were concerts all the time. All of us played, I was less of a performer than my sisters, but people would gather in the house attracted and almost mesmerised by this richness of what was going on. To me it was traumatic, it wasn't as blissful in the way that other people remember it, but what is memorable about it is that people flocked to the place because of this richness of what was going on, the music primarily. There were concerts, my sister was a phenomenal pianist and all of them played and so there were concerts whenever people came. In fact, there is one story - the windows were open while my sister was practising and there was a man, an Italian, standing outside and he heard the music and he was very attracted, and he eventually hesitantly knocked on the door and he gave his name, his name was Mario and he came from Milan, and he was travelling, and he was a businessman, and he loved music. And he became a family friend [laughs] he was attracted to the music that he heard through the windows of the sitting room and he was associated with the family for years to come. So yes, it was a huge, rich, babbly, chaotic place.

Was there anyone who had an important influence on you in your early life?

Nobody stands out in a conventional way, that this was a person who, as it were, became a role model, and I think part of the reason is that, as children at that time – fifties, sixties – we were awed by adults, adults were awesome people, they had power, and so the idea that you have somebody that could be a role model was almost, not disrespectful, but almost stepping out beyond what was legitimate for a child's relationship or a young person's relationship with an adult. So, in terms of technical things the answer's No, I felt fairly isolated. I mean, one example of the isolation is that, from the earliest age, I can remember I made things. My survival strategy in this chaotic environment was to make things because making things meant you were in an ordered environment that was, in a sense, passive, it was a dead environment. Because the attraction about passive was, it was unproblematic, there was a logic to what happened.

So what did you build?

Anything on earth – lampstands, lights but when I started building it was with electronics. From the earliest age I can remember being interested in electronics. Where that interest came from I don't know, there was nobody else I knew who did electronics, but there was a shop called Hamrad which was short for ham radio [shop] and they had army surplus electronic equipment. I sang in a choir, we got pocket money, and I used to go once a week at least to Hamrad and buy electronic components, military headphones, quartz crystals, all these things. I had a book published by Philips, the Dutch electronics lighting company now, and in it were projects, transistor projects, and I would work through this book in my ... and I had a bench in my bedroom which was huge ... I had a table tennis table in my bedroom, – the house was [ramblingly big], I had a table tennis table and a workbench in the bedroom as well as a bed and all the other things one has.

00:09:15

And we are talking about the sixties?

We are talking about the [fifties and] sixties.

So you were, like, using transistors?

Discrete components, yes, ... transistors and building little amplifiers. A friend of mine's father had a radio shop and he ceased trading and he said, 'Look, take whatever you want.' So there were all these abandoned radios there, so I salvaged variable capacitors, knobs, all these things, I had tons of the stuff, but in it was a valve tester with the manual for the settings to test valves [that was the prize]. So I knew about vacuum tubes because I could test them, I could change the grid voltage, to measure the gm, , I could change the anode voltages, I could measure gain, I could measure milli-amps per volt, ..., you know, I knew as a kid about vacuum tubes [laughs] because of this guy. So the things I made – what did I make? – one of the things out of the Philips book that I made was a transistorised transmitter and, at school - I was pretty obedient - but at school we did a prank and we put the loudspeaker inside a cupboard in the front of the class and I sat at the back of the class and said into the speaker, 'Let me out, let me out' so the teacher would think there was someone locked in the cupboard. I wasn't very comfortable doing it but that's it. I made a baby monitor. Cousins had a kid and they wanted to listen to the baby. The reason I mention that is, what is the early thing about electronics - and we may come to it later about the ten thousand hours, how you get to a level of accomplishment – but the reason I mention is that it wasn't just the design of these things and the functioning of the components, it was the craft of the manufacture, it was how the plastic, the PVC wires were bent round corners, it was the colour combination of the wires, there was an aesthetic to how you built something properly, and that carried all the way through. And another aspect of that period, which goes back to what eventually became quite influential, that was the idea of restoring and conserving things, being a curator. That must have been an ingrained, and inherent in me, from the earliest age. When I got my first bicycle I taped up the frames so the paint wouldn't get scratched. The issue was always, if I saw ... my sister had a little red bike and the paint was scratched and some of it was rusting, and my immediate reaction was 'How can I perfect this?', 'How can I make it new again?'. So there was already a thing about the discomfort of something not being as it should be, well you could say, 'It is as it should be because the way it is is a legacy of its history', but it was something that it wouldn't be ok unless I fixed it, that for some non-specific reason it wouldn't be ok. There was some dread about it not being ok. So, building things, making things, was an environment of a kind of security, it was a kind of meditation where – I won't say nothing surprising won't happen – but however difficult human relationships were, the world of objects, the world of artefacts, the world of machines, there was an inherent logical grammar to it which was the comfort. And why I say building things was a survival strategy – that was where the sensitivity for materials and machines, the relationship of materials and machines, between something that cuts and something that is passive to be shaped. So if you talk about that whole period, it was to do with electronics and if I thought about it, isolation, because I didn't know anyone else who was doing this. I was reading electronics magazines – I didn't know anyone else who was doing that – I don't know what the attraction of it was. Electronics is abstract, it's virtual, you can't witness what it is the phenomenon is, in the way that you can with mechanics so there was an inherent attraction to mechanical things, but somehow it was also the stuff about electronics. So my whole youth was spent doing electronics.

00:13:19

So what schools did you attend?

I attended a private day school which one went to every day and I cycled there every day, my bike with its taped-up frame so that it wouldn't get damaged, and every week I probably stripped all the bearings and re-greased them. Every individual ball bearing I'd do that. I went to school, yes, and it was quite a remarkable school. I did physical science, mathematics, Latin, English, Hebrew and Afrikaans, and I always joke that studying Hebrew, [Latin] and Afrikaans equipped me to communicate with a huge proportion of the world's population – I meant that ironically. I loved Latin because of its structure, it gave me more insight into English than almost anything else. Physical science is what was my natural language, I had an inherent affinity with it. Mathematics I loved although, in retrospect, I don't believe I'm a natural mathematician because, to me, a mathematician is in some sense like an artist and that is, you cannot acquire what they have, they can see meaning in abstraction. I can't see meaning in abstraction, I have to have a relationship between the abstraction and something physical. So, yes, I can manipulate an equation but my hand doesn't stop and halt and sieze up if I write a wrong equation. A mechanical thing will jam if there's something wrong. [It instructs *you*] So yes, I did mathematics but because I had no example of anything else, I didn't realise at university particularly, how stressful and how much application I had to give to it because there was no inherent understanding of abstract symbolism as its own language, as distinct from something you related to something that was intuitable, something that you would experience. And we did four years of pure mathematics, three years of applied mathematics and four years of physics, so the entire language of engineering and physics is mathematics. And it was only long afterwards that I realised that I was not a natural mathematician, I was an engineer at heart and the language of engineering is mathematics, but that was long after I left university that I actually figured that out.

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You finished high school in 1963. What did you do in 1964?

Extraordinarily, I was in the army. In South Africa there was still a ballot system where sixty per cent of the eligible people of my age were balloted into the army. So you had a forty per cent chance of not going. I was balloted to go in. You could get deferment if you were going to university, so you could defer so that probably I could have been deferred and not gone. I was not sorry to go. I grew up in a very protected environment, a very elite and privileged protected environment, I was white for one thing in South Africa and, to me, it [the army] was a physical challenge. How do I survive amongst a cross-section of the populus that don’t come from this very hot-house, cultural hot-house that I came from with all its cultural sensitivities and things. How do you survive, and I was staggered to discover there were people in trade ... suddenly I walked in and they said, ‘Where’s the other half of you?’ I’m not a big person, I’m a slim person, and the model in South African culture, particularly male culture, you had to be built like a rugby player, you’ve got to have legs like tree trunks and that was the standard of masculinity. Here I was, I wasn’t weak or minute in any way, I wasn’t, but I didn’t have tree trunks for legs. I was fast, I was a very good distance runner, and I was fast [enough] to play on the wing in rugby, but there was an element of masculinity that militated against things like philosophy, men being involved in philosophy, men being involved in art, men being involved in English literature or culture, it was a very masculine environment. Engineering sort of fitted, that was ok, you know, that was the intellectual side of masculinity if you like, and how this [split] manifested ultimately was that I was the first person in the history of the university of Cape Town to register both in the engineering department and in the philosophy department. But I found the discourses were so conflicting, the actual mentality involved in philosophy and the mentality involved in engineering which was to do with problem solving, there's a prescribed answer to the things you're looking for, philosophy was open-ended, were incompatible. I couldn't sustain the two and it was only after I'd done six years of academic engineering I went to Cambridge to do the history of the philosophy of science when I could devote myself to this hostile discourse, 'hostile' in inverted commas.

00:18:23

So let's go back to 1964, what did you do during that period in the army? You were talking about ten thousand hours.

Yes. I was in the Signals Unit and so the first thing that you did was that you learned how to use radios. These were vacuum tube radios, battery operated radios, military standard.

So for you it was, like, your environment?

Well, you weren't allowed to fix them because these were all vacuum sealed. You had to diagnose them so that the radio operator would call you and say, 'My radio is duff'. The first thing we were told was for ninety-nine per cent of people - of radio operators – who call you to fix a radio, the solution is, it wasn't tuned properly, and this turned out to be true. These were massively reliable devices and what you really did is, you knew how to tune a radio. Ok, I knew what was going on while I was tuning it because of the history of building these electronic things, and I was called a radio mechanic, but actually what you were doing was this. We learned about the circuitry, we learned about all that stuff which was a second language to me and the curious thing was that in our little platoon of radio mechanics I was the first person to be promoted – I mean, I was a kid of sixteen, seventeen – to a corporal and I walked into this thing [the classroom] when the instructor announced that, of this group, the first promotion would be to me. These guys who were, like, ten feet tall and built like tree trunks, looked at me and said, 'Are we going to follow him into battle?' and the instructor had to explain that in radio mechanics and in life in general there were attributes and qualities that weren't entirely physical [laughs]. But I remember that absolutely, this business that your ability to assert yourself in that environment was a physical ability and that wasn't necessarily my strong ... I was physical, I played tennis and I was a distance runner, I was eventually a first division squash player and played competition squash for ten years, I was college champion at squash, I was Essex University champion at squash, so I wasn't feeble but the model of what it was to be a man had nothing to do with intellectualism or intellectual art. So yes, I was in the army, I had no regrets about it because I learned how to command respect even though you couldn't do so in a physical way. For example, there was a huge prejudice against anyone reading. These people were not massively educated, a lot of them were in trades, this was a cross-section of South African youth – I don't say this as a criticism, just I was reminded of what a privileged environment I'd come from – and so you're lying on your bunk and you're reading and somebody's going to come and start hassling you because you're reading. There's a resentment. And you had to learn how to be confident and assertive and say, you know, 'Get the hell out of here, I'm reading, you're disrupting me.' You have a right to read. But the ability to assert that right was something I had to learn and that was probably the most valuable lesson. Eventually, after the radio mechanics stuff, I became a radar mechanic and the radars we worked on were mortar location radars of which there was only one in the country and there was only one person qualified to instruct us. And because it was top secret stuff, and not our role but this guy, they couldn't tell him he was about to be posted to a different place to go on a course, so we arrived at this permanent force camp, we were in a military camp but they were the permanent force, we arrived at ... camp, we had our own rooms, we had our lockers, we had every weekend off, this was extraordinary, my buddies were in the field doing infantry manoeuvres, and we were there to be radar mechanics and our instructor was posted just before we came. And they couldn't reveal to him that that would happen because of the secret of where he was going. So I had three months to prepare for university and I sat and studied vacuum tube technology. So that was '64, an extraordinary situation.

So in 1965 you went to university.

Yes.

What do you remember of those years?

00:22:41

Well, we did what was called then Light Current Electrical Engineering because there was no such thing ... well there was some form but it wasn't called electronics ... in fact, the subject was, I put electronics there, but it actually was called electrotechnics which is a combination of electronics and electromechanical because it was a transitional period. I was of the last generation to design with vacuum tubes, it was a transitional period so we learned about transistors, we designed transistors, we had h-parameters, and my thesis in '69 used chips, used TTL chips, integrated circuits. So I was the last of the transitional generations that designed in vacuum tubes, in transistors and ultimately in chips, in integrated circuits. It was unbelievable, the most demanding course there, it's four years of physics and all that stuff, maths, it was very demanding and there wasn't a day off. You were at lectures at 8.30 in the morning and you had laboratories every afternoon and this went on for four years, there was no break. We used to laugh at the BScs, the science students, they got a bachelor's after three years with one major, physics or mathematics. We had like three majors, we did an entire BSc course of applied mathematics and physics, and a course in chemistry in the first three years, then we had an extra year in which we did ... no, not an extra year, we did engineering all the way through in addition to things on the BSc and then we did our engineering majors. So we always thought that the science students had an easy life compared to the rigours we'd gone through.

Were there any women studying?

There was one who was the daughter of our electronics lecturer who was an absolute genius, a quite inspiring man called Besseling. I think he invented the microwave .. the heating, or who had a major role in the microwave heating of blood. He was a brilliant, brilliant man, not necessarily the most magnificent teacher because he sought absolutely the essence of something, he would write a single equation on the wall and that would be the entire lecture, he'd just talk about that because he understood it so profoundly, he understood the grammar of that interaction so profoundly and, yes, it was his daughter who was the one woman engineer.

How many men?

I don't remember but there were lots, twenty, thirty, forty yeah...

Ok. In 1969, you moved to your Masters?

Yes. The thing that attracted me hugely and my thesis for the BSc Honours was in architectural acoustics – a way to measure the reverberation time of a concert hall using a new technique. The classical technique was that you fired a gun or you popped a balloon and then you measured the decay. But there was a new paper that had been published that said, if you take the impulse function, if you take this shock mode and you measure the decay and you reverse integrate it and square the result you can recover the system identification function. So the first thing was, the good architectural acoustics where I instrumented the measurement of a concert hall on campus using this technique and produced ... designed and built the electronics to do with this and that was the thesis. And I would have gone on to do architectural acoustics because, to me, that was the integration of a mathematical rule and human experience, because you were in a life-scale environment whereas the electronics is all minute. So that led to a Masters – I didn't know what else to do after the Bachelors, so what I did was to carry on and do a pure research Masters in control engineering in which I explored using this technique of reverberation measuring by using this reverse integration technique. So the thesis is on that and I instrumented that and the conclusion was the two techniques do not match. There is something wrong with the theory or there is some reason why – it could be surface reflections – why this reverse thing in which the mathematics is beautiful. And when I tell you about the difficulty of mathematics, about needing an explanatory connection, a correspondence between the theoretical entity and the symbol in the mathematical equation, and the physical phenomenon – as part of our degree, of course, we had to give a lecture, or lectures, or at least one lecture, and I gave a lecture on my research. And I went in ahead of the lecture and wrote across two blackboards all the equations of the reverse integration for integrated reverberation-time measurement. At the start of the lecture the first thing I went to do is, I took a duster and I rubbed it all out and said, 'I cannot help your understanding through this mathematics'. I will try to help your understanding by explaining intuitively why every system will put its signature or whatever input comes in, so the signature, what it is, is in the output, you just need a mathematical process to recover it. Just as everything anyone else does is a signature of who they are, everything is there in the output and you can reconstruct ... I'm not saying it scientifically ... you can triangulate what this person is like or who they are by their outputs, how they express themselves, how they walk, how they speak, I'm not saying that this is no different, so the only way I can convey to you why this should work is by giving you an intuitive understanding and that the mathematics describes it but doesn't explain it. So, again, already there was the manifestation, firstly of a philosophical dimension and secondly to the role of mathematics in understanding. What does it mean to understand something? And to me, the understanding was always intuitive which is why the mechanics and physical things and making things was the grammar of the world, the way you understood the world was to understand what the connection was between things. So there was, underlying this, a kind of existential philosophy although it was not articulated in that way at all.

And in 1971 you had your Masters.

Yes, I left South Africa even before graduation. I didn't even attend the graduation ceremony. There was an opportunity because ... my first introduction to computing was through this Masters thing. A colleague, a friend of mine, joined after he graduated from his undergraduate degree the South African Scientific Research Association, SACSIR (South African Council for Scientific and Industrial Research), and part of his research he was doing at the university of Cape Town in our engineering department was involved with computing. And the computer was a Varian 620i which is a machine with 8K core [store] memory, with a teletype paper tape input and a three-pass assembly system and they wheeled this into the laboratory and he was working a few doors down from me. I started looking at this thing and within a very short time I transferred my thesis to the computer. The thesis was in control engineering called System Identification with M-sequences using a small digital computer. So what you did was, you fed noise into a system and you [cross-correlated input and] output and you could recover the system identification function. A lot of this has been personal. This actually, I think, has relevance to the way the IT professional world is structured. In South Africa you couldn't attend a computer science course. The computer science courses were run in the mathematics department and they taught you Fortran. We were engineers, we designed things, so we went to one of those and we walked out. You know, for us the computer was a bunch of chips and things. So essentially there were no courses on how you design or build or fix computers. So I'm auto-didact in that respect, so this computer is wheeled in and there are the manuals there, so I studied the manuals and I needed to take signals out of the computer to manage the generation of the external equipment that was doing the architectural measurement or whatever the system it was, and in this case it was an architectural thing. So, it was generating pseudo random sequences and I needed to take signals out so I didn't know there was a difference between software and hardware. I programmed in machine code, I programmed in assembler code and I was a design engineer, I was an electronics engineer, so I needed to take signals out of the machine to interface with the external equipment. It never occurred to me that you shouldn't do this or that you should get an engineer to do this. To me the software was a manifestation of the hardware activity and if you could relate them you could steal relevant signals to do what you needed to. It never occurred to me that this was anomalous. So to me, being an autodidact there was no distinction between hardware and software, to me there was no distinction. Programming was just the top end of a process that was rooted in the physical hardware. So my Masters was done on this machine and I programmed a huge thing.

Do you remember what was the company that produced this machine?

Varian, it was a 620i. My memory didn't sink in, I studied the manual inside out xx. Then, during the course of this, the department ordered its own Varian 620i which was shipped and it was dropped in transit. So my first connection with a computer was how do you fix a computer. So I had to work out how this computer worked in order to fix it which I succeeded in doing from first principles, in some sense ... of course, one had some contingent knowledge of that particular machine ... and I ended up running the departmental facility which was the facility provided by this machine. So there was a natural affinity with this: programming to me was like mathematics, it was absolutely logical, the structure of it all, but the thing I discovered which influenced me a great deal later was what the nature, psychological nature of programming was. It can be absolutely obsessive, that I would spend hours and hours writing programs. In those days I would test each function because you had panel switches where you could actually look at the specific registers, and I would test to see what it did with the registers to execute and then write the program. There were very few faults in these programs, because I had already verified [function], it wasn't what I thought the thing did and was not what the manual said. It's what actually the machine did, to inspect each of the registers, the source destination registers and so on. And .. what is the thread of that ...

That you graduated, you got your Masters degree and you left, even before the ceremony.

Yes, that's right. I finished the thing, the thesis was done. Yes, the thing about this, the idea that the topic could be absolutely obsessive which it was, the thread. And I realised that this [programming] is dangerous because it is so narrow context, it is so – the universe of that program is so confined - that you spend like eight hours doing it and you come out and you're almost unable to speak to anybody because you're so in this internal world, and I recognised that that was probably psychologically and sociologically not massively healthy to do that, certainly professionally or do it for sustained periods of time. So I knew what programming was about, I'd done a sophisticated assembly language and I realised that that wasn't something I wanted to pursue, not because I was averse to it, I loved it and loved the structure of it, loved the logic of it, loved the fact that it is an art and a craft because there is no internal rule that will tell you this is ok. So, ideas of branching, ideas of closed systems, idea of sub-routine calls and all that stuff, I like very much but I also recognise that the actual activity is such a narrow, low context in human terms of consciousness, it's such a low and narrow universe that it is not necessarily healthy sociologically and psychologically to do it to extremes. So that was my lesson from that.

00:35:19

So you decided to move to the UK.

I moved to the UK really because I didn't know what else I would do. There was only one electronics company there [in Cape Town].

Why the UK and not somewhere else?

Ah. In our family when each of us matriculated – that's when we were about sixteen – one of the parents took us on a European tour. I think I went when I was sixteen with my father and we went to Paris and I saw snow for the first time and to Greece which was just miraculous, went to Rome, and I stayed on six weeks, after my father went back, with my uncle who lived in London. So London was always the kind of family home and I stayed in this [uncle's] attic where there was television – I'd never seen television – to me if you had a television you could survive, you didn't need anything else. I was utterly mesmerised by television. I went to plays almost every night, I saw the original production of the satirical stuff that ... it's a famous thing, the names gone [Beyond the Fringe]... so I went to the theatre a great deal and then there was something hugely influential that happened to me. Four days before I was due to fly out of London I visited the Science Museum and there, as a public display, were the things I'd been building as a child. The small universe was suddenly opened to the world, suddenly it validated something that had been entirely private, building radios, building things, building transmitters, things electronic, there in a transparent cabinet was a radio with the parts laid out in accordance with the circuit diagram that you could use. This was miraculous to me. The Copernicum revolution moment for me was when I went to the aircraft gallery, which is still in the same place on the top floor in the Science Museum, this cavernous thing which looks like an aircraft hangar, and on the wall there was a rotary aeroplane engine, propellers, pistons, shafts, just on the wall. I then looked around to see if there were any warders around, whether there was any security and there wasn't, and I put my finger on the propeller and I turned it. Firstly, it turned completely smoothly, silky smooth the propeller turned, but to my absolute astonishment the cylinders turned. The shafts stood still and the propeller was attached to the cylinders, and the cylinders turned as the propeller turned, so that the crank shafts were driving the cylinders round a stationary shaft to turn the propeller. Now this is the complete inversion of everything you know about engines now, and that was the biggest single message to me about the value of historical artefacts and museums, the message that things weren't always the way they are now.

This inversion of this thing was a complete revelation to me. This was a Copernicum revolution moment. The universe was no longer, went round the earth, this was a solar centric universe. Suddenly, it wasn't necessarily the way you thought it was and you could not assume that this was the way it is, you see, it was the outcome of a long historical process and one should not take for granted that the way things are is the only way to do things. And that has been an abiding message through my entire professional museum career. I had no idea at that stage I would ever come back to London, I had no idea I would have any connection with the Science Museum, I certainly had no conception I would be a curator there, of computing of all things, and that I would become an Assistant Director and Head of Collections was completely incomprehensible. None of this was ever foreseen, I had no plan, all that happened, but that experience of that rotary engine and seeing the work of a chap called Keith Geddes who was the curator of electronics at that time, who made this radio and put the components where they were in the circuit diagram which is completely fusing both the theoretical understanding and the physical implementation, the map [circuit diagram] is a theoretical map, it not a physical map, but he had merged the two. I subsequently actually worked with Keith Geddes. So yes, those were pretty influential times. I spent the next four days before I left at the Science Museum. I went from the Science Museum to the airport to come back. Four days before I left I grabbed my first visit, I spent the next four days there and went from the museum to the airport to fly back to South Africa.

00:39:33

And you were sixteen?

I was sixteen, yes.

Then, in 1972, you chose to study history and philosophy of science in Cambridge?

Yes.

So when you were flying from South Africa did you have a stop in London before going to Cambridge?

Well, I was staying with a connection to my family, an aunt and her family and an uncle and his family.

And did you go back to the Science Museum before going to Cambridge?

I probably visited, it wasn't greatly significant then. What happened? I came certainly to ... I went to Walton on Thames on a course on the Varian, which was unnecessary xx – my programming was quite advanced by that stage, but very gentle, very nice people there. Then I travelled for six months in Europe which was a revelation for me. You could hitchhike, I hitchhiked through France and Spain. I was quite passionate about classical guitar so I visited classical guitar makers in Spain, that was my itinerary, to ask them whether I could watch them make guitars. And one of them said to me, 'We'd love to let you do this but last year we had a Japanese person who we let [in] and they stole all our things for their factories'. It was industrial espionage, he was sent there by a Japanese guitar maker to find out about techniques they didn't know, and all these techniques are guarded in the families because they are the legacy of so many generations, and so with huge regret he said he couldn't allow me to watch the guitar making. So I travelled for six months and then I took jobs. Now, when I visited Cambridge, when I came back to England in '72 ... '71, I left South Africa in '71, I visited Cambridge and there was a colleague and friend of mine who had done control engineering with me, and I went to Cambridge and it happened to be one of those utterly sublime days, absolutely still, beautifully clear and warm, and I went wandering round the streets and I heard in the silence a clacking sound, there was this clacking sound, and I followed the sound and it got louder and louder and then I could hear the sound, and I poked my head round the door, round this gate which was an open gate onto the street which I subsequently discovered was Silver Street, and there was the most exquisite scene I've ever seen. It was this beautiful and exquisite garden with this huge magnificent tree [Copper Beech] and a college and the clacking sound was people playing croquet. And I looked at this scene, and I had no idea what it was and I thought, who do you have to be to be here. Who do you have to be to be in this unbelievable environment? I went to visit my friend and he said, 'Well, why don't you come to Cambridge' or something like that, so I went – the only thing I'd be qualified to do was control engineering. I'd done six years of science, maths, science, engineering, science, maths, more science, more maths, more physics. I had philosophical interests in this. I had done six years of narrow science. I wanted to know what it was you do when you do science, what is it you do, what are the precepts, what are the presuppositions of these things. What is it that gives science its supposed privileged access to certainty? Is there a scientific method? What is special about the discourse of science in relation to the discourse of literature, history and other things? So, but the only way I could get in was to do something that I already had some expertise in, so I went to the control engineering department and walked down the passage – this was in the vacation time – and I saw on the door the name of Professor Coales and I had read a paper by Professor Coales. So I knocked on his door and I said, 'Hello Professor Coales '. I, you know, apologised for barging in like this, he was utterly charming, and I said, 'I want to come to Cambridge', and he didn't say what do you want to study, he said, 'Why do you want to come?' And I said, 'Because of the sense of bottomless scholarship that I sense here, you walk in the courtyards and you see stones that are hollowed out by generations and centuries of people walking on them, so it seems to be that there's no ceiling or, if you like, there's no limit to the depth of the scholarship that is expected here'. And he said,'Ok'. [laughs] So I was accepted into control engineering. That was before I went travelling, but because I didn't have an address, I had my uncle's address, that was the address I gave. I never received the papers that accepted me and offered me the place. So I went travelling for six months, came back and Alan Zinober, the friend of mine whom I visited said, 'Where were you? There's a desk there waiting for you and you didn't show up.' And I said, 'What are you talking about?' And he said, 'You've been accepted.' So I said, 'Oh dear'. So I wanted to go to Cambridge but I didn't want to stay in control engineering. And that is the magnificent thing about these old universities, Durham, Cambridge and Oxford, it's that once you're the member of a college you have pretty well academic freedom about what you study. And the reason I was accepted at that college was because I was a first division squash player and the Master wanted to improve his squash team, so I was accepted to Darwin College. That is the college that had the croquet lawn that I had seen previously and that building was the last remaining piece of Darwin's house and my room overlooked this exquisite garden for the period of time I was there. Ok, so here I am at Cambridge, I've done six years ..., I've been ... I had no money, I had no grant, I didn't know you had to plan in advance and apply in advance, I had no plan, but I wanted to go to Cambridge because to me this was divine. And I was standing in college, and it was four days before the start of term and I had to register. I could not go through with the registration for control engineering and each day goes by and I haven't registered and the term is about to start. And I'm standing on the stairs in the foyer of the college and there are two call boxes there and I overheard a conversation of a guy talking, and he said, he spoke about a degree, he mentioned a degree in the history and philosophy of science for one year for post-graduates, for people who had not done history and philosophy of science before. I'm a mild, shy person and the question is, what do I do, and I recognised, as I stood there, this is a turning point, do I confess that I overheard the conversation which is not a good thing to have done, that I listened to a conversation, do I apologise and confess and be embarrassed by this intrusion or do I say nothing and possibly miss this opportunity. So as he left I said, 'Look, I'm terribly sorry, I heard you mention history and philosophy of science, what is this?' He said, 'It's a one year course for post graduates' and I took the first strategic act of my life. I went and got the prospectus, I read who the lecturers were and I made appointments to see every single one of them. I went to them and said, 'I have to do this course' and they said, 'Well, why?' So one of them was Mary Hesse, a very famous philosopher of physics, and she said, 'Well, why do you want to study, what qualifications?' I said, 'Look, I've done four years of physics and four years of maths, pure and applied. There are things that have struck me about physics that puzzle me that I would like to explore, like the direction of time, like inverse causality, time always goes monotone increasing but the mathematics does not have any direction, mathematics you could run the equation backwards, why does causality only work in a forward way?' I didn't know that these were central philosophical questions but these were the things that had puzzled me. And she said, 'Ok, well obviously you're enthusiastic enough so you've got my vote.' I then went to see Gerd Buchdahl who was a Kantian and battled with him similarly and then the other one was Hugh Mellor who was a [lecturer in] general philosophy of science, and was accepted. I had no money so I had to sponge off my parents which deeply embarrassed me but I did. So I lived on seventy pounds a month for two years at Cambridge and did history and philosophy of science, finished the year and Gerd Buchdahl who was a wonderful man who had been an engineer, an anglicised German, who was a Kant specialist and he gave me as a thesis topic something that he himself had failed to solve, he said, 'Look I can't solve this, you're an engineer, see what you can do with this.' It was a metaphysical proof of Newton's Law of Action and Reaction, Newton's first Law of Motion: action and reaction are equal in the world and Kant has a metaphysical proof which is two and a half pages long or three pages long, and he says, 'I can't understand why he thinks he's proved anything. See what you can do.' And I took this problem and I spent a year locked in a room, I could not make head or tail of it. I could not accept that there was something too complex on the other side, not out of grandiosity, but there was something intellectual that was beyond my intuitive understanding. So I thought that if I read two words a day by the end of the year I'd understand – it didn't work like that, there was some primary concept that I was missing in order to understand this thing. So I wrote this agonised thesis, which I submitted after a year, and two of the three examiners couldn't understand it and failed it. Buchdhal wrote to a colleague of his saying, 'This is astounding, this is the way you're supposed to study Kant, you wrestle with it, you struggle with it, what could this mean.' My conclusion was that you couldn't prove an inductive law metaphysically and that is why it was so contorted, Kant was looking for a way to use the *language* of proof of something that could not be proven. But that is a very sophisticated thing for somebody who is an engineer, who is looking for a Euclidean idea, because the structure of it is Euclidean: proposition and then inference, conclusion and all the rest of it. And you can't see why he thinks he's proven anything. He uses geometry, he uses the fact that the centre of the earth would move if it was not the case, he uses all kinds of arguments and it's not clear how they are joined together. He uses Phoronomy which then was Kinetics. And so I wrote this thing and it was twenty thousand words, killed myself writing it, and two of the three examiners – one of them only read to page six and the other one read to page twenty-six, I know this because it was sixty-six pages long - and all credit to Mary Hesse who agreed to say, because my supervisor so strongly defended it, that it should be published and she would help me get it published. So I met with her, we went through the thesis and suddenly she got very, very excited, she gripped the page and she said, 'that's pre-Laurentian , that's pre-Laurentian ', and I said, 'you haven't read this, have you?' and she said, 'No.' She hadn't read to page sixty-six. She hadn't seen that the whole business of absolute and relative space was dealt with in the proof. So I walked out. [laughs] So that was the fate. That was probably the most intellectually challenging thing and probably my finest and greatest achievement was trying to prove this thing and not cracking the fact that it couldn't be proved. You had to step completely back and say, what is it you do when you prove something, where does the justificative strength come from? You couldn't prove that empirical law was metaphysical, you couldn't say, the reason the way world is, is because of the way we perceive the world. There is something out there that is independent of our perception of it. We can't construct the world as we wish, there is something that we receive from the outside world, there is something, there is input that structures our minds. So you can't metaphysically prove something true of the world. I mean, it's as simple as that. But he did because it was part of the architectonic of his epistemology and so I had to learn how to take all these steps back to see it as a discourse that was bounded by something else that would render it intelligible. So that was a fantastic discipline in doing something massively complex for which there was no known answer. And that's actually then why ... and to which I found most natural, in fact, trying to solve problems to which there are no answers and I have other examples, like working from first principles to solve things that have not been solved that [people] gave me the problem because they couldn't solve it. There were at least two or three other instances of that which showed me something about myself: one is I'm not brilliant, I'm very methodical and I need to understand, or I understand it, and it's that systemicity, there are people who are vastly more brilliant than I am, I'm not brilliant, I'm not a creative inventor or engineer, but what I build will last forever because I'm thorough and there's a reason why which we'll come to later, about why you build things that last forever in the Science Museum.

00:53:34

And then you moved to the University of Essex in 1974.

Yes. Ok, I did history and philosophy of science and I did this thesis on Kant, metaphysics, when I read Kant I felt he was talking to me. I was asking, what is it you do when you do science, what kind of discourse is scientific and engineering discourse, that's what they – Descartes and Kant - were talking about, this is what they were addressing so to me, my question is, what are the presuppositions of these activities, what is it you discover, where does the privileged access to certainty come from? This was completely natural. While I was at Cambridge I was also consulting, I had consulted for Atkins in Epsom which is a famous consultancy. I was looking at mini-computer applications in the medical environment and I did a survey, I travelled around the country looking for opportunities for mini-computers in optimising lift movements or whether you're doing it for clinical instrumentation and so on, and wrote a report. Now, the report hadn't been finished or there were some extra things to add on, so I was still attached in some very loose way to Atkins, and there was a conference at Wadham College in Oxford and I attended it because it was to do with mini-computers, small digital computers, and there was a chap called John Gedye who gave a lecture and it completely blew me away because, at that stage, computer facilities and the abilities of computers were pretty feeble and the idea then was, in artificial intelligence, that if ever you were going to have an intelligible conversation with a computing machine you would have to teach it English and it would therefore have to have enough memory for the entire vocabulary, it would have to have superordinate xx software to handle issues of parsing, of grammatical rule, of syntax and all these things. You would have to basically teach it to be like us before you could converse with it. And this guy completely, in the most brilliant way imaginable, completely bypassed all this and used the little digital computer to do rather extraordinary things. What he did was, he wanted to use people's language abilities to map certain psychological patterns, but if you interview somebody the computer has to have the linguistic ability – it was not unlike Weisenbaum's Eliza. Eliza doesn't know Rogerian xx psychology but it can actually mimic it very clearly but it doesn't know how to speak English, it doesn't know psychology. What it knows is that there is an algorithm that you can program and it will allow you to believe, would allow you to interact with it or whatever. So, what he did was ... the machine had no vocabulary ... what he did was to try and map word maps. So, if you were an obsessive everything I tell you will come back with the same response. Say you're obsessed with knives, I say 'cheese' you'll say 'knife', I say 'victim' 'knife'. Right. An obsessive has a particular verbal pattern and what he wanted to do was to map people's verbal patterns but he didn't have a computer that could do this, it was in the early seventies. What he did was, feed the word back to you, so he would explore your verbal space so that you would say a word, he'd give you the word back, right. He'd take another word, that's another word for computer, and he'd map that space. Now, at some point you're going to start recurring, now, how frequent are those loops? How big, in a set of associations, ... and related, and this is symptomatic.

The point about it is, you were interacting with a computer, using English as your natural language to a machine that had no knowledge of any of it and was producing intelligible things. To me this was genius because up to then computing power was pretty limited. So I went to speak to him afterwards and said, you know, ‘You blew me away, can I come and work with you’ [laughs] and so I kept in touch with him while I was at Cambridge, and when I got into Cambridge I thought that if I produced a brilliant thesis I would be given a fellowship. The world doesn’t work like that, I mean I was a nincompoop, I knew nothing about politics, I had no plan, I didn’t know a year before you’ve got to start applying. You had to have some credentials before you ... I didn’t know any of this stuff. I thought that if I just worked hard and gave this thing in a week later ... So I had no money, I’d been living on my parents’ credit all this time, and so I applied to the SACSIR, the South African Council for Scientific and Industrial Research, and got a grant to work with Gedye on computer-assisted human decision-taking, how do computers help people make decisions, which was a kind of AI, Man-machine studies it was called at the University of Essex, and went to work with him. It was wonderful, he was an absolutely extraordinary guy, but left after a year to go to America, he went to Baylor College of Medicine in Houston and I was supposed to follow him and the visa didn’t come through and I was stranded in London, waiting to join him, and the visa was delayed and delayed and delayed until I couldn’t figure out what was going on, so I went to try and find out what was going on. It turned out that the visa had been sabotaged by the Head of Department who had run out of money and couldn’t honour his letter of appointment which I was actually entitled to sue them about. I had a letter of appointment citing a salary which was very meagre but that was what my future was supposed to be. And the way I discovered this was through a very, very kind-hearted person in their administration. I said, ‘Look, I’ve been sitting in London for six months waiting to come here’, the visa application’s gone and nothing has happened and I said, ‘What am I supposed to do?’ The conversation went on then she obviously had a lot of empathy and she said, ‘Look, I was instructed not to process the visa’. She wasn’t supposed to tell me that, so I confronted my supervisor and said, ‘I’m writing a letter suing them’ and he said, ‘Don’t do that.’ I was there typing the letter and he said, ‘It’ll do a lot of damage’ because of his relationship and so on, so there was politics that affected me. In the meantime, while I was sitting kicking my heels in London I needed work, I needed money, and I looked at the Evening Standard and there was an advertisement for a contract engineer at the Science Museum. It was a fixed period contract - this was June ’75, and they wanted a six-month contract to work on the computer gallery that opened December 16th, 1975 in the Science Museum. They needed an electronics engineer to design the exhibits for the [new] computer gallery. I had already been registered with an agent, a person who found work for contract engineers, I’d done some contract engineering through consultancy and other things, I supported myself while I was a student through engineering but, interestingly, because of my experience, my ten thousand hours building radios, I was quite a skilled wire-man and so the way I earned supplementary money in the holidays was to go to the agent and get wiring work, so I worked for Plessey, I worked for various people creating wiring harnesses because here was a craft, where pvc bends and you make harnesses and terminations xx – all my childhood things. I had no training as a wire-man but I was probably one of the best wiremen there. I’d worked with the stuff since I was a kid. So I went to the interview and he plopped a circuit diagram in front of me and he said, ‘What does that wire do?’ And I looked at it and I said, ‘Well, that’s obviously an external input into a voltage device, it’s an external device which is controlled.’ And he said, ‘Right’, so I went to the interview and this chap called Arthur Rowles who was head of the department, and I went there and told him what I’d done, and he hired me. And I said, ‘when do I start?’ and he said ‘Now’. He took a punt on me, he saw something in me that was worth it, he took a risk on me. You know, when I walked through the door, I’m South African, I don’t come from round here. I said, ‘Look’ ... you know, I’d done six years of uni, I’ve been building things since I was a kid. But I don’t know the source of supply [of components], in South Africa I know where to get things, I know where to get components xx, and he said ‘That’s not a problem, we’ve got components suppliers and so on.’ So I worked for six months designing exhibits for the 1975 computing gallery which opened in 1975, end of December. We worked hard and I loved it, I couldn’t believe people paid me for it. I remember walking down Exhibition Road outside South Kensington, having struggled with philosophy and having bent my head round the stuff, that was the worthwhile stuff, to solve problems and I thought, ‘I didn’t get paid for that, and I walked downhill and thought of all the stuff I didn’t do, and they’re paying me.’ It was extraordinary.

1:02:58

What was your favourite machine in that exhibition?

My favourite machine in that exhibition was a way of showing the public how a hierarchy of interrupts work. So you had a separate processor with a computer, and you had a whole series of peripherals, and depending on the needs and frequency of each of these and the priority that each of those peripherals had, they were given appropriate and preferential service, and you did that by having lines of LEDs, so that when this thing requested attention it would signal and the line with the signal would go back and you wouldn't necessarily spot it. Maybe you spotted something else first. I think that was probably the one I remember most clearly. There were many others but this was the one that I thought was a really visual way of showing how a priority interrupt works, to somebody visually.

1:03:58

And you stayed in this role of electronics design engineer 'til 1983 at the London Science Museum, so your contract was renewed?

I worked by the hour, what's called OPA, Outside Professional Assistant – I was paid by the hour for seven years. I did consultancy in parallel with that and I came to the conclusion at the end of that that, when I was fifty I didn't want my relationship to my host organisation to be primarily a commercial one, I wanted to have something much more dimensioned. I didn't want the measure of my value to be primarily a commercial one, I wanted to belong to something. I wanted to be part of some bigger enterprise than making devices so what happened was, the transition from being an engineer, an OPA paid by the hour, I took a half-cut in salary because I was paid by the hour but not paid for holidays or benefits or anything, and the joy of this was I didn't realise what a wonderful thing it was to be in the Civil Service in terms of pension schemes, I had no idea, I didn't even look at xx my pension for another thirty years, but I was pretty pleased that I had done, but it was not a knowing thing, I had no plan, I just wanted to work in the Science Museum. And because I thought that I wouldn't be able to run a car, because of the drop in salary, I went and bought an expensive bike. The first day of work, I got up at six in the morning to get to work in time, and I cycled and I got there at twenty past six. I had absolutely no idea .. to me it was going to be a huge odyssey to go not by car and I got there.. So yes, that was a complete cultural change, from being an outsider. The beauty of being an outsider, I gave complete attention to the project, I'd no internal politics, I'd nothing to manage, I only designed exhibits, and exhibits I'm really proud of. How do you show why particular buildings in an earthquake fall down. The exhibit had been built outside [the Science Museum and] it was catastrophic and I used all my control engineering facilities to stabilise this thing to show that the extent of a building's excursions, vibration, is to do with its resonant frequencies and these can be controlled, but you had to demonstrate that so you have a platform moving with models of buildings of different resonant frequencies and you can see that one is going completely crazy and falling down, and the other one is stock still, and then you cycle it through the resonant frequencies and the buildings vibrate differently. I loved being the interface between the physical principle and the visual intuitive understanding. Echo-sounding, sending a signal down using rows of LEDs jumping, bouncing up, ... so I had a wonderful, wonderful time. Here was somebody whose earliest memories [were] of designing things, and [here] I was designing things, building them, commissioning them, installing them ... Yes, so I joined the museum. I was interviewed, it was a full Civil Service thing, there was no preferential treatment, it was an open competition, and I was awarded the thing. They asked me at the interview, as an example, of how you would give an example of an exhibit. It was something to do with architectural acoustics, I think, and they said, 'How do you explain to people what the reverberation time measurement is and how this would work?' and I said, 'Well, what I would do is build a scaled down model of the theatre, of the concert hall, and scale up the frequencies in proportion to the physical scale down and then have a travelling microphone in all the seats to see where the blind spots were.' It's a bit like Dolby, you scale the frequency up to reduce the physical scale of the phenomenon, and I think that probably got me the job. So it was devising exhibits, how do you convey these things which I then spent doing for the next twelve years, designing exhibits of this kind. That was wonderful stuff.

1:08:13

That was in 1983?

Up to ’85. In 1983 I became Section Head, I took over that group. At that stage there were four technicians. Nobody had ever counted how many exhibits there are, nobody had counted what complexity are they, nobody had counted what human resources do you need to maintain x number of working exhibits, so I did the survey and used it as leverage to recruit more people. There were six hundred working exhibits in the Science Museum with four technicians. The museum had an international reputation for being the push-button museum, and the biggest issue was reliability, because you couldn’t possibly police six hundred exhibits by doing a tour and . . .. So I wanted a centralised ... fault-monitoring to be centralised, and I produced all the quantification of how many people, what level of complexity, how many were the minimum complexity, how many were top complexity, I did sort of, not a time and motion [study], but analysed how long it took to design an exhibit of maximum complexity, a second-tier exhibit and so on , so that I could evaluate, when somebody, a curator, came with an exhibition they wanted instrumented, what resources would we need. So nobody had ever done this before. What I did there was ... so because there were four technicians and, as an engineer, if you design something, put it in the gallery in the public exhibition space, you can be absolutely sure that the designer made no provision for that equipment, either to house it in a place that doesn’t cook and get hot, or to get access. So you’re crawling on your knees in dusty cases behind the public panels to fix anything that broke, that is why I designed things that never broke. I designed things that were self-restarting, that had self-correction in them, that monitored themselves, that re-booted themselves after every operation so that the program was always refreshed, developed a complete set of techniques for unattended continuous operation in public environment - the techniques for continuous unattended operation in public environments - so that I would never have to crawl around replacing light bulbs .. so developing techniques - how do you make a light bulb last longer? You under-run it, you put a, what do you call it, bleed current through the thing when it’s not working, there are various techniques for doing this, so that it doesn’t experience a magnetic, an electrical shock, not to switch on when the filament is still cold, simple as a minute thing like that. How do you make a filament lamp [last], because there were no LEDs in those days. So the bedrock of those techniques were to get by with fewer technicians and a reporting system that doesn’t rely on humans. And I carried these documents in my inside pocket of my jacket and when I met the director then Margaret Weston who was a wonderful person, who had recruited me actually, and when I met her at an official do, I said, 'Look, we need new technicians, I've done all the analysis of it, we've got six hundred exhibits and you've got four technicians, we need another four.' And then she said, 'so how many do you need', and I said, 'Here's the documentary evidence', and she said, 'How many do you need' and I said 'another four'. She said, 'You can have two' so I said 'ok'. [laughs] So there was also politics. How do you exert leverage, you need statistics, you need a case, you need to present it and you need to have a passion for the outcome, which was 'How do you not make visitors disappointed by the fact that the exhibit doesn't work again'. So that was it.

And in 1985 you curated your first exhibition at the London Science Museum. The title was 'Frontiers of Chaos' and it was about the use of computers in experimental mathematics and fractal art.

Ok, there's a big transition in there, although you have said that as though there was a kind of continuity between engineering work and this work. I did that work in the capacity of a curator and there is a profound cultural difference between being an engineer and being a curator. One is an internalist discourse, you can make it externalist by talking about public and locus of perceptions and all that stuff and contrast-blindness and all these things in the perception of the exhibits, but there is a fundamental difference in the nature of the discourse of engineering which is internal to do with the grammar of electronics, how do those devices work, and you have to subordinate your mind to how it works. It doesn't know how you think it works and only works the way it works. You may think it best to capitalise a letter and if you haven't it's not going to capitalise. It isn't what you think it's going to do and competition squash is much the same. The reason I played competition squash was I wanted to root myself in reality, the ball was not where you think it is, the ball is where it is and it's for you to find that out, and you can't strike the ball, same with karate, you can't mistake, you've got to read the intention to see the outcome. So, there was a philosophy, an essential philosophy in these things. Now, the thing about engineering is, it's narrow. I was privileged and honoured and hugely fortunate to work [as an engineer] in the Science Museum which has an educational mandate and use electronics in an environment that was richer than electronics. So I could get involved in the exhibits. But I wasn't authoring the exhibits because the curators authored the exhibits; I was implementing them. The difference between ... the first exhibition I curated was in the capacity of the curator. What happened was, the existing curator of computing, a man called Oliver Strimpel, who was a mathematician who was a curator in computing, went to Boston on secondment, he was still Science Museum staff and he went to curate the Boston Computer Museum under Gordon and Gwen Bell who were very famous, the first computer museum there which started with the material legacy of DEC, the Digital Equipment Corporation which Gordon Bell was a hugely distinguished leader of. So the post was vacant and they filled it provisionally for a year, and then after a year he wrote back and said, 'Could I stay another year', and then at the end of the second year he said, 'Look, I'm not coming back.' So the curator of computing post arose in 1985 and was publicly advertised, and I went to the people I'd worked with and asked, what do you think I should do. There was a kind of bemused encouragement and the advice from the person I most sought his advice of, because I worked with him more than anything, he said, 'One of the strengths of this institution is that it can tolerate people like you' and that was a very double-edged thing. I didn't fit the mould completely because, growing up in South Africa, I didn't have a feudal idea of my position. I didn't see myself as part of a hierarchy, my life expectations were that of a privileged person, I didn't recognise there were any limitations to what opportunities there would be, I'd not experienced that. In England I found it very different. People were very aware of their place, they were marked by their accents, they were marked by their education. Much less so now, thankfully, but at that stage there was still, I still call it a feudal environment, and so being an engineer is almost a second-class profession because engineering is not a controlled usage of term, it's not a registered term. Anyone can call themselves it. A plumber, untrained, is called a plumbing engineer. Ok, the British Computer Society does as much as can be done to regulate that or give it some formal dignity, but whereas a curator in English culture is a gentleman's job. This is a culture thing, and the point about it is, curators for me, I was in awe of them, because they knew about culture, they knew about history. I was an engineer, and as an engineer I was deeply ignorant of things outside engineering. And so I was awed, but what I didn't know I was a better qualified curator – I'd done history and philosophy of science – a curator of physics in those days was a physicist, they hadn't done philosophy. A curator of medical sciences had been a doctor. And here I was, I'd been in Cambridge for two years studying metaphysics and philosophy of science, that's exactly what curators, you know, what of the presuppositions of this discourse. So crossing the tracks from being an engineer to being a curator is a fundamental thing in this culture, possibly in other cultures but certainly in this one. So, the Frontiers of Chaos, I could not believe it ... so here I was, I took the job, I was interviewed again, seventy-two applicants, I was offered the post in a national competition, full Civil Service interview, four people, independent, one person was an external science examiner, a Civil Service person – four. I know this system quite well because I subsequently did a lot of interviews through the Civil Service in the recruitment process. What they do is that the Board meets once and they rank order the candidates and then they disband, they never meet again. They offer it to the first, if the first can't or doesn't take it they offer it to the second, and I was the first. They offered it to me and I couldn't accept it because I hadn't yet been naturalised, and because you were a quasi-government you were part of the Civil Service in the Science Museum, only a Brit can be a part of the Civil Service. Now, I was eligible and my application was in two years previously but I couldn't accept. So, the Home Office was wonderful, they were approached and they fast-tracked me, and six weeks later I was naturalised, I was eligible and that was in process and whether the two were connected I don't know, but I was hugely grateful for the fact that I did not have to pass this opportunity up. By that stage I was what, thirty-five or something, in my thirties, I had been an engineer for twelve years, I'd consulted, I had mastered TTL. TTL was a second language to me, transistor-transistor logic, medium scale integration, and I knew what it was like to master it ... CMOS was coming in, I would have had to master CMOS to carry on designing. I knew what it was like, I didn't know particularly a lot about CMOS but I knew what it was like to know that stuff and it would have been more of the same and the question is, do I now take the opportunity. So again, history and philosophy of science was a completely accidental crossroads which I recognised as a turning point and seized the opportunity. It was like an intellectual homecoming, doing metaphysics, it was like they were talking to me because all those guys, those, Descartes, Kant … were worried about, what is special about science, what is special about the logic and discourse of science and engineering. Is order inherent in the world or is it something we provide and supply and project onto it? Well, Kant has got the most exquisite explanation of that. So, to cross from being an engineer to a curator was such a fundamental change it was glorious, and the first exhibition, within weeks of taking the post, was Frontiers of Chaos, and I went to Imperial College and spoke to people about ideas. Because I was a curator, I was therefore the editor in a sense, and I had to be responsible for the message between the experts – I was the interface between the public and the experts. And that transition, how do you make arcane things intelligible? And being stupid, and I'd say I'm stupid, I can only understand if I understand each element in a progressive way, and I assume that is what other people need to know. What question would they have asked? What question did I need to ask before I knew even how to ask the question? And when you answer that question without the person asking it you you've got their confidence that they understand where you are, and all my design philosophy of interactive exhibits was, where is the locus of their attention? You never do two things at once on a screen, you have to direct the attention to one thing then it happens. You create an expectation then let it happen. The analogy I gave when I later taught at the Royal College of Art and so on was that, you think of the attention, if you imagine a wire stretched on a slight incline and there's a drop of liquid at one end, and the liquid will run down the wire. If the wire is absolutely true and straight the drop will get to the end; if there's the slightest roughness, the slightest contraction or narrowing the drop will drop off. The drop is the person's attention. You have to take it and you have to not let it go. If there's a word that is unclear, that they don't understand, if there's a word that is vague, if there's an ambiguity, the drop drops off, you've lost them. It's a struggle for them. So how do you minimise the effort of attention in the visitor looking at an exhibit. So the exhibits were designed, the label you write is exactly the same, if there's a word that is unclear, if there's something that isn't common currency, you've lost them. So I developed, you know... this was a philosophy of interaction, and that is to do with, as I say, being stupid, there's a benefit in being stupid in this way. Because I'm saying, how do I explain to someone who doesn't know what I know, what is it they need to know to understand what I understand. So I'm not talking to someone ...now when you read a lot of user manuals they're written by programmers and people who assume they're talking to people who already know it and that this is confirmatory. So there's a completely different discipline which is why I was so intrigued by the Royal College of Art, being a visiting professor there, in the interaction of design, because I had spent an appreciable part of my life in developing techniques to articulate and to formalise the principles on which you would base a successful interactive exhibit. So, all this is to do with crossing from being an engineer to a curator, is the most massive intellectual, cultural shift because the discourses of history and ideas is completely different to the non-verbal. You can design without ever explaining what you've done, you can design an electronic exhibit which is why writing a user manual for an electronic exhibit is completely different. Now, at some level, if you build something that works you understand it in the profoundest possible way. It doesn't mean you can either explain it or you can talk about it. So writing a user manual is a completely different exercise; you're understanding it in order to disseminate and that is a completely different discipline. So becoming a curator, which is to develop a discourse of interfacing, arcane internal stuff, right ... beyond a certain point integrated circuits used components that were smaller than one micron. You're expected to know that a micron is a small thing. How do I tell you how small a micron is? You say, well, it's one eightieth the thickness of human hair. It doesn't mean a lot. If I tell you a micron is the length that your fingernail grows in ten minutes then you've clocked, yuh? So that's what I'm looking for all the time. How do you convey this? How do you explain microns in terms they understand. They don't know human hair, they may not know it's 80 microns or whatever it is, so many molecules, so to me that's what was going on, that was the satisfaction of closing that loop. Now, once you've closed that loop with a person you've got their confidence, that they're in good hands, and they will relax and listen to what you're saying, listen to the exhibit you've designed, so when I say, on the screen it says 'don't press the button, just look at the spot you can see now, then put your left hand on the button, press it and see what happens.' You see, they know where I [visitor] am, they knew that my attention wasn't there, and then you've got them, you've captured them, they're confident that they're in good hands and they're in the hands of somebody who will lead them, and that is in everything. You know, you pick up user manuals and, forget it, you need a pilot's licence to drive your car now, you know. Extreme example, I went and bought a car, always a second-hand car, I never bought a new car, and it was the right car, we'd done the research, and said, right, 'tank's empty I need to drive it away now', and they said 'there's a garage up on the corner'. So I went to the garage and the question is 'how do you open the flap on the tank?' I am the new owner and in the glove compartment there is a user manual with everything, and I look up, 'How do you open the tank?' There's a beautiful picture of the knob you push, the knob you pull to open the flap at the back so that you can get access to the tank. It doesn't tell you where the knob is. It's a beautiful picture, contrast, it's modelled, the lighting is excellent and it's sharp, but it doesn't tell you it's in the door. So normally you open the back, like something under the dashboard. I was there for ten minutes. An example, there was somebody who did try, they'd put a picture of it, but it didn't tell you where it was. So, who put themselves in the situation, somebody driving the car for the first time, so in documenting the Babbage engine which I'm doing now I'm putting myself in the situation all the time of facing this thing, I've never seen it before, what question to ask. For instance, it says 'turn the handle clockwise', well, I also want to say, well, what do you expect to happen? Right, if I turn it anti-clockwise it's going to damage it. So you say, there's a ratchet on it, you can turn it anti-clockwise, not a problem, you will hear a clicking sound, they trust me because there's an anxiety, if I turn the handle, what happens if I turn it the wrong way? So there again, you know, the whole thing, it's not something, the smallest, narrowest window I had to use it in that stuff was the Royal College of Art and there wasn't very much of that. So that whole era has sort of, not gone down the tube but it's something that wasn't formalised in the way that other people knew, but it's inherent in all the things that we designed implicitly.

1:27:06

So after Frontiers of Chaos?

Ok, so I did Frontiers of Chaos, I could not believe I was being paid to talk to people about ideas. This was just divine. I could go to Imperial College and talk to mathematicians about fractals, I could not believe I was being paid for this. You know, I kept going back, thinking I should be doing something, this was just exquisite, this was just glorious, I could not imagine anything better. So I became a curator. As a curator you inherit collections, so I was now the curator of the computing collection which was originally part of the mathematical instruments collection but it had been separated out. The prize artefacts in the computing collection are two categories: one is earliest prototypes of electronic computers, late forties, early fifties, and Charles Babbage's, all the relics, all the significant relics of Charles Babbage's efforts to build mechanical computers in the nineteenth century. And these had been on display, I had seen them many times in the galleries, and I inherited all the departmental books, and on the shelf were books about Babbage and the history of computing. So I was six weeks into the job and I started taking these books down and reading them, and I was reading about Babbage because I needed to know about Babbage, I'm responsible for Babbage's artefacts and I better find out about it. And I'm reading it, and finding it very interesting, and as I turn the pages and it said that he failed to build any of his engines. Babbage failed to build any, he was a genius and he had invented computers but he failed to build any, so I kept turning the pages, and the reason given – 'limitations of nineteenth century mechanical engineering'. It was stated, or implied, they could not make parts with sufficient precision for the machine to work. So I kept flipping the pages and, ok, when the precision was available did the engines work? In other words, was the engineering difficulty concealing, or masking, a logical impossibility with his designs, was he a nutter, was he an impractical dreamer or was he a designer of mechanical logic? And I flipped ahead to see what was the answer, and there was no answer, nobody had ever picked the question up. And within weeks or days of that thought – why hadn't somebody built an engine? – Allan Bromley appeared on my doorstep. I remember it absolutely distinctly, I remember the scene absolutely distinctly and I've described it in the book, 'The Cogwheel Brain'. I was sitting ... my office faced north, opposite the Queen's Lawn, Imperial College. So it was a dark office, and there were trees outside, plane trees all down that whole area, and there was dappled sun on my desk, and on my desk were the printouts of the contents of the museum's computing collection. I had never visited the collection, I was a new curator, and I went down and I tried to visualise what these things were, and I was aware of a movement to my right, which is where my door was, so I turned and there was this man, in a waistcoat with a big smile and a beard and a piece of paper in his hand. This was Allan Bromley. He was visiting, he visited every summer, I do remember this, he was an Australian, a computer scientist, and he visited November, December every year, to study Babbage's drawings, and in his hand ... first of all, he introduced himself and he said he had been studying Babbage's drawings for all this time, and he believed that Difference Engine No. 2 could be built ... in his hand was a proposal addressed to Dame Margaret Weston that the engine be built in time for the bicentenary in 1991 of Babbage's birth, 1791, the date of Babbage's birth. He had come to introduce himself, since I was the new curator of computing and the custodian of all these artefacts, and that was the start of it, that was the start of the whole building of the engine. So for the next seventeen years, in addition to everything else I did, which was curate exhibitions and all that stuff, and manage all that stuff that one does in a job, I picked up the challenge of getting the engine built, of building Babbage's Difference Engine No. 2 which would be the first complete engine built to Babbage's original designs, and we completed the calculating section for 1991, which drew international attention, there are some wonderful stories about the final unveiling, and then subsequently, eight years later from 1991, in 2002 – oh, it's eleven years later – we finished the engine by building the output apparatus which is an integral part of the design but for which we did not have funding or time to complete for the '91 exhibition.

1:31:51

One step back, so a lot of things happened in 1989.

[Laughs] Yes, what else happened?

In 1989 you founded the Computer Conservation Society.

Right. As a curator you are responsible for the national computing collection and the point is that no single person can be aware of the whole field and the point is that it is people's individual experiences of particular machines that makes them meaningful. Computers in general as a generic category but what actually engages a person to a machine, what actually attaches a person to his experience . . so I'm hugely grateful to people in the industry because they educated me. They would come to me and say, 'You have to save this because ..' and I'd say, 'well, why is it significant?' and they would tell me. There's no way I could have known that machine was significant, I'd never heard of the machine. They'd come and tell me, this is significant because, this guy did it, he did this and that, and *dedumdum*, so typically I would get a phone call, usually on a Friday, from some desperate person in the middle of nowhere saying, 'Hullo, I've been running this machine for twenty-five years, I've just been told it's being bulldozed, the building's being bulldozed next Wednesday, and this machine I've worked on for twenty-five years and it's a wonderful machine and do you want it, can you take it, can you save my machine for me?' And I would go into the middle of nowhere and I would meet this guy and he would explain the machine to me, show it to me, I would be looking at it, I'd consider whether to acquire the core store, the memory, is it visually interesting, what do you do, all these criteria of acceptance and meaning and significance, and make a decision about whether it was historically valuable to get. And as I would leave he would pluck my sleeve and say, 'Look, if you want to exhibit it I'll write programs so you can show it working, if you don't, what would you do? I said 'put it in store', and he'd say, 'could he come and visit it' like he was dealing with a relative, and he was talking to me as though he was talking about a relative. And when I left that one encounter, and there were many, many like it, I realised, these people are isolated, they have massive expertise, they have huge goodwill, they need meaningful work. I don't mean work in productive work, they need meaningful engagement with their expertise, but they didn't know each other existed, so what we needed was a social organisation, a club, where people from the IT industry and the computing industry could share their meanings of their professional experiences and their personal experiences. So the seed of the idea of the computer conservation society was to create a social organisation that would marshal and harness these people and create an organisation that they could join. There was another major factor ... so that's what was buzzing around in my mind ... that the bicentenary in 1991 of Charles Babbage's birth was to have been the new computer gallery at the Science Museum, and we had a complicated system of funding that was doing it and I was leading the project, and we had the Ferranti Pegasus in the collection, the NRDC 401, these are early vacuum tube machines, and we had early machines in the collection, I'd collected totalisators, I'd collected a Phillips Economics Computer, an analogue computer. Dog track, totalisators were huge electromechanical systems, we had all these things, and as an engineer I'd never questioned, I'd never asked anyone, does the museum .. the museum had an international reputation for being the push-button museum, you went to the museum to see things work. My first experience was Keith Geddes's array, of working with this thing, the propeller turning. It never occurred to me, I never even questioned the question, do you want these machines to work – you've got to have working computers, all working computers in the computing gallery. Where's the expertise? It's obviously not in the museum, and that's no criticism, there's no way the expertise can be there, the expertise is the people with the handson experience, people who have designed, the practitioners, the maintenance people. That's where the expertise lay. So I needed a group of people that could restore to working order the historic computers in the computing collection for exhibiting in the exhibition in 1991. So, connecting these two things, these isolated people without organisational coherence and the Science Museum and my needs for working exhibits, using and marshalling the expertise. So I went to the British Computer Society and produced the proposal and I gave a presentation at a meeting and gave examples of the kinds of exhibits I wanted to design, many of which I still remember, and said, ‘I want to found something called the British Computer Conservation Society’ and they said, ‘Well, we have a specialist group arrangement and so you wouldn’t need the word British because it’s already the British Computer Society’. The upshot of it was, Roger Johnson was at that meeting and he was a huge supporter from day one, and Tony Sale was present at that meeting, because he was the technical officer for the BCS at that time, and I told him what my philosophy was and why we wanted working exhibits and what the principle of all this was, and gave examples of things, and one of the examples I gave... I tell this story against myself ... I don’t know whether you remember there was a big public outcry here when Prince Philip’s – it wasn’t an email address at that stage – Prince Philip’s [Prestel Viewdata] mailbox, his online mailbox, was hacked, and this was scandalous because this exposed to the public the cyber security issue. One of the exhibits I designed was to challenge the public to hack this, and that we would arrange with Prince Philip to send a message back if they could, and this was a test so that the cyber security industry could demonstrate what confidence they had in their [online security]... of course, it was completely the reverse, they had no confidence in it, they had very little confidence, and so, as I described this exhibit, that this would be heroic to be able to crack something to show to the ... if you couldn’t crack it this would be of huge credit to the cyber security industry and I saw these pursed lips and the committee chairperson saying, ‘ I think we should probably leave that one out.’ [laughs] I mean the security at that stage was so ropey. So, at that meeting, and I remember not Tony Sale personally, I remember the presence of Tony Sale there, I produced this presentation that was favourably received, Roger was a huge stalwart supporter of the idea, and two or three days later Tony Sale came and visited me in the project office which was in one of the huts, in the car park of the Science Museum which I’d commandeered to put my research team in and he came in there wearing a brown raincoat, a bit like Colombo, and said, ‘I was at your presentation, you pushed all of my buttons, I want to come and work with you.' That was it. So I had funding for the exhibition and so I created a post for him to make the Computer Conservation Society, to assemble this group of people that would restore these things to working order and he just took off, absolutely took off.

1:39:28

What about the Ferranti Pegasus?

Ferranti Pegasus was one of the first, if not the first, it may have been the first, computer we chose for restoration to working order. So it was moved to what was the Old Canteen, it was called, because it was originally the canteen but it had been abandoned, so that I managed to commandeer it, and used it for our working and laboratories, and Pegasus I think was the first.   I think Pegasus was the first major machine that we restored to working order. There's another significance to Pegasus, particularly to the Computer Conservation Society. Pegasus became the flagship project for the society because we didn't know whether you could restore these things to working order and we did, we succeeded. And so it was a huge staging post of credibility and confidence that this programme of restoring old machines to working order was viable. So it was terribly important. You know, Pegasus, there's a special affection between CCS and Pegasus because it was the first and it proved that we weren't completely off beam.

How long did it take?

Not very long. The big issue was cooling, it was refrigerated but the original design did not have cooling so it could be run without it. It didn't take years, it took months, as I recall.

And in 1992 you went to Siberia to acquire the BESM-6 for the National Museum of Science and Industry, which was a bigger network of museums which London Science Museum is part of.

Yes, the Science Museum is, sort of, they don't like seeing it this way, it's the kind of headquarters for us in London, then there's the Railway Museum in York, and what was then the National Museum for Photography, Film and Television, as it was called then, I think it's now called the Media Museum.

In Bradford.

So those are the three museums that are part of the Science Museum Group. They were called outstations in the old days but, of course, now that everything has to be politically correct you can't diminish something provincial by calling it an outstation, so that they dropped all this language and they're now part of this federation of museums. And, of course, they were most recently joined by the Museum of Science and Industry in Manchester, so that is also now officially part of the Science Museum.

Ok, let's go back to your trip to Siberia in 1992.

Yes, we built the Babbage engine, it was a little bit under extraordinary circumstances in 1991, to the waiting public and all the television cameras, and it was a sensation, I mean, it was a sensation. I didn't realise how daft it was going to be, trying to do it, you know, I'd always built things, yeah, it was something that hadn't been built but we had the plans so we built it ... there was a more serious, the historical thesis was that, if the historical thesis was that the reason Babbage didn't build it was because he couldn't because of mechanical engineering, there was still a question of whether the machine would have worked, how important was engineering, and if we built it using precision not achievable by Babbage, in other words made it more precisely than Babbage could have done, then we hadn't proved anything, we hadn't proved that it was buildable in his day. So we didn't built it with a view to saying we know this will work because Babbage was a genius and we understand how it works; we built it to find out whether it would work and we took huge care to make no part more precisely than we know from measurements Babbage could himself have done. And the reason we know that is we did measurements on the parts that Babbage did build which we have in the collection. So, Difference Engine No. 1, the small piece with two thousand parts, is probably the finest example of precision engineering of the day built by Joseph Clement. If you want to know how precisely you can make anything you go and do measurements on that thing. So we measured that and the issue was repeatability. If you give Clement one part how closely can he make another part to match. What would the tolerance be?. What would the difference in the two dimensions be if you gave him a part to make? Now, they had no methods of production that had inherent repeatability - like casting, uses the same moulds and the casts are near identical, stamping, the same punch - so, the idea of tolerance did not exist because there was no standardisation. You couldn't make a nut in Manchester and a bolt in London expecting them to fit, because the lead screws on the lathes in the workshops were different, they were hand-cut. So, the question was, how do we methodologically and with due respect of authenticity build a machine using modern technology if we build it more precisely than Babbage could have done, so what we did, we made absolutely sure, we made no more precise a part, we made no part more precisely than was achievable by Babbage using possibly different techniques, so we unashamedly used numerically controlled computers and CAD systems, but made absolutely sure that the tolerances were poorer, were sloppier than Babbage could ever have done. We also used materials that we knew were available to Babbage and we did composition analysis on the bronzes, gun metal and bronzes ... gun metal, the steels, irons, to make sure that we got the best possible modern match, so that we could not be charged with saying that, ok you didn't prove, disprove any historical thesis because you built it but Babbage could not have. So it wasn't an antagonistic or an adversarial relationship to history, it was more us making sure that what we were doing was as meaningful as it possibly could be historically, so that was that whole exercise. That was in 1991, then, you know, I was a curator throughout this period receiving offers of equipment, historic computers and managing the collection's acquisition and all that stuff. During that period we acquired the Haringay Totalisator which was a magnificent system, the last big one of its kind, an electro-mechanical system for managing bets on dog races, dog tracks, which I've just written about. So, one of the things was, at that period was *Perestroika*, the Iron Curtain was disintegrating. Western computer scientists, computer technicians, practitioners, professionals, had access to labs and businesses in Russia from which they'd been precluded up 'til then, and they were coming back with very strange tales. They said, there's this blinking computer – I mean literally blinking, the lights were flashing – operating in half-darkness in Siberia, and it outperforms any Western supercomputer. They were saying, there's a supercomputer from 1963 which outperforms the

CDC6600 which was one of Cray's first supercomputer designs. Exactly contemporary, '63. And they said that the BESM-6 – this machine, they [the visiting computer people] didn't know it was the BESM-6 – they said the Russians are telling us this outperforms contemporary machines in the West. I didn't know what they were so how could I not go. So I went to Siberia on a foraging thing, I didn't know what I was going to find, and it was an absolute education in all kinds of ways. Because of the way in which PCs were then – I think it was '91 so four to five years into the PC era – I was interested in how available were computers for home computing, how available were computers to students, how recent, to what extent did their computer technology depend on Western developments. And the big principle was make or take, do you borrow or do you make it yourself. And the turning point for that, the BESM-6 was the last Russian computer designed in the Russian tradition. So this was the Russian supercomputer, every major software programmer trained on the BESM-6, and there was a BESM-6 in Siberia in the Institute for Informatic Systems , it was on three floors, there were three processors, full punch card systems, magnetic tape systems, and one of the problems was, that there were three of them running and two of them had been dismantled, and the reason they had been dismantled was, to get the gold from the [circuit boards] , it was 40,000 dollars worth of gold if you melted down the BESM-6. And there was one left working, and so the question was, how are we going to get this and stop them [melting down the last one], because this was foreign currency which during *perestroika* was invaluable. The actual title [legal ownership] of these machines is very intriguing, they were paid for by the State, this was now 1992 and these machines had been written off as of no value years ago, the question was who owned them. Who was able to sell the machine? Now, the Science Museum cannot acquire an object unless there is clear title. It cannot acquire an object unless it has clear legal title, it cannot possibly expose itself to any future claim that the person who sold this machine doesn't have entitlement to it. And because this was a fuzzy area, and was under argument, we could not buy the machine from them. But what we needed to do was to pay them the equivalent of the gold value to stop them dismantling it. So I got approval for that and went out there and we successfully negotiated three euro containers' of equipment with enough spares to reconstruct the machine, because what I wanted to do was for the Computer Conservation Society to restore this BESM-6 to working order and do an AB comparison with the CDC600 to see whether this was propaganda about these machines outperforming Western supercomputers or not. Wonderful historical experimental history. It didn't happen, I won't tell you why because it's too damaging to people at the museum, so I won't tell you why it didn't happen, but enough spares - the canvas for ducting the air to cool this thing was brought, all the spare cables were brought. The magnetic tapes and the programs were brought, spare tape platforms and handlers were bought, with a view to restoring the single one. So this was the only Russian 1960s BESM supercomputer in captivity in the West. But in that consignment there were other things because I went to ... my translator and guide was a chap called Leo Kusnetsov, he was a wonderful, wonderful guy who I'm still in touch with, and he designed a computer called Kronos which was exactly the same motivation for Apple. Nobody has ever heard of Kronos. Apple is massively successful. But the motivation for this, these were students who wanted their own personal computer, so they designed their own. And they had it in their houses. One hundred and fifty were built.

1:51:24

What year are we talking about?

They were still running when I was there in '92, and I documented the story at this time and I've never written it up. The stimulus for these kids to have their own personal computers was identical to what was going on in California and the 'home brew' thing, but later, slightly later. So I brought back various generations of Kronos motherboards and protographs of all these things. We went to a market and they said, for security reasons, do not speak English, do not try and buy anything. This was a dangerous place, in the snow, 'if you want to buy anything tell us and we'll do it'. And we went there and there is a Sinclair Spectrum, but it doesn't look like a Sinclair Spectrum, it's reverse engineered.. There was no disposable income, there was full employment, nothing to do in the factories, so what they did was make computers for sale on the black market. So they were reverse engineering the Spectrums, I brought back an AGAT, it was the Apple knock-off, the Russian Apple knock-off using the same operating system. So there's the Russian Apple copied from the American Apple which is AGAT, there's the Kronos which is an untold story of the personal computer movement in Russia which didn't come to anything, led by Leo Kusnetsov and his friends, Sinclair Spectrum reverse engineered machines . . . We also bought from the Institute of Informatic Systems various IBM things that they bought, huge tracts of memory, of core store that they used, and the big question is make or take, and the eventual machine was a Western machine, the one that replaced the BESM machine. So it was culturally very interesting, and I asked Leo, in the department ... and the PCs, you know, chunky PCs like the size of - unbranded but a PC like an original IBM PC - and I asked him, what access do people have to computers, do people have computers in their homes? What access do students have to computers? Where do these computers come from? He said, they're unbranded, they come from China, they're knock-offs, or they're over-production from some *whatdoyoucallit*, and so I said, what access do people have to computers, and he said, 'You see those bars on the window, and you see the spacing of the bars. The spacing of the bars is just too narrow to get a PC through.' So there was a massive public demand for personal computers, they were in departments and they had to protect themselves from disappearing, and the way that the home market was satisfied was through reverse engineered knock-offs of Sinclair machines and the AGAT, the Apple. So it was massively instructive in terms of an IT culture, what access did they have, did they want access to it, who controlled it, and what did these students feel the lack of. And, of course, *perestroika* was disintegrating, I mean, to get three euro-containers out of Russia in *perestroika*, where the structure was collapsing, was no joke, it was quite something to get them back, but we did and we got it all out and it all arrived. I mean, you know, the money, the way we did the title, we said, 'we can't buy a machine from somebody unless you can demonstrate title', and there was somebody, my intermediary with them, who was an English computer scientist and he said, 'OK, I'll buy the computer and you buy it from me.' 'I'll buy the computer and it will be my title, I will have the documentation, I will pay for it, I will have evidence of the transfer of funds, the machine will be mine and I will give you title to it.' And so that's how it was done. Now, the money went in dollars, which was 42,000 dollars for the Russian academic, I don't know where the money went, to the department or what, but there was a story which I won't tell about that, which gave me an insight into the difference between the Civil Service culture here which had phenomenal propriety and integrity. I was not allowed to accept anything that was worth more than five pounds or something without declaring it. There was no conceivable way, according to the Civil Service protocols that you can benefit by the project that you run. If you declare a conflict of interest then you will have nothing to do with it. It was absolute and you were fired if there was any question of compromise. These rules were known, it was part of the culture and that was the expectation. What this reminded me of, and this is not a story against the Russians, is that they wanted to be able to spend the money in the West. So they wanted to open an account in the West, which they were absolutely entitled to do as far as I know, but they wanted a way of somebody here that they could instruct to make purchases on their behalf. So they wanted to give me signing power over the account, and they offered this in a meeting openly so it wasn't a surrogate, this wasn't an underhand thing. So I said to them, 'But that gives me access to the money' and they said, 'Yes, that's the idea.' And I said, 'It's absolutely out of the question, there is absolutely no conceivable way the Civil Service, a civil servant doing their job, somebody working in a government context, could possibly benefit in any way at all by the project'. And because this was being done completely openly in a meeting it was not unusual for them, this was the way you did business. And I was struck then by the deep, deep morality of the environment that I had become part of, the public service ethos, and it's still with me today, to my detriment, because I regard, since I was paid by the museum and by the public sector, that my knowledge belongs to the public. I acquired it through being in a national Museum. That whole culture was so different, I mean you look now at the expenses scandal in Westminster and what's going on now, but you just think where were those days where there was integrity and morality and propriety. I'm not saying the museum is corrupt by any stretch at all, it isn't, by any stretch, but it is a kind of sanctuary of a legacy of that culture which regrettably in other areas of public service is not necessarily the case. And I was struck by the way the Russians did business, the only way they could get the stuff was in a collaborative organisation, they couldn't go to a railway person and arrange a shipper, you made arrangements and the less we knew about them the better.

1:58:32

And in 1993 you went back to university.

Yes. Well, I didn't go back to university, I [had] started doing a PhD. I'd always had an ambition to do a PhD, my father was a doctor and I never knew a Mr Swade. I only knew a male Swade as a Doctor Swade. I had no brothers so Mr Swade didn't sound right. That wasn't my only motive for the PhD because it's a kind of intellectual badge and the philosophical and intellectual side and the historical side of this field is something that deeply intrigued me. The whole business of building the engine was actually to examine through experimental history an historical theses that had been accepted for generations and that is, that the reason Babbage failed was because of the limits of mechanical engineering. Well, people who know about nineteenth-century mechanical engineering will know absolutely that you can make a part to any required degree of precision that you like. They would write on the drawing 'make to fit'. So you would fettle a piece 'til it fitted. You could make it as precisely as you like. The fact that there was no tolerancing, he didn't know how precise it was, it did not mean that you could not make the precisest thing to work. So what led me into history was the fact that the received perception of why Babbage failed was not tenable. You could make parts with sufficient precision, so is there some other reason that Babbage failed? Did the difficulty of building it mask a logical flaw in the design, or is it not possible to build logical devices with 8,000 parts, 25,000 parts. His first engine had 25,000 moving parts. The engine we built has 8,000 moving parts. Is it possible to build information technology, calculating devices, using other than an electronic medium, something which does not have wear and tear, possibly jamming and all these other things? So the question then was, what is the discourse that could address a question which is a non-technological one, or technological in the social context sense but not internalist. It's perfectly clear, you could make parts with sufficient precision, so you need a discourse other than a technological one to explain why Babbage failed. There were sociological factors, there was the social organisation of labour, no standardisation, Babbage's personality, funding, his relationship with the scientific community, all those things, and so history was the discourse I identified to solve the problem of Babbage's failure. So that's why I embarked on a PhD and it was to do with the utility of calculating engines. What made calculating engines desirable to possess in the nineteenth century? Not what made it desirable to us in the nineteenth century, in other words what we think made it [desirable], how did they think, why did they think machines were desirable in the nineteenth century. Of course, not everyone did and, in fact, Babbage's arch rival George Biddell Airy, the most prominent civil engineer of his day, was absolutely articulately and vehemently opposed to the utility of engines. He said it was bonkers, that mathematical tables are sufficiently accurate, that the investment in doing so would be better spent investing and using the dividends to pay human calculators. So it was not a clearcut ... the benefits of technology, the benefits of mechanising mathematics which is what Babbage was doing was not evident to everyone at all because, it was far from universal and Babbage was not the best advocate for his own position because he was feisty, he took offence very easily, his enemies could do no right, his friends could do no wrong, he championed everyone to a ludicrous degree and picked arguments, he publicly denounced people, he was a larger than life figure but very controversial. So the question was, it's not clear-cut that the benefits of technology were evident to everybody, quite the reverse, and the people who advised government were not Babbage, they were George Biddell Airy, because he was consulted as to the utility of the machine. So the study I did for the PhD was 'utility', how did people formulate, how did they express utility, why was Airy opposed to it, because almost everything quoted of Airy is that Babbage's engine was completely useless and the sooner it was finished with the better. And the question is, well, what's behind that? Is this just the dismissiveness of a rival, is this a piece of jealousy, professional jealousy, and it isn't. He [Airy] was a very rational man, so what I do is unpick from new correspondence and new archives in Cambridge the correspondence about calculating machines that Airy was involved in, and then rebuild his position in relation to mechanical technology for the purpose of that in calculation and then use that as the context for his pronouncement about Babbage. So that was the PhD. It was to find a bigger discourse that would answer a question, that the internalist technology account was insufficient for.

[recording ends at 2:]