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Interviewed by

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In the meantime you kept on working at the London Science Museum and, in particular, you were the project director of Japan UK in 1998 and you curated the travelling exhibition, Treasures of the Science Museum, in 1999. The exhibition toured in Japan, in cities like Kobe, Kitakyushu and Tokyo. Can you tell us a little bit more about this curatorial experience.

Yes. The Japan project was a very intriguing one, it was a kind of unique historical moment. There was this very high-level collaboration, the need for an event that would express the technological co-operation between Japan and the UK and the idea was that the *Yomiuri Shimbun*, the most widely-read Japanese newspaper, would fund this project. The idea was that the Science Museum would tour an exhibition, but what was rather exceptional about this was that it wasn't just any exhibition, this was the fifty most valuable or historically interesting objects in the Science Museum's collections. They had never left the building, let alone the country, since they'd been acquired, except in very exceptional circumstances. The reason why this came about was, because they had been taken off public exhibition in order to prepare for a new exhibition which was called 'Making the Modern World' which happened in 2000. So these objects, the most valuable objects - like Stephenson's Rocket for instance, is one of them – were going to be put in storage and Sir Neil Cossons, the Director said, 'Well, why not use this opportunity for making a wonderful exhibition.' So, fifty of the most extraordinary objects in the Museum's collections were used as the basis for this exhibition. Some of them are particularly of interest in Japanese culture, they weren't necessarily in Western culture, for example, one of the earliest lawnmowers. Now, one might raise eyebrows at that but the point is that the Japanese have huge, huge interest in English gardening, formal gardens, and gardening in general. The other one is a seismograph. There are earthquakes there and I think there's a connection with a Scottish scientist who used or invented, whatever, was involved in the first seismographic instrument. So there were things that were tailored to the Japanese interest. The whole project was terribly interesting in all sorts of respects because I was a curator, I wasn't a project director, I was a curator of computing, but, [for the Japan project] I had a direct line of report to Sir Neil Cossons, the Director, not via at least three tiers of management, which was extraordinary because I had huge freedoms to actually interact with the Japanese, on the Science Museum's

behalf, representing it. There weren't these layers of consultation that were needed to go through that would either impede or diffuse or would otherwise alter what the communication was to be about.

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How did you achieve that?

I don't for the life of me know. I think it was part of Sir Neil's vision of how to do things. You know, if you need to get it done then a very efficient way is to make somebody responsible for it, instead of having a committee ... also, I say this facetiously, Sir Neil knew it would happen because he knew the people in Japan, but I think elsewhere in the museum they allowed it to happen because they didn't think it had any chance of succeeding because of the totally bizarre idea. So there were very, very interesting museological and historical questions about this, but also hugely interesting cultural questions. The people we negotiated with barely spoke any English, they spoke some slight English ... Mr Motoiki was the chief negotiator from *Yomiuri Shimbun* and his 2ic was Mr Tada. Now, ordinarily in Japanese business culture the most senior people don't negotiate with each other, their 2ics negotiate with each other. The big guys may be present, and they can intervene, but the way no face is lost is if they actually are never put in a position of having to either refuse or turn anything down. So, firstly, there's a huge courtship one goes through in a Japanese negotiation, during which trust is built, and you may be negotiating but you're negotiating really over trivial things, because what you're actually doing is actually finding out about each other, how do they react to particular proposals, how amenable are they, how flexible are they, where are their red lines about things, and I don't think ... I left South Africa when I twenty-four and so I'm not a native to English culture, so I'm very aware, and South Africa had a very British culture, red post-boxes, pounds, shillings and pence, you know, the royalty, I grew up in the fifties there, I was a kid in the fifties, so English culture was very strong and the tendency is to believe that England is not a foreign culture because it was so familiar. England is a very foreign culture so I was really an outsider in the sense that I had to decode what was going on here in terms of social hierarchies, which are very, very layered here in ways that they are not in South Africa or because we were in a privileged position, we

didn't have to acknowledge them, so they didn't exist, the hidden barriers that seem to exist for people you had to meet, so there was one thing. So I'm aware that I mustn't take for granted that the currency, the cultural currency that I'm familiar with, is one that is automatically a currency of the other place. Now, in Japan that's even more extreme and if it weren't for the fact that I'd trained in karate in a *dojo* for ten years and knew something of the protocols of greetings, and knew something of the protocols of the culture of the philosophy of eastern existence and how it differs from western existence, if not articulated at least in behavioural terms. There's a very strict protocol in a *dojo,* in the formality with which one addresses and this was a Budhistic teaching, so it wasn't smash, grab and beating the hell out of people, this was to do with the philosophy of consciousness in which you didn't strike somebody, you gave. The Japanese words are to receive and to give. So, it's *ukite* and *semite,* so it's not an attacker, it's a giver. It's not a defender, it's a receiver. So there's a whole philosophy of what a conversation is here, you receive what the other person does and then respond in a way in the terms in which it was received, adding as it were, your particular signature of your position in terms of your consciousness. So I trained quite intensively for ten years, so if it weren't for that, being an outsider in a sense and being aware that one cannot make assumptions about what things mean, that is apart from the fact that the negotiating business culture in Japan is entirely different to the West. West is based on mistrust and self-interest if one is to be cynical about it, ... nobody is saying there's no corruption in Japan and nobody is saying that everything is glorious, and that things are nasty here, it's not the case, of course, at all, but the whole litigation culture in the West is to do with mistrust, the need for three quotes is to ensure the integrity and the propriety of the award of a contract. In Japan it's built on trust and that you would never dream of having dealings with somebody that you didn't already know, or in which you had not gone through the ritual of establishing the basis of trust. So if it weren't for that I don't believe the project would have survived because we spent three years negotiating, a lot of it over very little. There were linguistic issues, that they didn't understand the concept of procurement using three quotes because that would be based on mistrust, you don't trust them not to be ripping you off is the subtext of that practice, dignified as it is in our culture, and if it weren't for that awareness, and there were some bizarre situations in the negotiations which revealed this to me. One of them was ... well, they were very elaborate and they were long but the point is they were a huge insight ... I read three books on the

protocols of business culture in Japan, about what you do, what you don't do, what they respect, what they do not respect, and built up a very good relationship with these guys so the thing succeeded hugely, hugely well. It was a massive logistical issue, fifty major objects, you had to ... I was, in a sense responsible for the security. How do you value something which has no price? How do you value something that is utterly unique? I mean, this is for insurance purposes: how do you put a number on the value of Stephenson's rocket? It is an invaluable, priceless historical icon, it is in terms of the predicates it contains of the signature of its times, if you wish to examine how they made boilers in those days, you've got an artefact here which is irreplaceable in terms of historical significance, and there were fifty such objects. How do you go about, just in museological terms, formulating a system of value that would be credible and that would satisfy and that, in the event, if everything was destroyed, that the museum would be protected in some way? So this was wonderfully creative museological activity which I undertook with great willingness. I had three criteria for valuing an object: one of them was to compare it to an object in the arts world – what was the value placed on a priceless irreplaceable Picasso, just as a guideline, as a measure, so with Stephenson's rocket would a million, or fifty million, or a hundred million... how do you compensate for the loss of gate revenue for the public not being able to see a major icon. So I had three criteria, and it was terribly interesting. The other thing was, the question of the physical security of these things. In a Science Museum exhibition, in the museum if an object is inventoried and especially if it's of a particular historical significance, it would not be able to be handled by anyone other than a curator. Well, here we had fifty objects and this is in Japan, are we going to insist we're the only ones going to handle it, and the answer is Yes. It took twenty-six people three times, they mounted the exhibitions, so the logistics of doing all that. One of the interesting things in the negotiation, which was two and a half, three years into the line, the Japanese suggested that Sir Neil Cossons and I fly business-class and that the curators flew ordinary class, you know, that we would be comfortable, and I immediately, without consulting Sir Neil Cossons said, No, no, no, we'll all travel ... what is it, there's first class, business class and tourist class ... business class but the most important people are the curators, because when they get there they are the ones who, having not slept for nine hours, have got to nurse these things through customs, they then get on trucks with the stuff, go to the venue and then have to supervise unpacking. They are the ones who need the rest. And I

think that made an impression on them, saying, 'Hang on a minute, we're not ...' you know, while we can go first class or business class, this is a privilege, it was a question of actually, how does this thing work, and I imagine that that was a marker in their understanding of who they were dealing with, that we were not there to benefit in any particular way except through the success of the project. So we did this, it was a massively successful thing and we had a negotiation about, in the event there was an excess of gate money, how that would be shared, and that was an interesting negotiation. It was at that point, when it appeared that it would be successful, that the senior people in the museum thought, they're the experienced people, they should be doing it, what is a curator of computing doing, negotiating a two and a half million pound project with priceless objects with the Japanese. So they stepped in and started the negotiation and they did not have the three years of experience building trust. I don't believe they'd read the books on business protocol and they certainly hadn't spent ten years in a *dojo* and I was present at these meetings and just watched how, what the differences between a westerner coming in, making assumptions that what was of interest, of benefit to people, was the same as it would be to them. They made assumptions that what was of beneficial interest to them as a westerner would automatically be of beneficial interest to the Japanese and it wasn't the case at all. Also, the fact that these are protracted, you can't bail out after half a day's negotiations, it took over two days, and the final dinner of the second day we still had not resolved it. It could not be resolved because nobody wanted to say No, you do not lose face by refusing anything, the contract is to resolve all issues in a co-operative and friendly way, that's the contract. It's not a legalistic contract that says, if you don't pay us xyz, that gets written afterwards, the actual contract with the Japanese, after they've built sufficient trust, was that we agreed to resolve all things in a co-operative way. So we were at the final dinner, they were about to fly off and we had not resolved the question of how we partition any excess profit as a result of the gate money, and we're sitting at this table and our negotiators are there, the Science Museum negotiators, and our Japanese friends were there, and the directors are there, and when the desserts came round I said, 'How about fifty fifty?' and they said, 'Fine.' [laughs] This was after two days, because everyone was skirting around it. So it was a wonderful, wonderful experience, it was very successful which I'm delighted to say. I experienced jetlag the kind of which I've never experienced, I was wide awake at four in the morning, I watched more BBC world news than I would ever

want to watch again, because I was absolutely incapable of sleeping for nine days and if you think about the natural adaptation of the body, one hour per day, and it's a nine hour, eleven hour difference, it took me nine days before I slept, so I would be alert at four in the morning and I'd be going to meetings in the ambassadorial car and unable to keep awake, literally, attending these senior meetings because the negotiations were at ambassadorial level, certainly at high level and we were staying in the Embassy, and the whole connection, between *Yomiuri Shimbun*, with the Japanese authorities and the Science Museum, we were representing our governments, so it was important we keep awake just out of courtesy. But it was wonderful. The experience was wonderful. The cultural issues were glorious, I mean, the negotiating things were priceless to actually decode what was going on, and it was hugely successful for everyone. The gate far exceeded anything anyone imagined and when I went to the director after it all happened and said, 'Well, there is this contract which says we get fifty fifty' he said, 'Just wave it aside, these are friends'. He didn't care about that. It was a massively successful exhibition and all the objects came back successfully which was a big relief. So I think there were many lessons from that. One was the experience itself, and two, what an enlightened environment that [the] Science Museum was, to be liberal enough to allow a curator of computing, for pity's sake, to take on cultural negotiating, apart from a curatorial role, you know, negotiating with the Museum of Science people [in Tokyo] which was wonderful stuff, to negotiate with them, to speak to them and to hear the consensual way they work, and it's very, very different. Over here, if you own a company you can commit that company, you're in a sense committing all your staff to a particular action, you do the negotiation and the company delivers what you want. Over there, that's almost unheard of. As the top man you're the representative of a group, you're not the person who has the defining authority, the authority comes from the consensus of the people and so without this consensus you don't get buy-in. And we spent the littlest time in getting consensus, and it's a not a fake consensus, 'ok I'll go along with it if you do this', it's a question of agreeing that this is the best way forward. To experience that difference, to be in this hothouse, this cauldron of a project with that cultural difference there and attending the meetings at which curatorial consensus was needed for the content of the proposal was absolutely fascinating. I mean, one chap said ... every meeting we had, for weeks, he said 'but we must discuss the content', and we'd say, yes we will, 'but we must discuss the content' and one assumes that he

has a difficulty with the content and that he wants to make his case known. So after all this, after weeks and weeks of this, the Japanese person said, 'Right, we now are ready to discuss the content, what do you wish to say', and he said, 'No, no, I just want to discuss it'. My assumption was, everyone's assumption certainly on our team was, there is a difficulty here, he's not happy with the content, or has some objection to the content, there's some preferred treatment he wants, or ... it wasn't at all, he just ... we hadn't considered it yet and he wanted agreement. I mean, there's a perfect example, that's a quick one, there were much more elaborate ones to do with the funding agreement, so it was a wonderful, wonderful experience culturally and I'm indebted to that institution, to the Science Museum, that it was liberal enough to actually allow me, someone like me or me, the licence to do that and to have a direct line of report to the director which just cut out so much stuff. The time side was also interesting. If I got something in an email at night I would have a reply the following morning, because they would then have had their day. So that cycle was very quick. If we had to go through a committee structure at the Science Museum it would have totally scuppered the timeline. It's because we had this twenty-four hour turnaround, with only reporting to the director, that I could get approval any time I wanted immediately, I had huge licence to negotiate on the museum's behalf without consultation, that's what built up the trust and that's what actually got the thing going. So it was fascinating culturally, it was fascinating in business negotiating terms, in terms of cultural protocols, it was fascinating in saying, 'Do I understand enough of the social dynamic here to succeed? Can I decode what's going on well enough not to foul up, not to do something that would scupper the project?' And that was the same with the Babbage machine. It wasn't a question of 'we know we can build it', it was a question of 'what haven't I foreseen, what did I not foresee that could still sabotage this, what did I not foresee? And so I knew – it was like karate. In karate you're waiting, you're waiting, you're waiting, and a point will come where you have to decide, are you going to intervene, are you going to externalise what's going on, in action. Right, now with the Babbage engine it was like, I always had to be in readiness to deal with what I had not foreseen, so anything I could foresee I dealt with instantly. If I saw an obstacle I dealt with it because I had to be ready for the next one, that one that I didn't foresee. And that comes from, and I've never actually said this publicly and I've said it to very few private people, it comes from what happened to me at school. I mentioned that ... there's a thing in the form that says, what is your

memory of that period, and I said, invisibility. Ok. So when I was fourteen, fifteen, I felt invisible. I had the first historically strategic insight that I'd ever had and that is, I recognised I'm in a relatively small school – there were only a few hundred pupils – I'm in a closed protected environment. When I leave school I'm competing against the world. This is the last time I will be in an environment where the total population is so small. In other words, if I don't have any great ability, if I was going to be visible at all this was the environment in which to do it because there'd be no other pond that was this small, if you like, and it wasn't done cynically, it was a question of how to become visible. The way I was going to become visible was to train in athletics and go in for the last sports day and win – I was the second fastest sprinter, I had natural stamina so eight hundred metres was my distance because I could sprint and the strategy suited me. For a while I was a good miler and I also started training in high jump and long jump. And I started training six months before the sports day, which was unheard of, on my own, and read books about technique, about high jump – the Fosbury Flop hadn't been invented yet, it was all scissor technique - long jump and running stamina. And I ran thirty-two laps round the rugby field on a Friday, and I wasn't feeling that well over the weekend, and on Monday my dad, who was a doctor, took a look at me and he said, 'You're jaundiced. You've got a liver infection.' I was in bed for three months and they never told me that I wouldn't run. This was the first strategic decision I'd made in life, I was going to undertake this thing and I was going to try and excel by directed activity to a particular goal. I had never had any goals; this was a goal, to try and prove to myself something about myself. I was in bed, the way they treated those things was they put you to bed and you didn't do anything. I was good enough at school, I didn't have to sit exams because I did well, and they never told me I wouldn't run, and that's what prepared me for the Babbage story. I had to be prepared for everything I couldn't foresee, that was the strategy, because if something had come along that I could not foresee and I could not control, that would mean I couldn't deliver the project. I didn't have a signed envelope from God saying 'you can build this engine, you just have to find out how', there was no guarantee, there were a thousand reasons why the engine wouldn't be built, a thousand reasons why it could fall flat – funding, internal opposition, accidents, damage, anything could happen. The company went bust, which it did do. So I relate those two events, the first experience of failure over which I had no control because of an event that I could not foresee and Babbage. With the Babbage thing I

was prepared, both because of the karate training that prepared or cleared the way to deal with what you can't foresee and the idea that there was no guarantee it would succeed. So failure, in a sense, was one of the best lessons from that thing. [laughs] That's on record now and that's the first time, I think I've probably only ever told two people about that, but it was something I was very conscious of at the time, like how do you prevail here, how do you prevail. And the principle of karate is how do you prevail. Prevailing doesn't mean winning, prevailing doesn't mean beating somebody up, but it means how do you prevail over the situation, how do you behave like a higher mortal in a situation. It could mean running away which is perfectly honourable, so this was again, how do I prevail, do I understand enough about the world and the way the world works to navigate through what needs to be navigated in order to accomplish what the goal is. So that to me was an exciting moment. Japan was a wonderful, wonderful arena in which to exercise this, always aware, don't make assumptions about what it means to them, when you say words do not assume that they mean what they mean to somebody else. And also to talk very, very simply. I talk in very elaborate ways to impress people to make them think I'm clever, which I'm not, and that [simplicity] is the exercise of being a curator, being the translator, making intelligible in terms that are understandable to the receiver, who doesn't yet know it, something that is quite difficult and possibly obscure. How do you talk simply, not in constructed sentences, to a foreign language person. You have to use nouns, it doesn't matter how they are linked. To get the essential idea is the only thing that should stand out. That's very similar to writing a label for an object. So all those things to me were ... and there's a later question which I think comes up about balance, which I'll maybe turn to. So Japan was wonderful and it was a wonderful experience. It was wonderful having the freedom and authority to get done what needed to be done without the viscosity and the bureaucratic viscosity of an institution which has committees for all good reasons. There's a story which I love telling which, actually, is something that Professor Maurice Wilkes said. I asked him, because he constructed EDSAC, he was the first to produce a usable computer in this country, and I asked him, 'Well, how did you succeed where others failed? How did you succeed in building EDSAC and a usable computer in a university and other people failed?' And he said, 'Others had committees to help them.'

00:27:03

That's great, thank you. [laughs] In 2003 you got your PhD and you left the London Science Museum.

Yes, the Science Museum underwent a structural reform and they changed the whole structure, they made it a fairly flat structure and the senior managers. I was at that stage Assistant Director and Head of Collections so I went from being a curator and in 1999, immediately after the Japan exhibition actually, I was interviewed and offered the directorship of the Computer History Museum and that was a wonderful experience. I went there, I gave lectures, you strut your stuff and give lectures and things. I'd been through many Civil Service recruitment boards as an applicant, twice, and then also I sat on them as an examiner, as it were, and I sat at this table with all the trustees of the Computer History Museum. I was used to the British system, where they have a procedure and they have certain things they ask, and I'm sitting there, at the head of the table, and the trustees were all around the table and one guy goes to me and says, 'Tell us stuff.' That was the interview question – 'tell us stuff'. And it's saying, ok, how do you deal with a situation, what are you made of, what are you going to do here. And sitting next to me was Gordon Bell, of the Digital Equipment Corporation, who was one of the trustees [laughs] so that was ... So, I was interviewed for that, I was offered that, and had a terrible, terrible dilemma because we had been told that they would not have an internal appointee for the assistant directorship of the Science Museum, they would not appoint an internal candidate. So, there was nowhere ... not nowhere for me to go ... if I wanted to go beyond being a curator of computing, if I wanted to have some more structural influence in a museum organisation I would have to go somewhere else because I was a senior curator. So I interviewed for the assistant directorship and they didn't appoint anyone – sorry, there was an interview and a whole round, and I didn't apply because we were told 'no internal appointment'. They didn't appoint anyone, they couldn't find anyone they were happy with so they readvertised and allowed internal candidates and I applied and was given it. So I had to choose between going to America to be the director of the Computer History Museum, and to be Assistant Director at the Science Museum and it was the most agonising decision to make. It was absolutely agonising because every... my brain said go to America and my heart said stay here. America was the next big frontier, this was the only museum dedicated

to the history of computing in the world, it had the most extensive collection. Len Shustek, the chairman of trustees, a decent and very fine guy who had terrific pure ambitions for the institution, and I chose the Science Museum, only to be told in two or three years time, three years time, when there's a new director there, after Sir Neil Cossons had left, that there's going to be a structural reform which meant that our posts vanished. So, the moment I left I spent four months locked in a room finishing the PhD. I'd written half of it already and ... I'm very, very pleased and it gave me huge personal satisfaction to do something that sustained and that uncompromising in its scholarly approach. But the main thing about that is, which is terribly important in relation to trajectory and discourse and IT – what kind of discourse is IT? What kind of discourse is history? – is I had to make the professional transition from being a professional engineer to being a professional historian. There's a wonderful story by [pause to remember name] ... historian of the computer, from [Princeton] who died suddenly ... Mike Mahoney, who was a wonderfully distinguished historian of computing, and he told a wonderful story. He swam every day in the university pool and a fellow colleague of his, who also swam every day was a professor of neurosurgery, he was a neurosurgeon. Mike Mahoney was coming up for retirement, something he was looking forward to hugely because he loved travelling and he had a lot of research projects, and so he was going to work half-time and then retire, and he was going to come to the Computer History Museum, I was arranging that he give seminars to the curators there so that they could broaden the whole scope of things, and he relates this conversation with the neurosurgeon. So, he heard Mike was retiring and Mike asked him 'what do you propose doing when you retire?' because the neurosurgeon was roughly the same age, and he said, 'Well, I'm very interested in the history of my subject and I'm going to do the history of surgical neurology', and the neurosurgeon asked Mike Mahoney, Professor of History, 'what are you going to do when you retire?' and he said, 'I thought I'd do something in neurosurgery', the point of the story being the assumption people make that history does not have professional protocols and practices and that, because you are a party or a participant or a practitioner in a particular field and have a personal history in that field, is not history, that is a first person account of what happened. So this was a way of bringing out, the story that he brought out was that history is a profession, it's a different discourse and it's entirely different to the discourse of science. In science, if there's evidence you can't explain it does not form part of the corpus of science. If there's a

physical phenomenon that's not explained you will not find it in a physics book. The reason rainbows are in physics books is because we have a theory of refraction in optics, there is a theory of optical refraction which will explain a rainbow. Rainbows would be in nursery tales and nursery rhymes and nursery books but they would not be in physics books if we did not have a theory of optical refraction. So science excludes things it can't explain. In history you can't, if there's an event that happened, you may not have a causal explanation for it if you can talk about causes, historical causes, it doesn't change it. Babbage failed. The explanation given, the cause was limits of mechanical engineering in the nineteenth century. Once you take that away the explanandum, what needs to be explained which is Babbage's failure, doesn't go away because you don't have an explanation for it. So the relationship to evidence is entirely different. So it requires a professional apprenticeship to an historian to understand this. Because I'm interested in philosophy, what is it you do when you do science, I was interested in what is it you do when you do history, historiography, and I was massively fortunate, I was at UCL, and massively fortunate in the two supervisors I had. One was Martin Daunton who was most wonderfully encouraging and he was the one who, in a sense, effected this transition. He knew I was an engineer because the first thing I went in and said was, 'What I want to do is to prove who was right', my Phd I want to be . . . Now, Babbage said that printed mathematical tables were riddled with errors. George Biddell Airy said they were accurate enough. Who was right? Now, they couldn't resolve that then, because there was no way of verifying printed tables. They had to rely on experts so what the historian does is, articulate why did Babbage think that they were riddled with errors and why did Airy think they were not. And that's what you do in history. But, as an engineer, the way you resolve issues of contention is through experiment, so I wanted to scan the tables in [to a computer] and do an error analysis. I presented this to my supervisor and said, 'that's what I want to do with my PhD' and it was the look he gave me that was probably the most educational thing about this whole process, because it was amused scepticism, what he was saying is, 'this is not what historians do, this is experimental history but what historians do is find out why they thought what they did'. So I was hugely fortunate and he was the one who effected this transition, crossing the tracks from this engineering culture to an historical discourse. I was massively fortunate and he was hugely encouraging. Then Martin Daunton went to Cambridge and I met Martin recently and I hadn't seen him since way back,

and I asked him, and I said, 'look that's what I gathered from the lesson', and there was another episode where he gave me a funny look, and I said, 'Was I correct in that?' and he said 'absolutely'. I said, 'I want to know, what is it you do in your history, can you give me some ...' so he looked at me with the same look and he said 'read Tosh' – that's a book on historiography – but what he was saying is, what it is you do when you do history, the question is [in itself] not doing history, doing history is reading sources and having the professional experience and instruction about what you do, how you evaluate evidence to join the dots to find out what can legitimately be said in the light of evidence. So it was hugely important to have Martin Daunton at first. And then I had Julian Hoppit, who was my second supervisor, who took over the supervision because Martin went to Cambridge. Julian was wonderful because he was absolutely meticulous, he'd read every word and commented in the most gentle way. So I'd presented something to him and he said 'you've used present tense here and past tense here' so I said, 'oh yes, but I've got...' and he said 'I'm not criticising, I'm just observing', you know, in other words, you may have good reason for this, I'm just pointing out, are you aware of that? I couldn't have been more fortunate in those two supervisors. So, it was very, very significant, doing a PhD is sustained, as anyone who has done one knows, it's massively sustained, it's a test as much of stamina as it is of scholarship. I did vastly more than was needed for the thing but it gave me huge personal satisfaction to nail it down, to nail every reference down, not to make any assertion that was not argued for or justified in some way, and that huge structure, doing it in a sustained way in 100,000 words is something, whatever anyone else thinks about it, it gave me huge satisfaction to have done that, to have seen the course and to have done it. So I locked myself in a room and did it and finished it off. That was 2003.

00:38:53

In 2004 you became a Visiting Professor of Interaction Design at the Royal College of Art, so now we are going back to interaction design and art which makes me think about your first experiences at the Science Museum as a designer.

Yes, interaction design intrigued me hugely because I'd never formally trained in it, but I had been designing working exhibits and formulating perceptual aspects of the

experience of the visitor or experience of the user of an interactive design. So it was wonderful, it was quite short-lived, I was completely bowled over by the creativity and the quality of students there, it was mind-blowing what these guys came up with. They did not have engineering disciplines to the extent that I would have liked, you know, you need to understand materials to make new things, and I felt that that discipline wasn't there, but the creativity was absolutely mind-boggling and that was hugely rewarding. The other thing that was massively rewarding was holding seminar sessions with them because they were so diverse, they had such diverse backgrounds. Some of them knew philosophy so we could talk about metaphysics, some of them knew ... and that to me, to be able to sit round a table and have a philosophical discourse with a bunch of bright people, that to me was all I asked for. That was excellent, to be able to try and formalise aspects of these designs that I'd monitored. It was fairly short-lived and it wasn't very demanding in the sense of time so that was, you know, it was a part-time thing, but I loved being there and loved the environment and found the students absolutely inspiring, and the levels of creativity. You see, engineering is very structured, the model is Euclid, the proposition is inferential logic *dadadum*, things follow from other things. Literature and these more fluid discourses are more associative and less deductive, less linear, and that is, less convergent. I think that people who are attracted to engineering tend mostly to be convergent thinkers and the philosophy and ideas always interested me. It was actually the philosophy of engineering, I don't mean philosophy in some high-falluting way, but the meanings beyond the internalist significance. You know, when you put something close to something else, the whole issues of proximity and layout, these are not... there are no rules for them, so there was a craft and an art in them. The art issue, the paradox. The paradox of computing is this: that computers are completely deterministic and [at the same time] unpredictable. They are completely deterministic because they are completely rule-based, they are utterly rule-based. The point at which they cease to be rule-based is when they're broken. They operate in a way that they are instructed to operate, in accordance with the way they've been built by their chip designers, and according to their programmers and their software structures and all, they're totally deterministic and yet they are unpredictable. They are unpredictable not because they are faulty, they are unpredictable because the complexity of decision-taking they are making is beyond anything we can foresee. So there are huge paradoxes. They are also very brittle. One bit wrong the machine

crashes. But they are also massively flexible because they have a plastic function, you can alter it very easily by altering its software. So why is this significant? Because there are discourses about technology that are not within technology, so as an engineer you don't get to discuss these things, they are discussed outside engineering which is why I needed to break out of the paper bag, which is why becoming a curator was such a massive liberation because it gave you access to these other discourses without excluding internalist discourse. You see, you can only talk with authority about history of technology if you know what that technology is. That's not altogether true, there are people who can do histories without knowing the technology and very fine histories, but to me it had to be rooted in both. So I was not only responsible for the bits and pieces of the [Babbage] engine, I was also responsible for explaining what its historical significance was, so the complete spectrum from deep internalist technology to deep internalist scholarly history to glossy cover-feature articles in Scientific American and New Scientist. How do you be appropriate to the audience? A lot of karate training, all of karate training, is how are you appropriate to the situation. Now, being appropriate maybe you have to overpower somebody but being appropriate may be you diffuse something. So the question is to do with appropriateness and so the question is, how, if you have a piece of knowledge, are you appropriate to a lay visitor or a lay person which is what a curator is addressing all the time, and how can you be appropriate to readers of the New Scientist or Scientific American, how can you be appropriate to the IEEE journal, if you're writing an article about the same thing. So it is all to do with appropriateness. So, the Royal College of Art thing, the question now was, this was a broader discourse, these were people designing things, people designing tables, why assume that a table has a flat unchanging surface, why not animate the surface. Well, that was a bit like the Copernican revolution, it's all so mind-boggling, you know, they were completely dismantling, defamiliarising, so there's a convergence about engineering training, it is rule-based. One of the paradoxes of computing, one of the dilemmas, one of the conflicts or apparent conflicts between art and computers, is that computers are rule-based, and we might say art is not. Art is inspirational, spontaneous and all the rest of it. Well, there's a whole lot more technology in art than a romantic view of it acknowledges. And there's a whole lot more artistic about designing programs and doing engineering than is acknowledged by artists, so I think it's an absolute false dichotomy that engineering is rule-based and has no subjective content, and no

engineer would dream that that was the case, and that art is somehow not rule-based and is entirely inspirational. So there is vastly more rule-based media in art and there's vastly more subjective creativity in engineering than either party would recognise, and the wonderful thing about interaction design is that those two things converge. And there was an environment in which the brightest practitioners of that generation were there for me to talk to. So, although that was a very small job, as a visiting professor, but it was really priceless, quite valuable. I see you agree with some of that, yes.

00:45:50

Then 2006 'til 2008 you were Guest Curator at the Computer History Museum, so kind of ...

Full circle. [laughs] Yes. After the Science Museum ... leaving the Science Museum was quite traumatic for me because I'd been there for twenty-six years, it was a part of my life, a curator was not just a profession, it was a personal identity. I identified very strongly with the importance of material culture and the history and the permanance of substance the histories embodied, which is why I wrote about curatorship and museology and the significance of physical things. It was deeply imbued in me, right from the beginning, taping up my bike as a kid, making things, so to leave was actually losing ... look, I should not have invested as much in it, a professional career, as I did, I should not have invested personally as much as I did, because being a curator was about the cultural identity, coming from a foreign country, this is what I was in this society, but it was also a personal identity in saying, this is what I stood for, I stood for the meanings of material culture and what you could decode from these things. As a position in the world this is what was worth excavating. So to leave was to leave. And the museum was the home of that, the apex of it, and to have risen to assistant director and head of collection was something I could never have foreseen, I could never have dreamt that that would be the case, I was the chief curator, the person responsible for the cultural agenda of the place or at least to protect the values of that cultural agenda even while they were being besieged by the new Science Communication movement, which was a big issue: is it modernist or is it to do with the past which is a dilemma that the Science Museum has very

successfully balanced in the past but this was becoming into a turf war between science communication and history of artefacts. I was very happy to be the advocate for that [history of artefacts] so leaving was more than just leaving a job. So, I was not ready, really, to do anything else 'til I'd spent some time. So they [Computer History Museum, California] were doing a major exhibition funded by the Gates Foundation and I had always kept in touch with Len Shustek, the chairman of the trustees there, who had recruited me. He attended a lecture I gave in Manchester and came to me after the lecture and said, 'What are you doing after this?' and I said, 'I'm going to have a sandwich', and he said, 'No, no, what are you doing after this?' and I said, 'catching a train back to London' and he said, 'No, no, no, what are you doing after this?' I said, 'what do you mean?' and he said 'in career terms'. [laughs] So he interviewed me at an airport and then I went off, so I'd always kept in touch with him and they were doing this big exhibition and he was always wanting to tempt me over. There was some question of building the second Babbage difference engine over there, we built a second one, the second Difference Engine No. 2. So I kept in touch with him over that and he was inviting me, saying we wonder if you would come, and I was kicking around and I wanted to have an experience at an institution that was exemplary, that I would exit with everyone, not just leaving out of the back door in a sense as I did when the Science Museum restructured. It was not done in a very skilful way, I'd been there twenty-six years and I threw my own leaving party because the [new] director couldn't look me in the eye. So I needed some recovery time, in which I finished the PhD, and then this came up, and so I went, and it was again massively intriguing, much as the Japanese one was. So I went there for stretches, I commuted to California, in Mountain View, the longest I spent was seven months, I spent stints of three, four months, came back for a month, went back, and again it was culturally terribly interesting because their history of computing is entirely different to our history of computing. They had a totally different history of computing and the trustees of the museum are the major movers and shakers of Silicon Valley. Many of them were actors in the fifties, sixties, during the solid state era, many of them were primary designers of chips and integrated circuits, there was a top expert in minicomputers who was a trustee, Gordon Bell, John Mashey, a major pioneer of solid state physics, these guys sit on the exhibition committees. It's their history that's going to be told because there's a rather unreconstructed view of what history is. So I found it utterly fascinating because I had to tell a story, your job as a curator

is to tell the story of their times using material artefacts. So it's not to say that this is universal. Ok, so in the seventies Apple was significant and the first Apple was part of that story. So it would make absolute sense for a curator in the late seventies, early eighties, to collect an Apple computer because it's a story of our times. Now, I'm going there with a European story, Pegasus, Colossus, NRDC 401, Manchester Baby, these are the tribal icons of British computing. I'm going there and they're talking about Sage, Whirlwind, ENIAC – what? [laughs]. Yes, of course I know about them, yes, I've read about them, but that's not the history ... and so what I had to do, and I'm deeply pleased and a fine piece of work followed, even if I say so myself, I spent three months just speaking to people, listening to their stories. What are the tribal icons? What do you see as the history? What is your history of this? And I then wrote the prospectus for the exhibition, both designed the layout which I'm very pleased with, it's called an Icon Alcove model and the idea is that, if you've got half an hour you can stand on a platform and look at the exhibition floor from on high, and you would have an intellectual and physical map of the history because down the central boulevard there would be the major icons – fifteen icons from each era – and around the [icon] there would be an alcove, which is a special exhibition about that. So for [computer] graphics there'd be the original teapot that was the model. So the teapot would be there – 'why is there a teapot there?'. Interesting question. And the trustees, as it happened, were opposed to the teapot, they wanted a very impressive [screen-based] graphic in it, and I said, 'No, no, no, a teapot is what makes people ask'. These were the discussions, I had to explain the principles and protocols of affect to visitors. They're going to say, 'This is a computer museum, why is there a teapot as an icon?' That gets them engaged. So, these were the kinds of things. So, we chose the fifteen, sixteen icons, and subsequently there were more, and now, the idea is that, if you just had a visual impression of the fifteen icons you could reconstruct the history but if you had more time you could go down and go through the alcoves. And I wrote the prospectus for this, mapping the geography onto the floor and the icons and the messages for the icons, what they were, what they stood for whatever. It's very dense but it gives the philosophy of the boulevard, something you stroll down at leisure and amuse yourself by looking. There's the whole principle of the thing. So, it was wonderful explaining this to them, not [so much] explaining, as articulating the difference between the dimensioned exhibition and what's called visible storage: we have an object and you say, now this is the first blue one, and all

the rest of it. To their credit, they wanted to go beyond that, the trustees, the museum wanted to go beyond that, they wanted a fully integrated graphics museum where the bigger story was told than just the technicalities, and the colours and whether it was the first or not. So, to their credit they did, but it was a terribly interesting experience. I finished the prospectus and was very gratified by the fact, that exhibition exists now, it was then implemented by their team, their staff under Kirsten Tashev but it was terribly interesting, I had endless, endless conversations with one of the trustees, it was a software man, and he collared me and we had meetings, probably once a week, for months on end, and what he was trying to convince me to do was to say, look, he's got on top of software, now there are these categories of software and this is where all the historical links fit. I don't think he even said that, he said ... basically what he was saying was, 'I'm looking through a modern template at history and can structure the past for you by putting what happened then into this taxonomy of categories of software.' These are abstract things, they are not historical things, they're not about time, they're about function, and what I needed to try and communicate was, that what you are doing is telling the historical story in the terms of the period that it happened. You can't retrospectively project backwards a concept from the twenty-first century or the twentieth century, and say, those were the terms in which it was actually enacted at that time, the whole perception was entirely different. So there was a wonderful way of becoming aware of the difference in a treatment rooted in historical principle and a treatment rooted in a structural, logical and, if you like, a superordinate principle, and I don't believe I ever succeeded in convincing him that what you told in an exhibition was to reflect the story of the contemporaneous time that you were actually engaged with. But there were wonderful things. I mean, one of the things I researched while I was there was the question of the significance of the stored program computer, because every book you pick up says this is the defining feature, the modern digital computer or the electronic digital computer, is the stored program computer, and I thought, ok, I didn't formally study computer science, I'm a self-taught computer engineer, I studied six years of maths, physics and control engineering and engineering and electronics, so there must have been something in my education about computers, that it must be obvious why this internal stored program is the defining feature of the modern computer, it must be obvious because nobody has explained it. Nobody has ever told me why. I gave a lecture in Jerusalem and walking next to me was Copeland, the Turing man ... what's his first name?, I

know him well ... it will come to me [Jack]. So I'm walking with him, having given a lecture, so I was feeling fairly relieved, and I said, 'Look, don't tell anyone I'm asking you but something I've wondered about for a long time, what is the significance of the internal stored program? Is it practical, is it theoretical, is it logical, what is the significance? It must be obvious because nobody has ever explained it.' And he said, 'Good golly, I've never thought about that', and I thought, well, what have the historians been doing all this time? I was a curator, I didn't see myself as a historian of computing, I was a Babbage expert on nineteenth century calculating engines, and yes, I knew about electronics, I'd worked with them and fixed them and built them. So we went to lunch, and sitting round the table name any prominent modern computer historian, they were all there – Mike Mahoney, Martin Campbell-Kelly, Bill Asprey, Jack Copeland is his name, the Turing man, everyone you can think of was sitting round that table, and then, to my acute embarrassment Copeland says to them, 'Doron's just asked me an interesting question walking over here, what is the significance of the internal stored program?' And Martin Campbell-Kelly was sitting next to me and he said 'speed' and the guy next to him said something else, and the guy next to him said something else. There's nothing quicker than a switch that's already been thrown, so speed wasn't overwhelming, it didn't carry a consciousness of its necessity to me, is it practical, is it an issue of principle? And the first observation was, everyone's answer was different. The second one, there was no overwhelming thing that, as I say, carried a consciousness of its own necessity, so [that] suddenly the lightbulb went on and I said, 'of course, unless the program's inside the computer, you can't do all the things we do', or another thing that I proposed to them was that, if the program is in the computer then the program can operate on another program as an object and therefore you've got the possibility of compilers, and the idea of this reflexive principle, that a program can operate on software as an object, is a profound, philosophical and a technological issue. There was complete silence, there was no response to this. So this was terribly intriguing. So in subsequent ... whenever I had the opportunity, I'd ask ... Brian Randell ... I was up there [Newcastle] giving a lecture in his department and we were sitting around in the big computer science department, 'what's the significance of the internal stored program' and he said, the reason is you can apportion the resources of the machine according to the problem, so if you need more memory you can do that, but there were other things like the lack of distinction between data and program, for instance,

is that a fundamental, is that something of principle, is that something of practice? It's a digit stream in a memory, is it a program or it is data? In one sense it's data, in another sense a program, but there is a qualitative difference between them, is this an issue of principle from von Neumann's 1945 paper ... so what was interesting there was ... how did we get onto this, this was to do with ... the computer history museum, yes. So here, I'm sitting in Silicon Valley with these people who created the modern world and I asked them, 'what's the significance of the stored program computer?' I asked Len Shustek, and he said 'that's interesting, I'd have to go back to my – he was a PhD graduate from Stanford in computing – notes and look at that. I asked the first person who programmed ... it wasn't the Harvard Mark One, it was the one that predicted the election ... famous machine [Univac]... it will come to me as we speak ... so he was in the basement, programming this first general-purpose computer and I said, 'what is it you could do with the stored program that you could not do before?', and he immediately said, 'matrix inversion'. So here you've got the first programmer of a stored program computer telling you it's got nothing to do with principles, it's got nothing to do with theory, it's to do with, I could index the matrix automatically without having an external source, and I could have the conditional and what the outcomes were, to steer the program. So the computer history museum was wonderful because you had access to the people who were responsible for creating these things in the first generation, so it was wonderful and that thing subsequently got taken up by Tom Haigh and there's a three- part ... Tom Haigh and Mark Priestley I think ... series. I wrote some of it up, there was the fiftieth, hundredth anniversary, whatever it was, of EDSAC ...the fiftieth anniversary and Maurice Wilkes was there, and I gave a paper on the significance of EDSAC, and in it I mentioned this encounter I'd had asking people, all giving different answers, to what was the significance of the internal stored program ... why am I telling you this? ... EDSAC, yes, and I mentioned there this experience of asking people and getting different answers and went through this and said, 'well, the significance of the EDSAC was that it had an internal stored program, it was for general purpose, the first useable machine and all that, and when Tom Haigh picked the question up, which is a central piece, and my question still is, 'what were the historians of computing doing that you had to get to 2010, 2015, before you ask a fundamental question like what's a program, and in Tom's thing he cites this EDSAC paper using 'Swade's confusion' as the ... basically saying it's not surprising because if you do historicise it it's pretty

complicated, it's no single inventor, it's no single reason, it's a multitude of interrelated things. But I was always quite proud that Swade's confusion was the starting point for an inquiry, or if not the starting point, it is featured in an inquiry about such a fundamental simple question. So that was a wonderful experience.

1:03:27

So the title of the exhibition was 'Revolution'.

Yes.

The first two thousand years of the history of computing. So now I have got, like a, provocation – so if these are the first two thousand years of the history of computing when was the first computer?

'Provocation' was the right word because that's the way in which you could drive the computer historians mad or get them to leave the room. The reason for two thousand years is to remind people that it wasn't Bill Gates who invented computers. Ask a school kid who invented computers and he'll probably come up with that. Maybe Bill Gates is not even in the frame anymore. But they think of computers as only electronic computers so the point of the two thousand years is, it makes it perfectly clear that the conceptual roots of calculation computing and what we now call computing actually go back to pre-history, that pre-dates electronic implementation. Also, it's long enough to describe that computing, or the activities associated with what we call computing, actually go back to human activity, all the way back, and are not new, they weren't invented by electronics. Electronics isn't indispensable or a prerequisite of doing calculation and computing and the idea of the first two thousand years is a clear declaration and assertion that the story is not ended, that we are not at the end of the days, that there is more to come. I don't know if I originated that title but I remember explaining in the prospectus why that was chosen. Revolution caused difficulty, unexpectedly, to the trustee board and the exhibition committee for a reason that was very intriguing that may be interesting for the history of IT. When I first did the first presentation on the treatment for the exhibition the principle was revolution and the revolution was this fusion chamber of thirty, forty years of solid

state physics which resulted in the integrated circuit and Moore's Law. If you look at the history over two thousand years you've got this spike before you, which is a blink of an eyelid in the two thousand years, forty years during which things went crazy, they were totally transformed. The principle of this, and in the Computer History Museum - not its prospectus, its mission statement document - I think revolution occurs thirteen times in the first five pages. So I went there and explained why this was a revolution, looking at the implied trajectory of material culture to the beginning of automatic computation, and then the integration of communications control, calculation, automatic computing, converging into the information age, and this happened in a very short period in historical terms. And there was an outcry and I couldn't understand why. They really had trouble with the idea of revolution and this astounded me because what I thought they wanted to talk about and to display to the public is the miracle of this revolution, of how Moore's Law, in this short period, had transformed a lot. So I was absolutely taken aback because this was the distillation of twenty years of thinking, because I went there with this diagram of the material continuity where function and form are decodable, and then you get something like a smartphone which is a multifunctional thing where its formidable functions are relevant and it completely supersedes countless dedicated objects, like fax machines, telephones, all these things, completely subsumed into this single object. That is revolutionary and in material cultural terms let alone in technological terms, that's the technology that underpinned this revolution in material culture and this is a museum in which its primary medium is material culture so surely there's a wonderful convergence here. Outcry. There was more heat generated in that room than light. It was completely bewildering. Afterwards John Mashey explained, he was a lovely guy, and he said ... he wasn't opposed to revolution and what he tried to do was to explain why this may have touched a nerve. The explanation he gave was this. He said, 'Moore's Law is not a law. It doesn't happen anyway. We went into work every day, in a solid-state physics lab, to make Moore's Law work. If you call it a revolution it sounds like it was inevitable and it diminishes the practitioners that implemented it.' And I understood. Now, whether the others were aware that that's what the button that was being pushed I don't know, but Mashey was big enough to actually be self-reflective of himself and say, that if you call it a revolution it sounds as though . . if you call it Moore's Law and don't articulate actually what you mean . . . there's no inherent law in nature which says it's going to double your whatever it

is every year, you had to make that happen, it was within the parameters of nature to allow that but it didn't happen in virtue of those parameters. It happened because of us. So, historically, one should not diminish the people responsible for the IT revolution. And I thought that was a profound answer because it explains why forty years is nothing in two thousand years but in a lifetime it's the entire professional life of the generation of people who actually made it happen.

1:09:32

So how did you manage to have Revolution in the title eventually?

I'd left, I'd given the prospectus, and I don't know ...words 'two thousand years' and Kirsten Tashev who led the project was responsible for the final thing. So they accepted it. I was very gratified that they ultimately accepted both the layout, the viewing platform, the icon alcove pattern and the whole principle of revolution being the driver of what was exceptional about the story that needed to be told.

So there was some kind of ...

...reconciliation. There's a cultural message there. You know, the two thousand years, I wanted to say there's a pre-history, the first two thousand years we're not at the end of days, and revolution is the story. One might dismiss revolution, but there was something behind that and they were willing to accept it.

In 2008 you created another exhibition at the Computer History Museum.

Yes. '*Another Age must be the Judge'* is the name of the Babbage exhibition I did there.

So it's a quotation you use, so what is the judgment about Babbage?

Yes, the big question is Babbage was deeply embittered and disillusioned by the fact that he got no recognition, that people didn't understand what he could see about the potential of computers. He was quite embittered by the end of his life and he refused

various honours because he said that 'I will only accept honours for the engines, not as a compensation for not having done the engines'. I dug that quote out of his ... in 1989 something else happened, which we didn't discuss. I read the entire collected works of Babbage in eight months, I spent eight months going through eleven volumes and cross-referencing the content, and that's essentially what I based my Babbage career on, on those eleven volumes. I read everything he had ever published. Now I've looked at every single manuscript page of the 7,000 pages of manuscript but at that stage I hadn't. That creates an authority and the reason is not an authority because that means I know something that no one else knows, it gives me an authority because I know there's nothing I'm going to find that Babbage said about this topic that alters or modifies or qualifies what I have taken to be the case. And until that is the case you cannot say anything with absolute authority about what Babbage thought could be because it's changeable. It's terribly difficult to deal with Babbage because you'll find in a paper on taxation something crucial about the engine. And so he keeps looping back and repeating things and putting things in very unlikely places. So, having read the entire collected works of Babbage, you know, I did this evenings, whatever time I had I'd use, I didn't spend eight months full-time, it took over a period of eight months I read every volume, cross-referenced it by categories I created so I could always look up things to do with various things, what was his interest in patents, what is his attitude to patent protection, what is his attitude to various things, and in it there is a thing where Babbage is saying that nobody takes any notice of these things and he says he is convinced of the importance of this work, he is convinced of the importance of it, and he said, 'another age must be the judge'. He's saying, Ok, you've rejected it therefore another age must be the judge, in full confidence that they will see ... what did he say ... it's a wonderful expression he used ... to the effect that it will take somebody else later to really understand what I've done, as indeed proved to be the case. There's practically no logical principle of a modern electronic digital computer that is not explicitly embodied in the mechanics of Babbage's Analytical Engine. So when he says another age must be the judge, and he has an exhibition with his engine in it, so that was the strapline of the thing. That was done to coincide with the delivery to the Computer History Museum of the completed second – it's not a replica, it's a multiple original – of the thing that was in a private collection funded by Nathan Myhrvold, and it was delivered there and the exhibition

was to host the engine which was run every day for seven years then, to the public. And it was a sensation, it was a magic exhibition.

And this brings us to the importance, also, of why working machines for the public, for the people to understand what a computer is, or what that specific computer was, what it meant to use that machine.

Yes, absolutely. It was a piece of experimental history and the idea was to use it to print tables to see what was practical. It wasn't saying, oops, yes, this produces tables, how did it produce tables? You put Plaster of Paris in the trays, the Plaster of Paris has to be the right consistency, if it's too loose it doesn't give the impression and will break the *whatdoyoucallit.* How long would it take to produce one volume of tables. I reckon it's eight hours a day for one month. That means you have to get a team of people mixing Plaster of Paris to make sure that the replacement tray is exactly the right consistency for when you need it otherwise it's going to take longer. So the idea was to explore practically how, if Babbage's vision had been realised in the nineteenth century, whether it was a feasible thing. Maurice Wilkes says it wasn't, it was a nonsense idea. An interesting idea but not a practical one. So the idea was to do experimental history in that way, and we did, we produced tablets of prints.

Going back to the judgment about Babbage, what about Ada Lovelace?

Ada Lovelace is another way in which to get a computer historian to leave the room, because so much has been written about her which is, some of it, well-founded and other not well-founded. Ada Lovelace is supposedly famous for four things: she was the first programmer - I'm not saying this, I'm saying this is why other people have celebrated her – she was a mathematical genius, she had a major influence in the design of the Analytical Engine and she was a prophet of the computer age. Those are four things journalists say Ada Lovelace is famous for. Right, was she a mathematical genius? The answer is, she was a very promising novice, she did not discover any new theorems, she left no long-lasting mathematical legacy, she was possibly a very good mathematician, she died before it could be verified, she was a scintillating and hugely interested and monstrously bright student of mathematics.

Babbage was a mathematician, he was a professional mathematician, he'd published thirteen papers by the time he was twenty-one. He's not regarded primarily as a mathematician, he discovered no new theorems and left no lasting legacy. Calculcus of Functions was his biggest thing which was incidental. You could say Babbage was a mathematician, you wouldn't say Lovelace was a mathematician in professional terms. So one [claim] is that she was a brilliant, a mathematical genius. Second thing, I said she was the first programmer. The reason she's thought of as the first programmer is because, in 1843, she published her single publication called a 'Sketch of the Analytical Engine' which was a translation of a shorter paper by Menabrea, published in French, which resulted from a visit that Babbage paid to Turin in the early eighteen forties. So he [Menabrea] wrote about the analytical engine based on Babbage's lectures. Lovelace translated this. Now, in it she has notes which are three times the length of Menabrea's article and, in the notes, there is the table of how you would set up the Analytical Engine to predict Bernoulli numbers, and the reason she's thought of as the first programmer is because this was 'the first program'. It wasn't even the first program published, because in Menabrea's there are three of Babbage's programs. It is possibly the most advanced, there is arguably one more program which is of comparable complexity that Babbage wrote earlier, but even if it is the most advanced it is still ... right, so she was 'the first programmer'. There were programs published by Babbage through Menabrea previously. If you go to the manuscript archive, the L-series in the Science Museum library has at least a dozen programs by Babbage that date from six to seven years prior to the point at which Lovelace even got involved in the Analytical Engine. And the structure of the program, which is to say how the page is laid out, what information is on it, the progressive stepwise algorithmic nature of the thing, is Babbage's structure. The format of Lovelace's program is the same structural format as Babbage's program six years earlier, so it was not the first program. It may have been a very complex program, it made demands on the machine that Babbage hadn't fully explored, that the conversation with Lovelace might have been stimulating to him is probably the case, but to call her the first is historically wrong. The reason people do it is because of journalistic shorthand because if you really explained why she was useful it's a much more interesting ... so, mathematical genius, sorry, bright, brilliant, even brilliant but not a genius is as far as we go, but genius in those days didn't mean what we mean by genius. We mean by genius a superordinate ability that is in excess of

almost everybody else. What they meant by genius was affinity, your genius was your affinity with the thing, your capability of the thing, so we are possibly misjudging when she says I'm a genius. So, a mathematical genius, first programmer, a major influencer on the Analytical Engine. The major work on the Analytical Engine was done before Lovelace had even worked on the mathematics of the first difference engine. Lovelace was born in 1815, Babbage conceived his analytical engine in 1834. Lovelace was late teens at that time. There's no doubt he discussed it with her, I say there's no doubt although I don't know whether he did or didn't but the likelihood is because she was hugely interested and inspired. What she is, and deserves all the credit for, and more credit than she gets for being the first sodding programmer, is the prophet of the computer age. It was she who saw something that Babbage did not see. She saw that the value of computing was the ability to manipulate symbols according to rules of representations of the world. So, a symbol contained a representation of the world, so an ASCI code is a letter of the alphabet and you can manipulate those according to rules and therefore the computer can say something about the world when you map back. So you assign significance to a number and the computer manipulates numbers and you map back those numbers onto the world and you've got a computer than can ... so what she should be heralded for is that she was the one who articulated – not in the terms I'm explaining – but articulated the principle that the significance and importance and future importance of a computer was that it could manipulate representations of the world according to rules, in symbols. And so she uses the analogy that, if you can teach the computer rules of harmony then it can compose music, of any complexity. It may be that there's a reason Babbage didn't see it. The reason is, mathematics was regarded as the grammar of the world, so if you had a mathematical model and you had a machine to do mathematics you didn't need the abstraction between the phenomenon and the symbol, because the mathematics dealt with that, it was a seamless connection, it was what made the world tick, the world operated mathematically. Therefore you didn't have to make a symbolic abstraction between the representation and the thing represented, you didn't have to make that . . ., the letter A and the ASCI code because once you had the mathematics it just explained it. So, there may be a cultural reason but those are interesting things to explore, but the point is, nobody articulated it in the way that Lovelace did. And that is what is extraordinary. So, a prophet of the computer age, I'd say Yup, and I think that's a lot more important than saying you

wrote the first program because quite clearly you didn't. I have absolutely no expectation that the world's perception of Lovelace as being the first programmer will ever change because it's not to do with history, it's to do with the social and our sociological need for people to have a representative, an advocate of a particular viewpoint in relation to science. So, that is at the expense of history, but that's how it is. So Lovelace, Yes, she was very important to Babbage and she was an extraordinary person and I would frame her massive contribution in that she understood, in ways that nobody else did or was able to articulate, the potential of computers to be relevant to the world because of manipulations of a representation in number. All a computer can do is operate on number, it's only if you give meaning to the number that it can say anything else in a program other than about numbers. And so it's that mapping that she saw, that abstraction between symbol, the thing represented, and what was representing it. One of the basic theses of the piece I've just been involved in and written is, in order for a machine to compute requires the physicalisation of number, because the machine can't operate on numbers, it can operate on representations of numbers, so you've got an entire technological history of computing through that. In the nineteenth century it was mechanics, the physicalisation of number was in cogwheels, so you've got a wonderful membrane which runs through – a thread, which runs through the whole thing, that how did they physicalise number, and they physicalised numbers in monstrously bizarre ways – delay lines, the delay-line memory, I mean, that is really unlikely. You get a blob of mercury and send something in and wait and then keep circulating because it takes a period of time to go through, you know, that is pretty far-fetched, so how did they physicalise number in order to do this thing, why was it so important for them to do, to go to these astonishing lengths to do it. Ok, Babbage had mechanics, he never saw anything beyond mechanics, how could he, and Lovelace saw, and it doesn't matter how it's implemented, so yes.

1:25:10

In 2009 the Ferranti Pegasus on display at the London Science Museum had an accident, during or after the demonstrations, on 29 July, so what were the consequences of this event?

Yes, there's a small amount of history to do with that. One of the things about founding the Computer Conservation Society is that we'd bring in practitioners, experts, people who had expertise in these machines, to work on Science Museum inventoried objects. Now, an inventory object in museum culture is sacrosanct, only a museum professional or a curator or somebody authorised can even touch the thing. The reason is, because there's a chain of accountability between that person and the Minister for Education or something, whoever it is. What I was bringing into the Computer Conservation Society were people who were now going to work, they had no conservation training, they had no restoration training, they had no preservation training, they're not imbued with museology, they're engineers, they take pride in making things work. If they can make things work with a paper clip that's good, but for conservation [ethics] it has to be a contemporary paper clip, and there has to have been a paper clip there to begin with. So, one of the questions was ... so, part of my role in creating the Society was to imbue the first generation of what we called the 'working parties', the chairmen and the leaders of the working parties, we set up a working party on each machine, so Pegasus had a working party and it had several chairpersons as the years went by, and we actively imbued them with the curatorial culture, that the ultimate object, evidentiary object in museum culture, is the physical object. What I did was, try and articulate to them why is the object the ultimate reference and the answer is a paper I wrote called Napoleon's Waistcoat Button. It was to do with the fact that, how do you explain to someone who doesn't already subscribe to the idea that objects are sacrosanct in museum culture, that they are the ultimate evidentiary source. The Director of Finance will come up and say, 'look, here's a curator, you can have Napoleon's waistcoat button with a proof of provenance, we know he wore that button at the final battle which he lost, on his waistcoat.' You have a replica of that button, indistinguishable, you have another button from Napoleon's other waistcoat which wasn't worn on that night, but is also physically the same, you have a hologram of that, you've got six objects. And the curator has to choose one. My instinct tells me the curator will choose the original artefact. The question is why. How do you justify to the Director of Finance that it's worth spending n-million on Napoleon's waistcoat button? And the answer I give is this: that objects are the repositories of predicates the [full] significance of which cannot be known. In other words, you interrogate an object in the light of unforeseen enquiry, you don't know what the significance is, you cannot exhaust the significance

of an object and you don't know how you might want to interrogate it in the future. The example I use is, a news story comes along with the thesis that the reason Napoleon lost his last battle is he was allergic to snuff and he took snuff for the first time the night before the battle. Now, it's obvious it would not make sense to examine the replica, the other button, the hologram, for evidence of snuff. It only makes sense to examine the original for traces of snuff to verify this thesis. And I'm saying that that is what underpins the psychology of why objects, original objects, are prized over and above object surrogates, including virtual objects, simulated objects, why the original object is prized over object surrogates in museum culture. Now, I had to translate this, that's one of the techniques, the examples I used to imbue into engineers who take pride in fixing things regardless how – if they can get a fix from somewhere else and improvise something they would regard that as good engineering because the machine works. The machine and the fabric of the machine is a repository of predicates the meanings of which we cannot possibly foresee. In the light of unforeseen enquiry these objects may need to be interrogated and we don't know how they're going to be interrogated by future generations. So if you change a worn-out piece of cloth-bound conductor and put pvc in, in fifty years time somebody is going to come back and say, 'I'm researching the production of pvc in electronics, there's one in Pegasus and it was used in 1952.' Right, you've altered the fabric, you've altered the original datum, the datum of the predicates, and that I believe is what underpins the mystique of the original object. It's a way of describing it. So, here I am inviting people from the outside world who are going to be let loose with no conservation training on the museum's machines. So, we took the three most senior [working party chairpersons] and I inducted them by talking to them in this way and explaining why computers exist, permanence of substance, the significance of material culture, the fact it transcends generations, the way in which you can alter the evidence by getting something to work, the fine balance between whether it's more important to have something working but in a non-original state or it's better to have it intact but not working for the purpose of predicates of subsequent examination. That first generation we dealt with, and those were the people responsible, the Computer Conservation Society was, if you like, the incubator for the major reconstructions: that's Colossus which Tony Sale led [at Bletchley Park], the Manchester Baby, and to some extent, but to a more limited extent, the Bletchley Bombe, these were the major reconstructions of our modern era and they were all

incubated by that group of people that were the first generation, the working party leaders of the Computer Conservation Society. So, we're going back to the Ferranti Pegasus and the display. A smoke alarm was set off while this thing was being demonstrated, so Ferranti Pegasus was on the gallery, I was responsible for getting it there, I used my discretionary funding as assistant director to fund the project, I curated the display, and it was exhibited once a week or every two weeks, whatever.

Two times a week, I think it was Wednesday and Thursday.

Yep, and at some point it set off the fire alarm because there was some fluff in, I believe, there was some fluff in one of the connector strips which caught alight. It was completely safe, nobody was ever at risk, but this flagged for the museum management which was not part of my generation - I was the last chartered engineer on the staff of the [Science} Museum], there are now no engineers, there are generalists and sociologists and all these things. So to be the curator of physics you're no longer a physicist, you're somebody who knows about physics and I don't know if there is a curator of physics anymore, but all that subject specialism is gone. There are now very fine curators who are generalists who can really marshal the real guts of what an argument or what a particular field is to produce exhibitions which is the primary social utility of having objects – but this flagged for the management what commitment the museum continued to have to have working exhibits. Now the museum had an international reputation to be the push-button museum, they pioneered through the children's gallery in the 1920s by having interactive exhibits. Kids can go on the pulleys and wheels and things and touch things, and they founded that entire movement of interactive museums. Now it was coming to the conclusion that the priorities had shifted, they were more interested in generalist audiences rather than specialist audiences, so [in the past] if you were an engineer or a communications engineer you could go to the museum and there'd be an exhibition on telecommunications. If you were a physicist there was an exhibition on physics, a chemist there was an exhibition on chemistry. So the two and a half to five million people who went to the museum was an aggregation of a lot of specialist audiences of scientists, physicists, all these things, the medical galleries. The thing shifted to a general audience, that the lay public was actually, if you'll forgive the obscenity of saying 'customer', to pollute the cultural world with the language and rhetoric of

commerce, it sullies my tongue, but the audience now was not the specialist audiences. That was just a sort of historical accident almost. It was because of the way the early curators were serving their specialised tribal groups, if you like, so the physicist had support and was of interest to a group, the community of physicists. Now the community of people, the people out there wanted ... what does technology signify? is technology always good?, you know, there's water pollution, there's plastic causing awful damage, it's climate change and all those things. Is science an unconditional good. These were the things that were brewing in the eighties, nineties, so the curators are no longer necessarily subject specialists, or they're a subject specialist in one area but they actually have much wider briefs. And this was a period in which they wanted to shut down – there weren't the resources to support demonstrated working exhibits and so the Ferranti Pegasus incident was one which finished off the act of restorations of computers which had started from the 1991 exhibition, in 2009, so that's how long. I was there as an engineer, I wanted to share with the world my joy and pleasure in making things work, and that's what we did and the people who hung around and spoke to engineers ... we built the Babbage engine in public view and it was fascinating.. do you know what questions the public asked? The question they didn't ask was 'if it's a computer how does it work, what is it', most of the questions were to do with 'how did you make that?' because the parts were very intricate. 'How did you make that?' It was to do with manufacturing. Which is terribly interesting because what they were interested in is how was number physicalised, not how does it manipulate number. So, all that value has gone but they have taken a conscious decision and priorities change and it's the case, they don't have the resources, to marshal, to manage, a volunteer organisation, and the way we got over the chain of accountabilities, how do you make somebody who's not a museum staff member accountable, to intervene in an object, for which I was responsible, I was the curator, I'm responsible for those objects, I'm inviting Chris Burton to come in, I'm inviting who was responsible for the Manchester Baby, or I'm inviting Tony Sale in, what happens if something goes wrong? I'm responsible. I am accountable. I am extending that chain of accountability to them and I can only do that by making them responsible by inducting them into this thing. One of the important things about the organisation and about the computer conservation side is, how do you expand the circle of accountability beyond people who are accountable through the reporting structure of a museum organisation, and we successfully did

that. The way we did it was, they examined the machine, they worked out what needed to be done, they wrote a proposal, they brought it to me, and I signed it off. I am then responsible for it. That's how we finessed that, and so we developed the protocols for enlisting the assistance of people outside the chain of accountability of a huge community. And that was copied and used by people subsequently.

1:37:18

In 2009 you also received an MBE from Prince Charles for services ...

To the history of computing, yes. Are you asking a question?

Yes, the question is, what was it like?

It was wonderful. The Palace staff know how to make you – and go out of their way to make you – feel terrific. This is for you, this is the way the nation thanks you. And the entire organisation is geared towards that feeling, creating that feeling in you. It was hugely enjoyable, you were aware all the time that ... firstly, it was fun, secondly, that this was a thank you, it was very gratifying to get, I mean, it was really very gratifying. It was lovely. One, the recognition is wonderful and I'd say I'm invisible and I still think in some archaic way I will be invisible however visible I am and I'm still invisible, and it was something that can be repeated to oneself – can I be invisible if that's [MBE] the case. So it wasn't a question of grandiosity or pride, it was a question of actually being touched by being valued in that way. The other satisfaction is, I did nothing active towards the award, it was done by somebody else who said 'this guy, because of the Babbage engine deserves some acknowledgement'. It was done by somebody else entirely. My principle always has been that honours are not the purpose of good work, they are the result of good work, and that was a wonderful manifestation of that. Somebody else thought I deserved it rather than me saying I'm putting myself forward for it. It never occurred to me to put myself forward for an award, an honour, and so it was a great vindication about the principle and the purpose, that the purpose of good work is not reward, the purpose is to do good work, not to be rewarded.

1:39:41

Plan 28 is a charity established in 2010 to build Babbage's analytical engine. Where did you get it from – can you explain in a few words the meaning of the project, that you went so far on the next steps.

Yes. We built Babbage's difference engine. One can argue Babbage's difference engine is not a computer, it's a calculator. Once we'd built the engine, which was no small thing, I mean, it was a significant technical thing, and also it's a beautiful piece of sculpture the like of which is not seen. To watch this thing working is quite a spectacle. The moment we'd finished it, they said, 'well, when are you going to build the Analytical Engine?' because the Analytical Engine is ten times bigger and embodies almost every principle of the modern general purpose digital and electronic computer. And so the question was, 'ha ha ha, when are you going to build the Analytical Engine?' So that had all been going on but what I didn't know is that one of the people ... we built the difference engine in public view, you could not walk past the main steam gallery of the Science Museum without walking past ... there's a long story about how we got it there ... without walking past the Babbage engine that we built and the engineers were working in the public area assembling this machine. What I didn't know is a chap called John Graham-Cumming used to visit to watch this thing grow, it was built over a period of about eighteen months, and he was quite inspired and taken by this and he is a computer science graduate and a computer science PhD currently working in cyber security, one aspect of cyber security. So, there's people saying, when are you going to build the Analytical Engine and really, the vindication of Babbage is actually with the Analytical Engine, is that a sound design, and I get an email from somebody called John Graham-Cumming who I'd not heard of, asking me about Babbage sources and it was perfectly clear from this ... ok, the history of computing world is quite small and the historians of Babbage are even smaller, you know, maybe there are two [laughs] or four or something. So for somebody to be knowledgeable about Babbage sources that I hadn't heard of was intriguing and he was clearly knowledgeable because he was asking questions about quite obscure sources. I wasn't going to give anything away because I didn't know who he was, so I wrote to him and sort of obliquely said, and then as I was composing this reply to him, essentially trying to conceal, I thought this is ridiculous so I said,

'look, who are you and what's going on here'. So there were a few exchange emails and I told him about some sources and then he emailed about something and we arranged to meet. We met at the Royal Institution and we sat down and I looked at him and I said, 'Who the hell are you?' basically saying you're involved in Babbage and I don't know about you. It turns out that he wants to build an analytical engine, he wants to do what it takes and he wants to know whether I would be interested in joining the show, joining the project. So I listened to him and, to me, the question is 'what are the motives?' and the way he articulated motives would have any public sector educationalists or any person in the museum who was an advocate for the educational value of (a) working exhibits and (b) the value of material culture in explaining things to the world, you could not have articulated more soundly and profoundly than he did. So I knew, his motives are completely to do with education, bringing to the public things for historical purpose. So he created the charity, he is the prime mover in this, I joined the team as it were, the team is myself and Tim Robinson, and he created the charity. We could not do the work without digitising the archive. The archive involved digitising some 500 drawings and some 7,000 sheets of manuscript. Because they are held in a library seventy miles outside London and access is restricted, you could do four hours a day, the round trip is nearly five hours to get there and back, so it was not practical to study these things in depth. So we started negotiating with the museum to get the archive digitised which we succeeded in doing, we now have licensed to access to it and it's indispensable, and what we've done since is, we decided to try and understand the Analytical Engine by cherry-picking the main drawings. We found out, after several years, that we could not reverse engineer Babbage's conception of the engine from the known few drawings that were there. Tim Robinson, who built Meccano versions of the first difference engine and the second difference engine, has decoded Babbage's thinking but gone further than we've gone because he's trying to translate it into a new medium, how would you implement this in Meccano if you can't custom-fashion objects. How do you make a Lego version of a Babbage engine which goes beyond just understanding design of it, and saying how do you translate that design. So, it's been established, the charity exists, I don't believe it will be difficult getting money for it, you've got crowd sourcing or ... I think if we said, here's a plan, this is the engine we want to build, it's the Analytical Engine, the most extraordinary thing done, I think we will get the money. But money is not our restriction right now. The question is, to

understand the designs which we could not reverse engineer. There were questions that we could not answer from the known famous drawings which were the ones we had access to. We now have access to the whole lot so what we've been doing is going through the entire archive, going through 7,000 manuscript sheets to find every reference to his mechanical notations. The Mechanical Notation is like a Hardware Description Language, something he [Babbage] devised which is a symbolic description of the machine, and we have a three-year research project with Leverhulme for me to decode that. And the way we decoded it was wonderful. We used the Rosetta Stone principle, ok. If you can see an engine as a text, you have an idea and you express it through syntax, in this case mechanical syntax, as a text, but we also had the Notations of the engine and we built the engine without reference to the Notations, these strings of quasi-mathematical formulations, because the language has lapsed into disuse and there was nobody who can speak the language. So now we have an engine which a few of us understand intimately and know what every part does, and we have a Notation which describes what every part does, using crazy cryptographic symbols, and we can now decode. The way I did it was to decode the description of the engine from the drawings and the knowledge of what each of the parts do. So, we've cracked the Notation and Babbage used the notation massively, extensively, in the design of the Analytical Engine, so the question is, is there logic embodied in these notations to the Analytical Engine that is not in the mechanical drawings, we were not in a position to know until we could decode the Notation. We also need access to see every instance in which Babbage referred to the same topic because his stuff changes all the time. As he developed something else he overrides and supersedes something that's gone before, he doesn't re-adapt what went before. So if we build a meaningful engine we're going to have to make design decisions about what version of this engine we're going to build. What Plan 28 is, we thought we were going to build the engine. What Plan 28 is right now, is a research project to put us in a position to specify an engine that will be historically meaningful from Babbage's analytical designs. That's the aim of the project and that is what we are currently doing. Whether it gets done in my lifetime I don't know but what would be massively satisfying is to crack it, is to actually understand the Analytical Engine in ways that Babbage intended.

1:48:14

Thank you. Over the years you also worked as a consultant for research and development for a wide number of clients. What were the most interesting ones?

They were interesting for different reasons. There was one consultation I did for a legal firm which was very interesting. They were involved in a kind of trade descriptions, a copyright or a trade description, the use of a word in the description of a product which the engineers, that the company producing this, wanted to protect. And they wanted to know whether this had been , as it were, bespoken by any other – not formally but historically – and they wanted to know the state of computing in 1943, the mid 1940s. So that is the most direct consultation you can have as a consultant in early computing, what was considered to be a computer in 1947, and would it be correct, you know, so it was a way of inputting historical content into a legal case to do with what was understood by what a computer was. I thought, you can't get a more direct consultation as an historian of computing than to be asked by a law firm what a computer was. That was one of them. Another one was with W S Atkins, the consultancy in Epsom. I knew I was going to Cambridge and I had four months and I took a job there to, I think I might have mentioned earlier, to do a survey of mini-computer applications in the medical field. Because I was, in a sense, self-taught and because when I got into computers, which was in the late 1960s, early 1970s, the field wasn't fully professionalised, the idea that you were either a programmer or a hardware designer was completely alien to me because I was an electronics engineer so I knew how to design digital circuits and, in fact, my thesis involved a TTL noise generator, and so I left South Africa with both hardware expertise and programming expertise. And sitting at Atkins, in the desk alongside me, there was a software programmer, a software man, and he was tearing his hair out because a situation had arisen in which the group I was with was exploring a particular mini-computer and the software guy said, 'we need to communicate between the mini-computer and the mainframe in the other building and the mainframe people say it's the mini-computer's problem and the mini-computer people are saying [otherwise] and I'm just the software guy who writes the programs and we're stalled, we can't do anything'. It wasn't my job, it wasn't my brief, and so I started talking to him and said, 'Well, look, an engineer resolves an issue of contention by experiment. There's a direct wired line between the mini-computer and

the mainframe. Tell the mainframe people, we'll get the mainframe people to connect these wires up so they can receive a signal from us. You write a program that sends a signal down the line. We tell them it's coming, if it doesn't come it's us. If it does come, and they receive it, there's no problem. If it doesn't come, or if they don't receive it or there's a problem, we'll loop the wire at the far end and see if the signal comes back to us because then it will be them, not us'. So I was just chatting to him and devised this thing and, because it wasn't part of my brief, which was being billed to some other budget, we decided to come in on a Saturday to do the test. So this was David and Goliath. It was a little French mini-computer and there was this huge mainframe. And the two of us came in on the Saturday, to run this test, and what I didn't know is that the senior managers of the company, including the head of our group, had heard about this and they came in on the Saturday to observe. So we ran the test and we sent the signal and they said 'we haven't got the signal'. So I said, well loop the wire and we'll see, and the signal didn't come back, so it was in the minicomputer. So they went to the manufacturer of the mini computer, actually it was a French company, and said, 'we've got a problem here, we've had this issue and we've done the tests and it's your computer'. And they said, 'Yup, it's still under development'. Now, why that's significant, is because the silos of the professional areas of expertise of software and hardware didn't exist for me which is why it wasn't a struggle to see what needed to be done. You had to get the two together and have a conversation to see who didn't reply. So that was a realisation about the fact that the professional structure of IT, that my experience of it had not been a traditional one. Yes, that's a legal one, that was Atkins, there were others, Felix Learning Systems, Interactive Teaching, Webster software was to do with advising them on ... it was a period where business and gaming software companies were becoming rivals, the question was how could Websters get some advantage because they had huge numbers of games and business software coming in, how do you get them to buy ... this was stuff being sold at W.H. Smith, it wasn't big software stuff, this was consumer items, how do you get them to say 'this is the one you need to buy'. So I did a consultancy on that, how you would run them, if you wanted to run them to demonstrate. So, it was all kinds of stuff, to do with minicomputers and software. All of them had lessons. Simtec in America, that was a six-month consultancy. I was systems integration manager for the second-biggest Apple dealer and they started Apple schools. This was early eighties, '81, just before the IBM PC came out, and

because I had museum experience, *whatdoyoucallit,* the idea was that we were going to create classrooms where you gave courses on personal computers, where each of you had a personal computer in the room - this was revolutionary stuff - wired in to a central thing where the instructor was, and because I had the whole WordStar programs I knew that whole suite inside out and that's what they were running [WordStar, DataStar, SpellStar, MailMerge, CalcStar . . by MicroPro International:]. So I was systems integration manager and I was responsible for the technology of producing this classroom, if you like, and did a lot of other consultancy roles there. It was good, six months working in the corporate environment in America was interesting.

1:55:42

You were interviewed many times for radio and TV programmes, what was your first interview like, or what about the most exciting?

Wow, I haven't given thought to that so I will think about that on the spot. I can't remember what my first interview was like. One is, I talk very fast and that's not good for being recorded, you need to spell everything out and my mind races ahead and I tend to gobble things up as will be evident from this recording. I've got better at disciplining that but when I get excited it goes to pot, so I suspect that the first interview – and I can't remember what the first interview was, it may be in the list somewhere – would likely have been excitement and nervousness. What is the most exciting? I would say that that was to do with working with a man called John Feugi . He makes documentaries and he's an absolutely uncompromising purist with documentaries. He will not use anything that is not original, so he will not use dramatisations, he will not use actors, and if he does something on Lovelace which he did, he will film it in Lovelace's apartments and have a voiceover. He contacted me because he was doing this movie, it was a documentary on Lovelace, and he wanted to interview me on Babbage and I was then at the [Science] Museum so we set up some wonderful things for interviews, contemporary artefacts, and the curators were wonderfully co-operative, and he gave me advance ... and I said, you know, 'what sort of things do you want to discuss?' and he gave me an advance list of this and this and this. We had many interviews over the three years the thing was made, and we

demonstrated the Engine to him and he had a superb cinematographer who took some footage and stuff, and what happened was, he always threw me a curve ball. He always asked me a question that he had not prepared me for, and I said, 'Hey, why did you do that, why did you ask me a question that I'd not prepared for, that I didn't know was coming?' and he said, 'What we've found is, that if you ask something unexpected that people are more transparent, you get a truer first reaction than if there's been time to actually rehearse and polish what you say.' Now, with Babbage, because I've written so extensively about it, repeatedly over decades, when I'm asked a question I don't think of it afresh, I don't think of it in a fresh way, I use something that is through lectures and writing, countless lectures, something that is already at the tip of my tongue, it's already rehearsed, it's very clear, but inevitably it doesn't have the immediacy of something you're thinking about as you say it. And he said, 'the reason we do that is we find that there's a greater immediacy if you ask something unexpected' so I think that probably was the most instructive point. By and large, television and radio are one of the most depersonalising remote things imaginable. You are not present, you are a talking head, you are a figure, you're a curator, you're an x, it's not to do with you, it's to do with an agenda of communication, and that is quite ... I won't say shocking ... it was unexpected and quite distancing from the thing. It's quite ruthless. They're interested in the particular agenda they have, it's very rare that you are asked questions in an open-ended way and listen to what comes out. Almost all media is directed and they have a preconception about what it is they want verified, vindicated or justified, there's very little open-ended material in there. Often enough, and what it is based on, they use secondary sources, they use Wikipedia and things, so you get this perpetuation of these preconceptions. I've spoken to people who talk about Lovelace, who will not budge from the idea that she was the first programmer, who will not budge to give her credit for something else that actually is more important and they get quite dogmatic about it. They have a conception of a story that they will tell that is relativised and tailored to what they believe the public want, and that was one of the beauties of being a curator because you are the communicator, you are the person responsible for the integrity of the communication. It's a massively privileged thing to be and by acquiring objects you are determining the histories that future generations will tell of our age. And the same is true of any form of education so, in fact, the media is in some sense a diffusing influence by perpetuating what appears to be dramatic, theatrical, declamatory and sensational. So,

the overall experience is that it's useful to do because it creates outreach. Media is about outreach and I justify it, from the public service standpoint, in that it creates awareness of what we're doing. In itself it's a medium that is not rewarding to get into.

It seems to me that, during your career, you managed to have a perfect balance between your theoretical role as a scholar, curator and manager and your design engineering and practical skills. What do you think about this?

Well, that's embarrassingly flattering. I recognise it but not possibly for the reasons because I didn't actively try and balance anything. Because balance implies that these things are separate, you have to balance this against that, or do as much of this as you do of that, practical and theoretical, you know, which is more important, and I've never seen it as separate so the thing I would flag on that is the notion of a balance: I've never seen .... I have a workshop, I've always had a workshop and I make things ... I've never seen fashioning a piece of wood or sandpapering as any different from panel-beating a paragraph of language into something. I've never seen the difference in it. I do not regard these discourses as separate. Being a curator, being a manager? Being a manager is being a social engineer. What parts do you need to make this function work? Do you have enough understanding of that person, in the same way that you have enough understanding of that integrated circuit to make the circuit work? Do you have an understanding of that person for them to function in a wholesome way? And the first thing I did when I became Assistant Director and Head of Collection - I was responsible, there were 120 people in the collections division – I sat down with every single member of staff and spent as long as it took to ask what they wanted to do, because I know that, if what they wanted to do was productive in terms the museum understood, and I created an environment for them to do it, you would have somebody who would work ten times better than anyone else. So the job was to tailor the environment to the person's aspirations and every team I ever set up had that in mind. The disappointment was, that I didn't realise people weren't as aspirational. I thought people were like me, they were dying to bust out of the cupboard and write four books or six books, or do exhibitions, and I realised that people come to work, not necessarily with that ambition in mind. They want to do a good job, they want to do a responsible job, but there was a difference between

process management and goal-directed [activity] so there are goal-driven people and we have process-driven people, people who do a wonderful job, and the goal-driven people rely on the process people because those are the people who implement. So the question is one of balance. I've never tried to balance everything, I'm a useless balancer because I'm obsessive, so I will work for six months and work myself to exhaustion on one thing because I find changing difficult. Fighting mental dispersion is difficult, I get interested and excited by too many things, which is why I have to have a really convergent discipline to do just one thing which is why the PhD was very self-satisfying. So, I would question the word 'balance'. I've never seen the difference between being a curator, being a manager, being an engineer – they're all to do with a quality of judgment you bring to the appropriateness of what you are creating. So, for a group of people who work together they have to have appropriate relationships, for a device to work in relation to another device it has to have an appropriate relationship, and I don't see them as any different. I've never seen sanding a thing to bring out the grain in a piece of wood any different from crafting a paragraph that subconsciously anticipates the way the person is going to expect the language to run and then confirming it. The way I would compare it to is riding a bike. You come down a hill and the question is, can you go down the hill and use the momentum without braking, without using the brakes, and it's that continuity, that seamless continuity, so when you start a sentence – you're writing or you're authoring something – you're creating an expectation of what's to come by the way you say it and then confirm it by saying it, and that is what satisfied reading is. That's not without surprises and all those other things, but it's to do with that momentum, you're creating a momentum, you're going down a hill, you know you're going down the hill, you know you're in the sentence, you know there's a train of thought here, that if you can get them plugged into the train of thought by creating their own expectation of what is to come, and you've got them writing it, and then you confirm that by saying it in a way that articulates the unasked question. So, I see all that in a curator, a manager, a practical worker, as part of that appropriate relationship, creating an appropriate relationship.

2:06:18

Is there anything you would do differently if you had the chance?

Yes. I would be more assertive, I was much too apologetic and I was not nearly confrontational enough. I wanted to be liked too much to actually ... so I buried a lot of what I thought and wasn't nearly articulate enough and a strong enough advocate for things. Yes, I regret the many situations in which I should have been more assertive. At the meeting, at the Computer History Museum, when they were dismayed by the use of the word 'revolution' I should have said, 'Gentlemen, this is the distillation of twenty years of work, that's all I've got, you don't need me.' 'If you don't want this you don't want me.' I wasn't assertive enough. I was appalled, I thought what have I done wrong, what's wrong with this thesis, there must be something wrong with the thesis. So, yes, I would probably have been a better planner, I would have been more assertive. It gets better as you get older, you care less, but I was much too awed, humbled and deferential in situations where there were things that needed to be said. The advocacy for material culture in museums, as the primary mission of an institution, compared to science communication and temporary exhibitions, that needed to be ... I was the ambassador for that, I was the advocate for that and I should have used the environments and arenas I had more publicly than I did. Yes, assertiveness is the one-word answer I would give.

What do you think are the biggest challenges and opportunities for computer museums in the next ten years?

Computer museums?

Or science museums that involve computers...or IT.

Material culture. One is to maintain the continuity and depth of collections. Because there are now few, if any ... the exception is the Computer History Museum, the exception is technical museums, the exception is the old traditional museums in Europe that still have subject specialists ... but I'd say, for the cosmopolitan museums, without subject specialists ... I say that, the huge privilege of being a curator and the value of a museum is to use the permanence of substance to create a material record of technological change. The legacy, the residue of our tenure of curatorship, or a museum, is in the physical, in the collection. And it's the permanence of substance,

things that outlast us, that is the legacy of the story of our times, so we need to tell the story of our times leaving physical artefacts as evidence. People may reinterpret them, they may change the story, maybe things will be revealed that we didn't know about, that's not the point. Our responsibility is to tell the story as we experience it in terms of the physical artefacts. Now, the point at which you cease to have subject specialists makes the story very difficult to tell. How do you know what is significant? Ideally, you're a practitioner so you know what's significant, for example, there was a curator, he became the curator of communications and he gave a paper to an assembled engineering thing, to a group of engineers, in his official capacity and he was asked a question, 'How does the microphone work?' Ok, I told you, from the age of six or something I was buying army surplus things and taking microphones and earphones apart to see how they worked and experiment with them. I don't need to be told, nobody had taught me, that the Coherer microphone has carbon granules in it which you have to shake every so often to disaggregate them. Nobody ever told me that, it's because I opened microphones and saw them. So, as curator of computing and communications, and somebody asked the question, 'how does that work?' and the curator of communications didn't know and it caused difficulty because the engineer wrote to the director of the museum .... this was [about] a member of my staff ... and said that 'I was appalled that the museum could field somebody who doesn't know how that microphone worked.' And the director gave it [the letter] to me - and I was the assistant director and this was one of my staff members, this was my curator – to write to this guy, and I said that he was there to present artefacts, that he's a custodian of artefacts, that yes, ideally, he should be so on and so on, so I fudged and tried .... and he said, 'that's not good enough, you're the Science Museum', so ... how did we get onto that?

The biggest challenges and opportunities for the future of museums.

Yes, so that's an example of somebody who was not a subject specialist, he was a very fine curator who had risen properly and appropriately high up in the hierarchy of museum management. He was very conscientious, a very bright guy, he had a PhD in a computer-linked subject. There's an instance in which somebody who wasn't a subject specialist could not have collected, in a way that a subject specialist would have collected, the subject expert could see that that is of interest because it's an

anomaly, not because it's generic. He would take a failed exhibit, a failed product, because it illustrates something of a misconception of the people who conceived it. The generalist would say something like it's typical of its kind, it would mean that somebody would need to tell them that this is special because, hey, this is the one that didn't work, you know, the Apple Peanut or whatever it was. Apple products were good because there were two which didn't fly, at least, there was the Apple 3, there were two Apples which didn't fly and they are interesting stories to do with this. Now, it's only somebody who knows ... how would you evaluate what a specialist comes to tell you about the meaning of an object unless you have the internalist's knowledge of it. So, the challenge to museums is, how do you protect the future of collections to ensure the same, almost eccentric authority, as in the past. The curator was the custodian of that collection, it was his collection, her collection, they had a very strong sense of personal identification and curators had huge power to acquire what they wished, they didn't have to justify what they acquired, you could scribble on a piece of paper 'acquire this object' and a whole team of people would go and get it, do an inventory and put it away etc, you never needed to say why. Now it's much more bureaucratised, you have to make an acquisitions case and it goes to a committee. So the person who is passionate about the object is not the person exercising the criterion of its acquisition. It's somebody else. Now, the collections are as rich as they are because half the curators were nuts; they were obsessive about their subject matter, they knew all the kinks and cracks and what's in the collection, if you like, is a serial progression of personal takes of what the story that we're telling is. The biggest challenge to museums is, if you don't do that how do you ensure the integrity of richness and authority. Collecting has dropped from two and a half thousand objects a year, when I was Assistant Director, it's under two hundred now, I think, that may have changed but the last time I looked that's what it was. They shut down collecting when they outsourced it, curators couldn't be bothered going to committees, writing reports and all the rest of it. I hope it's changed. So, the biggest challenge to museums is not now, there's enough to draw on, but what will future generations tell of our age as a result of the material record that our contemporaries now have left upon which they are to construct our histories. That's the question. That's for institutions, yes.

What advice would you give to someone who wished to pursue your career as a museum professional today?

My answer would be, try and apprentice yourself in a major national institution where the traditional curatorial practices are still part of the culture. You can deviate from that, you can do whatever you like after that, but that rationale that I have articulated about why it is original objects are prized, why it is in museum culture they are sacrosanct, the notions of evidence, the notions of the sanctity of artefacts, the principles of permanence of substance of people's relationships with artefacts, the stories you tell. Do that from the people who do it best or sample at least the previous culture that has been superseded. In most of the big nationals, actually the culture has remained to some extent intact, the ones with three or four hundred curators, there are not many of them but they exist, and I would say, get into a big organisation where you can experience the kaleidoscope of skills involved in museology, of conservation, of restoration, of documentation, of management, of project work and all that, exposure. Exposure in the environment that is most representative and the fullest part of a museum institution. I would say, make sure you apprentice yourself well, is the advice I would give.

And now, instead, what advice would you give to a young historian of computing?

That's difficult. I would say, always try and do good work. The fascinating thing about history is, there is no guarantee that there is enough evidence to reconstruct the story. So, for a young historian, you have to learn the techniques for reconstructing the best story you can from the available evidence, which may be fragmentary. I would say, again, an apprenticeship, learn that from the people who do it best. Learn that from the people who do it best.

Thank you for your generosity today.

Thank you for your endurance!

It was not that difficult, and it's been a real pleasure talking to you.

Thank you very, very much for listening in the way you did and leaving the thing open-ended to allow me to wallow in the extent of my own loquacity.

Thank you.

[recording ends at 2:17:48]