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AN ORAL HISTORY OF BRITISH SCIENCE

Professor Sir Tony Hoare

Interviewed by Dr Thomas Lean

C1379/52

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Interview Summary Sheet Title Page

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Occupation:	Computer scientist	**Date and place of birth:**	
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Track 1

How about we start with me asking you to introduce yourself?

Certainly [laughs]. I'm Tony Hoare, often publishing under the name CAR Hoare, which stands for Charles Anthony Richard Hoare but in recent years I have come to be known as Tony.

When were you born?

11th of January 1934 in Colombo in Ceylon which is now Sri Lanka, at the Fraser Nursing Home and I spent my first eleven, ten years or so in Ceylon mostly. My father was a colonial civil servant and my mother was the daughter of a tea planter in Ceylon and they met out there and married out there. And had four children out there and I have two brothers and two sisters, one of whom was born in England after we came back in 1945.

What were your parents' names?

My father was called Henry, HSM, Henry Samuel Malorty, and my mother was called Marjorie Francis Villas.

Could you describe what your father was like to me please?

Yes, handsome, fairly thin man and … [both laugh] … and he looked after us well [laughs].

What was his personality like?

Very pleasant, quite humorous and sometimes a bit strict, but we had our usual sort of spats during adolescence but I've certainly come to respect him a lot more since then [laughs].

And you said he was a colonial civil servant, whereabouts in the civil service did he work?

Well it seemed to be rather general, he had a spell as the secretary or *aide de conct* [ph] of the governor but the longest spell was probably as principle collector of customs at Colombo port, a post which he occupied throughout the war. During the war his – the entire family, who were then just three boys and my mother, because refugees in – in Africa, we went to Africa to escape the dangers of the war in Ceylon because on the sinking of *Prince of Wales* and *Repulse* and the fall of Singapore Ceylon became indefensible and everybody was expecting a Japanese invasion. Which fortunately never happened, all that happened was a single air raid while we were still on the boat crossing to Africa, otherwise he was untouched by the war, as we were in Rhodesia. My father arranged that we should stay initially with a school friend of his who was a tobacco planter in Rhodesia, that was our introduction to emigrate life [ph]. We spent eighteen months or so in Rhodesia, my mother took a job as a matron in a school in Bulawayo and I and my brothers went to school in Gwelo. My brothers went to a nunnery school and I went to sort of conventional school based on the English model of a prep school called the Kingsley Fairbridge School, whether I did very well academically at least, but I was a bit of a handful [both laugh] from the point of view of discipline and … and particularly with my mother, apparently had some difficulty [laughs].

In what sense a handful?

I think just basically just rude and disobedient in the way that [laughs] children are. My granddaughter had similar attributes at a similar age [laughs]. No, I think my own children were better behaved than I was. Well after eighteen months there was a prospect that we would be able to return to Ceylon and so we migrated to Durban which was the port of embarkation for a trip across the Indian Ocean. Unfortunately I think there were some resurgence of hostilities and so we had to stay there for six months, I went to school again there.

[05:50]

And eventually made it to meet this strange man who came [laughs] aboard to kiss my mother and welcome us home. And again went to school in Ceylon at a rather progressive school in Bandarawela. So I had a bit of a disturbed education which I remember chiefly from the fact that every school I attended I learnt least common multiples and greatest common dividers again [both laugh]. Then after quite a short time, oh perhaps six months in a school – in the school in Ceylon we got a passage back to England. Well I think it was delayed slightly by the birth of my sister, Dorothy Anne. And went to school in Oxford, Dragon School, which was the same school that my father had attended and started again with LCMs [both laugh] and … but I'd had very – very disrupted educational background, so I was starting in a fairly low form of the school and that they used to give fortnightly reports to the parents on the progress of their children and my progress reports weren't very good. So after a month they put me down, down a whole year in fact, to – to learn with the brighter students who were a year young than me, that was a very good move. And in fact I was – after a few weeks I was no longer bottom of the class and by the end of the term I was top of the class.

How did you feel about being put down that year?

Well [both laugh] I didn't – don't remember resenting it [laughs]. But the school had a very progressive policy and when I was top of the class they put me up again to my standard year. And I followed similar progression from the bottom to the top and after a – a year I'd made it to the top form in the school in all my subjects so [laughs] I wasn't quite top of that, in fact I was fairly low, remained fairly low down in the top class [laughs] [doorbell sounding].

[08:45]

So my subjects were traditional at that time, Latin and Greek of course, mathematics, French, geography, divinity, physical education, which I never either liked or excelled at. And all these subjects I had effectively started my education when I came back to England. And made very rapid progress, sufficiently that they thought I would – had a good chance of getting a scholarship to a public school and there was a public school which had a closed scholarship which of course would be easier to get. The

Kings School Canterbury had a scholarship which had been founded in memory of Milner, the sort of colonial, African colonial apologist and guru. And indeed so it proved, I got the scholarship and it supported quite a good proportion of the expenses of tuition at that school at that time. Both my brothers also got scholarships to the same school so we had a somewhat cheapened education [both laugh].

And did you have to go through any process to get the scholarship?

Oh there was an examination, examination I think held at the prep school as far as I recall, which was marked. Since it was at – the scholarship was closed to the sons of colonial ex-civil servants so probably [laughs] wasn't a very great field. So I went through the normal – entered the school in the fifth form and went through the normal curriculum of taking the school certificate after one year, and did very well in Latin and Greek and mathematics I think, and something else. And so the year after I was entered for the classical sixth form where I continued more intensive studies of Latin and Greek and subsidiary French. Subsidiary French I studied one year and subsidiary divinity for the other. And divinity was because I could read the – read the gospels in – in the original Greek, so that was not a very divine activity [laughs] but quite an interesting one.

[11:55]

Were you religious at all when you were growing?

Yes, well intermittently, I lost my faith already at the school in Ceylon when the headmaster, whom I must have admired a lot admitted that he had no faith, but I reacquired it at the prep school and became in fact quite religious in the public school before losing my faith again some time in the sixth form. And I have never been tempted that way again since.

Why did you regain it?

I don't know, I just suddenly was thinking, I think it was a sort of act of humility, how silly I was to set myself against the accepted wisdom of many centuries of religion.

And I lost it again because I couldn't any longer believe in immorality of the soul, I couldn't believe that I would – was condemned to live forever [laughs]. [Break in recording].

[13:15]

You were saying about not believing in mortality.

Yes. So I've been quite reconciled to lack of religion for many years.

Was there anything in particular that caused that change in mindset?

I think it was just thinking quietly to myself about things in general, and coming up with a conclusion that would have surprised me if you'd asked me [laughs]. I can't – never thought of any other – other reasons, other than pure reason for setting my beliefs I suppose [both laugh].

Were your parents religious at all?

They were religious, my mother was a Roman – brought up as a Roman Catholic, her parents were converts I think and indeed when I was born there was some doubt about my survival and she made a resolution to bring me up as a Catholic and had me baptised in the Catholic which she sort of always felt was the truer faith. However I think she lapsed somewhat [laughs] in subsequent years so I was brought up as an Anglican. And – but she did attend a sort of revivalist meeting given by Billy Graham after some years – some years we'd returned to England and both she and my father became more religious and took a lot of – quite a lot of interest in parish affairs, in fact my father was a lay reader for many years. So I think they were – that was before I'd lost my faith for the last time and told them about it, I think they were a bit disappointed but never showed it [laughs].

[15:40]

You've mentioned a lot of different sort of schools in passing and I was just wondering, you know, which of them do you remember the most?

Well probably the Dragon School was the most memorable, most recent and the one I stayed in longest perhaps, all of a year and a half [laughs]. The Kings School, I was there for nearly five years and so I remember that quite well, and I'm a member of their old boys association. That was a lovely place, in the precincts of Canterbury Cathedral and I think very good teaching and that brought me on quite a bit. I took my higher school certificate or advanced levels after only one year in the sixth form which was a bit unusual, and in fact I scored top of the upper sixth form for the remaining three years that I was at – and I was [laughs] high up in the lists. I was always beaten by somebody called Barry Lock, a very nice chap whom I met again recently, last year and – and was very good for me not to be top I think [both laugh], you know.

Why do you say that?

Sorry?

Why do you say it was very good for you not to be top?

I think one can become arrogant, I happen to know [both laugh]. Always have something more to strive for [laughs]. Anyway, when the time came to go to university I naturally applied for my father's old college which was Merton College at Oxford and this time I went to – to Merton to sit the examinations and they awarded me an exhibition which is a sort of lesser scholarship paying only eighty pounds a year instead of 100 pounds a year. But at that time the scholarships were supplemented with a state scholarship and so my expenses and fees were paid in full, I didn't have to borrow. And I chose the usual for year course for classical students which is Latin and Greek for the first five terms, and … philosophy and ancient history for the next seven terms. I was not a brilliant – I was confident but not a brilliant student, I got a first class honours just in the first examination and a second class which would now be called a 2:1 in the final examination in philosophy and ancient history.

What had actually taken you down that route in the first place?

[19:05]

Well first of all in those days it was expected that bright children would study classics, and go to, you know, if you went to Oxford you'd take the classics course, but I was interested in the philosophy aspect in advance. I'd spent time in my school library already reading works of Bertrand Russell and Joad who was a sort of populariser of philosophy at that time. I was most taken by the teachings of Russell, both his philosophical teachings and his moral teachings, which weren't by the standards of those days very moral, so I read works like *Marriage and Morals*, but also philosophical works. I think I probably read more of them after I'd left school than there, but my memory is reading quite a large tone [ph] called *Human Knowledge, its Scope and Limits* which is his – practically his last word on epistemology and philosophy. I tried reading it again recently and found it a lot less attractive [both laugh], but I have a copy and I have a resolve to read it again.

Well what about Russell's ideas did you like?

Well Russell's ideas were very reductionist and he tried to reduce complicated concepts like knowledge and ethics and morals to simplest possible terms and show how as a sort of logical structure of the subject, and I think that appealed to me a lot and still appeals to me and still really describes my own approach to research in computings as well as my interest in philosophy. I did – I did meet him, well I sort of met him once when he was the guest of a – an Oxford graduate society and they invited him to give an after dinner speech at a dinner in the Café Royal but I didn't get very close to him.

Why did you think you started actually – I mean philosophy at school, that seems quite a young age to develop that sort of interest, what actually attracted you to it in the first place?

Yes, it seems – I don't know, I think it sort of seemed a – an easy way to get to know everything, it's philosophy is the science and study of everything, and so perhaps that's what attracted me and I'm speculating I think about the past [laughs] bit. I used to read translations of Plato's dialogues also, quite interesting. Erm … what else, I was a veracious reader, I mean read – read parts of the Bible, read books on psychoanalysis, novels of Aldous Huxley … practically every week I was taking new books out of the library and used to read them late at night at home and get up rather late in the mornings as a result [laughs], as teenagers do of course. Don't read so much now I'm afraid, I'm – perhaps I write too much [both laugh].

That's interesting about the philosophy again, was it actually part of the school curriculum at all?

No, it didn't appear, most of the scholarships in those days did have a general paper at which they would ask any question and perhaps – perhaps I was introduced to philosophy as a means of answering such questions on such a paper. But I can't remember.

[23:55]

What had been your favourite subjects at school?

I think probably mathematics actually. I studied Latin and Greek but I don't think – well I liked Greek better than Latin but I don't think I was ever terribly enthusiastic about any particular aspect of those languages or the literature in fact. Did what I was told more or less. But mathematics again I would read and indeed work at independently, I read – I read well large – parts of a rather large book called *Mathematics for the Million* by Lancelot Hogben and that was very good for me. I was very interested in probabilities, gambling, no not gambling really, just probabilities. I used to – I read that if – if there were twenty-three people in the room there was an even, better than evens chance that two of them would have the same birthday and I worked out why that was so. And then I generalised it, so that I was able to answer the question how many people would you need to make reasonably certain that you had four of them sharing the same birthday, four or was it – and then

the general formula and I calculated that in a school of however many pupils it was, there would be a day on which four of the people would share the same birthday, I looked through the school roll and found that indeed it was so. So probability I think is perhaps a sort of entry point. And the question is, how can probabilistic measures give you any knowledge; what is the nature of the knowledge in which what you are predicting has a good chance of not occurring, and I remained interested in that for many years and still am of course. I – and that may have been one of the reasons why later in my story, as a graduate student, I went back to Oxford to take a certificate, a qualification in statistics.

What about that sort of – that particular branch of mathematics do you think actually interested you as opposed to other ones?

I think probably the relationship with human knowledge and I suppose the fact that I could actually work out what the probabilities were. I was using something which I later discovered was called the binomial theorem and had been discovered before by people like Newton but that didn't discourage me, why should it [both laugh]? So I think the ability to work, to go beyond what you have learnt is really what attracts me about mathematics, and still does. You can think it out for yourself and I really enjoy doing that, and I'm still doing it [laughs].

Do you consider yourself an applied or a theoretical mathematician?

Erm, I think applied, at present, because the subjects that I study are suggested by their possible utility in computing, and computer programming. But as a – as a computer programmer my studies are extremely theoretical [laughs] and quite a long way from practice. The – and I think theory is sort of more safer than practice [both laugh] …

[28:50]

And did you have any particularly good teachers at school who stick in your mind?

Yes, I think the maths teacher was good, my maths teachers have been good. I think they've all been good, this is sort of in the heyday of private education and teachers just were – knew their stuff, so I don't think I can single out any particular one. I very much liked my classics teacher, Mr Macintosh, but I just took it for granted that he was a good teacher [both laugh], certainly taught me well.

Is this at the Kings School?

Yes yes.

Can you actually describe it to me?

Kings School?

As you remember it?

Well it was a somewhat traditional public school which was regarded by other public schools as being in the second league behind the Etons and Harrows of this world. But was determined in – in – under the guidance of a very energetic headmaster that was Canon Shirley, also a canon of the cathedral, to make their way up the scale and I think very largely succeeded. So the pupils wore uniforms, and when they went out into the town or on special occasions or on Sundays they wore quite a posh uniform with black coats and pinstripe trousers and black shoes and wing collars, so [laughs] laundry bills were quite – quite large I should imagine. The – they had a – a prefect structure with – it was of course almost wholly a boarding school, there was a day boys house but the day boys didn't really count, not among the boarders anyway. And the residents were houses and the houses had *esprit de cour* [ph], had a housemaster and they played all the sports against each other. In fact I even played rugby for my house at one time which was a bit – bit strange, I had such a dislike for sport [laughs], and quite enjoyed it. Well yes I tended to play in the junior leagues where the other players were smaller than myself which was a great advantage in rugby. The – and there were house prefects that were looking after the younger – senior pupils, looking after the discipline of the younger ones and school prefects. I

think in the end I was a house prefect but I was never a school prefect, my progress was mainly academic.

Did you enjoy being a boarder?

Yes I think so, we used to look forward to going back to school and look forward to the holidays as well in the way that all children do.

What does one actually do as a boarding student when the classes are finished for the day?

Well there are games three times a week, unless they sometimes arranged a detention that [laughs] prevented them from playing – playing the games. That is cricket in the summer, which was really hopeless for me, and rugby and hockey I think in the other term. But the small balls didn't suit me at all, rugby perhaps with a larger ball was more visible or something [both laugh]. And there were meals and then there was prep, the homework, so set period after supper for – for doing whatever assignments were set during the day. So there wasn't a great deal of time left over, it's like being in prison you know, you can't [both laugh] – somehow or other the day manages to get filled.

Why the dislike of physical education?

I think because I was so bad at it. I was a bit short sighted at that time, and my hand eye coordination was poor and so things like cricket and hockey were just purgatory. Erm, but I think this was quite often … goes with just not being very interested in it.

Did you have any other hobbies instead?

I was quite good at swimming, at least at my prep school, because of course in Ceylon one spent quite a lot of time in the swimming pools so I could swim quite fast and, you know, was actually a member of the first racing team [laughs]. But I didn't keep it up after – I mean as competitively, although I have – I have kept up swimming until very recently as a hobby.

[35:05]

I'd like to take a break in a moment 'cause we're thirty-five minutes in and I'd just like to ask you just one little question just to round off the school section to some extent. Just wondering if you could just sort of paint me a picture of yourself as you were as a teenager at the Kings School?

Yes, I suppose a bit reserved. I'd always regarded myself, and at the time certainly was, a very unpopular pupil among my fellow pupils, so – and this actually is – is in my memory of school, right since the earlier days in Ceylon in Africa, that sort of being a new boy, being a foreigner and actually being a bit, erm, unappreciative of the susceptibilities of others. A little bit rude, a little bit arrogant shall we say [both laugh]. They used to called me Prof which was [laughs] not always meant kindly I think [both laugh] but it did predict my subsequent career rather well.

When did you acquire the nickname?

Oh probably already in school in Ceylon, I can't – certainly in Africa. I was always one, you know, the first to put up my hand to answer the questions and tended to use a rather disdainful voice when talking to other people [laughs]. Fortunately I seem to have grown out of that, but I was quite surprised when somebody described me as a popular student, in my later years as a popular student, just hmm, I suppose I am [laughs], quite surprised.

[End of Track 1]

Track 2

I was wondering if you could tell me a little bit more about your earlier years in Colombo, where exactly did you live?

Well various places, I think we moved around. I went back there again to sort of celebrate my 70th birthday, took my family with me and visited some of the places that I had sort of remembered or knew the names of at least, including for example the customs house and the port, and one of our houses I think I identified as much smaller than I remember it [laughs] but that's quite usual.

How do you remember it?

How do I – oh, a garden.

If you could describe it to me, your memory?

It was on the corner of two roads, it had a garden in the corner with a big mango tree in it I think it was. And then it had the family quarters and a corridor leading down to servants quarters. Of course in those days we had quite a number of servants, a very good cook named Alvis who we managed to poach off the governor of Ceylon himself apparently, and he served us in a number of different places for many years. Erm, and that's – I think that's about all I actually remember.

What was the neighbourhood like?

Ah, well I remember it seemed very run down when I went back and it might have been even more so when I left [laughs]. I don't think we had very much interaction with the neighbours or neighbourhood but I can't remember very well. This was before we went to Ceylon in 1941, I would have been six or seven years old so it's not surprising that I don't remember a lot.

What are your strongest memories from that early period?

Oh I think my headmaster at the rather progressive school that we went to in Bandarawela who's name was Mr Bevan, was quite adventurous about taking us out into the countryside and even into the jungle and one – on one expedition we went and stayed in a rest house in the resort of Yala which is on the South East cost of the country. And that was quite exciting, we saw tigers and elephants and [laughs] plenty of buffaloes and quite a number of dramatic incidents, like coming across the footprints of a mother bear. The mother bear walked on all fours and carries one of its offspring on its neck and the other one walks besides holding onto it. We didn't actually see this touching sight but we saw – we saw the footprints and they were explained to us. But the first reaction of the tracker, the tracker who's employed to look after a party or indeed an individual, visitor, when he saw that there was a mother bear with cubs in the vicinity he leapt forwards, waved him arms and shouted a charm to prevent the bear from attacking us [laughs] and that was … one excitement explained to us. On another occasion we were out in the jungle rather later than we should have been and the – I think we sort of stopped in a group and the headmaster saw a tiger, or the eyes of a tiger peering out of the – sorry I lied, it was a leopard [laughs] and sort of instinctively in those days people used to – he raised his gun to his head and shoulders and shot it. Well there you are, that it was only – it was one of a pair of leopards and the other one was probably prowling around circling us waiting on to see what had happened but he very much wanted to skin it [doorbell ringing]. [break in recording]

[05:35]

Talking about the shooting of the leopard, did he skin it [laughs]?

He did skin it I think and we got away safely but we were told to hold a torch and shine it around the place so that – I think more to scare the – scare the other leopard rather than to actually see it [both laugh]. And another occasion we – again we were out later than we should have been and passing through one of the villages we learnt that there was a rogue elephant on the road in front of us, and the instructions there was that if you had any suspicions it was close by you got off your bike and walked, or in an emergency left the road and hid in the ditch. Unfortunately then – well my headmaster had unfortunately used his last elephant shot, rifle shot on killing a wild

boar which he wanted to cook for lunch on Sunday [laughs]. So we were rather unprotected [laughs] but we got through alright, but those sort of things do tend to ingrain themselves on your memory [both laugh].

[07:00]

What was the school called?

What was the school called? The Hill School Bandarawela, no Hill School was our hated rival school I think, I've forgot. I tried to find it again when I went back and – in 2003, '4 but failed to do so, failed to identify where it was … I'm not …

I'm just wondering why you said it was a progressive school?

We'd started attending his school I think when it was just a kindergarten and it was modelled after the Froebel teaching about schools and education, Froebel school, F-r-o-e-b-e-l I think.

Heard about it but I'm –

I haven't heard much since.

I've heard about the – I'm not familiar with what the differences from normal education [laughs].

It was progressive, the students were encouraged to do their own thing and there weren't any very strict rules or punishments or anything, and certainly no uniforms surely, no. Seemed to work quite well.

I was wondering as well during sort of your – what sort of people you were friends with, were they Europeans or locals?

Oh yes, everybody at the school would have been European, yes. The – I did go to a school at – briefly when I – that was in Colombo just before leaving – leaving for

Africa, where the – I suppose the richer native, we used to call them native children, were being educated. But I think I remember that was sort of slightly bullied there, wasn't a pleasant experience [laughs] and I probably learned lowest common multiples and highest common divisors for probably the first time [both laugh].

I was wondering when you described yourself I think as a disruptive child earlier on, I was wondering, you know, why do you think that was?

I – well I didn't sort of – myself, I wouldn't have described myself that way at the time and therefore I didn't see anything needed explanation. Erm … no, can't think of a reason now [laughs] on the spur of the moment. But many – surely many people are.

You mentioned that you had some – is it four siblings when you were out there and –

Yes.

Rather more when you returned, and where do you fit into the order?

I'm the oldest, and er, my second brother was very handsome and very very popular, very, you know, maybe there was a bit of sibling rivalry coming into it there. My youngest brother was a bit mischievous and humorous, still is. And my sisters are quite a bit younger and so we still keep in good touch with each other …

We spoke quite a bit about your father earlier on, I was just wondering, I'm not that familiar with sort of colonial service hierarchies, whereabouts does he fit in?

Do you know I don't know. I should have thought by the time we returned to England he was quite senior, was principle collector. He was given the option when Ceylon gained independence of either taking early retirement, with a – a pension, or going back and he chose to take early retirement. I think – well a lot of people did and there were family reasons too, it meant that we could be educated in England, which indeed we were. And he got a job as a temporary civil servant in the Board of Trade to supplement a pension.

[12:20]

We were living – because there were no boarding places at the Dragon School, we bought a house in Headington, to be – so that we could be day boys at the prep school and for some time we cycled down every day and back, or took the bus into school. But when places became available for boarders we all moved in as boarders.

What sort of hobbies did your father actually have, what things interested him to put the question another way?

I should – should remember better, we used to listen to the radio quite a lot together, plays in particular I remember being allowed to stay up for. But I think probably reading mainly. No [both laugh] sorry.

How much of him did you see?

Well he was always slightly remote because of I think the two years absence while we were in Africa was – was one cause, and then of course we were boarders for – both in Ceylon and in England and I think in those days people didn't spend so much time with their children anyway. We had – we always had an ayah, a nanny, a native nanny, oh well we had an English nanny for quite a period and looked after all three of us. So I think that tended to – to avoid too much contact [laughs] or too much from one point of view or the other contact between parents and children.

[14:25]

We've talked quite a bit about your mother – rather your father, I was wondering if you could tell me a bit more about your mother, what was she like?

Yes, she was – she was a brave person, she never had a university education, and – but she had a very definite hobby with the Girl Guides. She was a leader of a Girl Guide troop or pack, whatever they call them, in Ceylon for many years, and when she came back to England she maintained this and became a district commissioner for

Guides in Kent and only retired when – well when she felt no longer able to give it as adequate attention [laughs]. So she – she took the three of us across by boat to Africa and looked after us and got a job and, er … was very success – I mean I think she did very well by us [laughs]. So – and then of course she had two more children, two girls came later so she was looking after them as well, I think it all worked out very well.

What's your strongest memory of her when you were growing up?

Erm, springs of memories [ph], I remember sort of losing her, sort of thinking that she was lost and I couldn't find her anymore, I suppose that's some sort of memory that one would feel was rather a strong memory in the circumstances [laughs]. I don't think that otherwise I think I have a – any particular – one thing, well she taught me typing, she herself took a secretarial course in order to qualify for a job and bought a little Remington portable typewriter and I learnt to type following the five figure exercises that one is supposed to do, and I still do five finger typing, proved to be very useful. In fact I kept her Remington portable during my university years and used it to type the odd thing then. And I've used the five finger typing ever since. We used to play Mah Jong a lot, and I remember reading – was it me or my brothers who read the contents of her hand in her dark glasses and was able to win the game [laughs] thereby. And she taught us bridge, and on the ship on the way back we used to play bridge quite – quite frequently during, when was it, during action stations I think, I think we were probably first class or action stations was just to go to the first class lounge and wait for instructions rather than stand out on deck [laughs] with our actual life jackets on. But we did have a real scare and submarine scare and the – the sirens went off and we put our lifejackets on and played bridge of course [laughs]. One memory I have of her is that she always on these occasions used to keep a little small case with her make-up and essentials with her which she called her spare face, so in the lifeboat she would still be able to present herself properly. And, you know, when I recounted this memory to her many years later she couldn't remember it [laughs], that was very sad.

What do you think the strongest aspects of her personality were?

Oh, I think the sort of determination and she knew – she knew what needed doing and she could do it, that's – that was great. She didn't like very small babies, but when we could – when – I mean same with our – with our own children, she would welcome the visits once they were of an age of talking, if not of reason, that was great. But I mean perhaps I'm – I'm trying to remember the early – my early experience of her which may be why my memory seems so defective. I remember her better of course from the later years, when our own children were visiting her and … but I'm keeping off that for a time being in case you want to move onto that later.

[20:15]

I was wondering as well, you mentioned nannies and what was the other word, ayah?

Ayah is the word for a native employed as a nanny, a-y-a-h I think. And well, they were a bit more primitive and a bit more superstitious and a little bit less sort of [both laugh] up with modern theories of child rearing [laughs].

What makes you say that?

Oh what was it … I can't remember, I'm – just that sort of things that she would say, sort of things that she would threaten us with I think perhaps. Not in accordance with modern principles.

How much of a part of your growing up were your ayah?

Oh I think not – not so much, I mean the ayah was looking after three children and probably more after the younger ones, so … but I think it was accepted in those days that a child did not have supper with his parents, so the ayah would give us the supper, and – and then mother would obviously come to kiss is goodnight [both laugh].

Was wondering how you found this transition to being in Ceylon, Colombo, sort of having to move because of the war to Africa?

I think that in an age in which we just accepted what was happening, never enq – I never knew at the time that Ceylon was in such danger of invasion, and really only learnt of that a long time afterwards. So only now do I really know what my parents went through in this period. No, we just – that was the way it was, yes [laughs].

How did life in Africa compare?

Well we had no servants, we did live for a period in a boarding house and it was meals – meals provided. And then of course – ah what happened? Did I – I must have become a boarder at some stage, yes of course I did, yes. My mother complained to the headmaster at how badly behaved I was and they agreed that I should become a boarder [laughs]. Badly behaved at home that is, yes, I mean I think I was reasonably well disciplined at school, I was just a bit too pushy for – intellectually pushy for comfort.

What sort of ways intellectually pushy, it seems –

Well just always being the first to put up my hand to ask the questions and telling people in no uncertain terms when they'd got it wrong [both laugh].

Is that something you were really conscious of yourself at the time?

Not so much, no. I mean as I say I knew I was unpopular but I didn't really know why, should have – but [both laugh] I think I've probably learnt to become a little bit more appreciative of other people's feelings now.

Did you have many friends?

Yeah.

When you were at school in all these different places?

Usually had one close friend one would play with without reserve, and – but of course I didn't expect him to actually stand up for me when I was being bullied, perhaps

wouldn't have – two of us against the crowd [laughs] would not have been any better than one. So … yes, that was –

Did this unpopularity take the form of bullying a lot?

Not excessively I don't think, no, no, it was quite within the range of tolerance. And on the whole I was happy at school, but no … I don't recall being miserable.

[25:30]

What sort of hobbies did you actually have outside of?

I, as I say, was a veracious reader, I did at one time take up model aeroplanes, and I suppose I tried my hand at writing short stories, for a short while, didn't – didn't get anywhere [laughs]. Otherwise I think I used to work really quite hard.

Why?

Well I think some people are made that way aren't they [both laugh]? I think the – even if I wasn't particularly interested in the subject I think the actual process of mastering it was – was a pleasurable, and knowing more tomorrow than you know today is how you can chart and measure progress in that sort of way. And that remained with me throughout my educational career at least. Because after all there is no – no other product from education other than self improvement is there? When I could begin to write for other people then the achievement was a bit more externalised, I could publish something and that was a completed achievement of which I could look back on, although I didn't usually do so, usually too busy with the next article.

Were you a competitive child?

Yes, yes I think so, clearly. I tried to be as – the best at everything I did, well all the intellectual pursuits anyway, I didn't worry about – too much about being good at

games I'm afraid. I played chess, that sounds like a hobby but rather an intellectual one I think. As I say I read both fiction and non fiction.

Any particular authors you think were influential on you?

Well Russell and Aldous Huxley I remember quite vividly. I read popular science books, from Julian Huxley for example. In Ceylon I used to read a bound edition of a series called the *Children's Encyclopaedia*, edited by Arthur Mee and they had sections on science and history and probably learnt more from that than I did from school [laughs]. The human body and art I think. Don't recall reading about music, but certainly that was – we used to have siestas in Ceylon after lunch and that always gave us – gave one an hour's good reading time.

You talked a bit about Russell but I was wondering which of Huxley's work did you read?

Point and Counter Point, *Eyeless in Gaza*, I mean I sort of went through the complete set of works in the library [laughs]. And I can't remember a great deal of them. *Antic Hay*, do you know these books?

Very little of Huxley but I'm always interested to learn more, it's [laughs] –

Yes.

What's the attraction of that, why do you like reading Huxley I suppose is the question I'm trying to get at?

I suppose because he described aspects of life that I had no experience of, rather than sex and politics and science fiction and so on. And again I'm extrapolating backwards [laughs].

Half an hour in, do you want to take a short break again?

Hmm hmm.

[End of Track 2]

Track 3

I was wondering how you found England when you actually arrived there, had you actually been at all in your youth?

I had visited England when my father was on leave for I suppose six months, at the age of about three or four, no recollections. England of course was the country which in the colonies was always called 'home' so coming home was the way my parents looked at it anyway. For me it was experiencing things that I'd only read about, for example cold, I hadn't really encountered before, snow I certainly had – was purely mythical, a substance as far as I was concerned. Apples tasted just different, in Ceylon the only apples we had were cold storage apples brought in the cold storage ships from Australia and they didn't taste of anything at all. When I first had an English apple I thought it was a pear [laughs] so all that was really quite exciting. And well I suppose we'd – again we just expecting everything to be different and that it was in many respects.

What sort of backgrounds did your parents actually come from?

My father was the son of a schoolteacher at the Haileybury Public School and he was also a classical scholar but took, he tried teaching for a while but took civil service exams for the colonial civil service and that was his chosen career after that. My mother as I say was – her parents were as far, as I know, actors and musical artists. My grandmother was a musical artist and my grandfather was for a while at least an actor, both of which professions were highly disreputable in those days, and I think positions that as essentially a manager of a tea plantation was considered as definitely settling down for them [laughs]. So my father's back – educational background was very similar to mine, classics and philosophy degree from Oxford and …

[03:00]

As I say my mother didn't – I think regretted not having attended university, feel sure she was bright enough for it [laughs].

Was there any family left in England for you to return to home?

Sorry what –

Was there any sort of family left in England for you to return home to?

Yes, my – both my grandparents were back in England, well my grandmother remained in England throughout the war, and my mother's father retired from being a tea planter presumably about the same time as my father retired. He had – he bought himself a rather large – well small estate in – near to Winchester, which I somehow think he couldn't afford to maintain. And he actually employed a butler and a housekeeper for a while but I don't think they could keep that up and in the end they came to live in Kent, in Barham close to Canterbury. My father's mother had a house in Harrow, which we went to stay in initially and which my father continued to stay in during the week while he was working in the Board of Trade and we were living in Oxford to go to school. So we – we got quite a bit of support from grandparents. And we had uncle, an uncle and an aunt living in a very nice house in Sussex, and we used to visit during the holidays. And we had – and my father's elder brother and – had one, two, three, four, five children, and we used to occasionally visit them. But he died and she suffered from – from a form of insanity which meant that her parents were a bit – her children were being neglected and the three younger of them came to stay with us, so my mother in addition to her own five children brought up three nephews and nieces as well which, you know, was a great accomplishment. When she died she had seventeen grandchildren so it was quite an achievement.

[06:00]

How do you actually get on with your siblings when you were growing up?

Growing up a lot of rivalry, but obviously also a lot of play fellows. Since then at a distance we're very good friends and we still see quite a bit of each other on occasions that we organise, or just personal visits or on – on celebrations like my 70th birthday party and miscellaneous anniversaries. Yes, they were great – great fun.

Which do you think you were closest to when you were growing up?

Erm, probably none of them really, I was in years very close to my next brother who was born only eleven months after me and we were very similar in appearance, we still are. So we have quite a bit in common. The younger one was a bit more different, and the – the daughters are – were almost like children, that they were – we helped to look after them, I used to knit dresses for my two sisters when I was in Ceylon.

[07:30]

Interesting you mentioned – we talked about this change in taste of apples when you returned to England, were there any other big changes in your life when it happened?

Well the no servants one I think was particularly noticeable, we had to learn how to wash up and dry up and sweep the room out and so on [laughs], which we would have never done before. But, again, whatever changes there were were mostly due to changes in natural growing up changes. I think perhaps that's really why children don't recall the – or can't explain, they don't take so much interest in the explanations for what's going on because growing up is such a dominating experience [laughs] that it's merely happened externally is relatively minor importance [both laugh].

Talking about growing up had you had any ideas of what you wanted to do yet?

I wanted to be at times a writer, an author, and an inventor. And so both of these aspects, both of these ambitions have been sort of fulfilled, programming is a lovely exercise of invention and writing is what academics do the whole time.

Why those two careers?

You're asking for explanations again [laughs].

No, just the thought that occurred to me was that it seems they're both quite creative things.

They're both creative and they're both intellectual I suppose, and probably don't involve too much interaction with the fellow man, which was my character in those days. They – they both are giving maximum exercise of freedom, and to some extent establish a dominant relation over readers and users of the invention, that might be a – might have been a secondary explanation.

Did your parents have any ambitions for you?

No, I think my parents were always very free and easy about our choice of career, as long as it made us happy of course. And so I never felt particularly pressured by them.

[10:40]

And the decision to go to Merton?

Well it wasn't a fixed decision, I did also enter for the other – another group of colleges, including Balliol, but my attempt at a scholarship there failed and it succeeded at Merton so it seemed a natural choice. I still have pleasant links with Merton and they elected me an honorary fellow not so long ago which strengthens the links a bit.

How did you take to starting university?

Well it's surprising how much more work you get through at university than at school [both laugh]. Reading the whole of the Iliad rather than just one book, the whole of the Odyssey, the whole of the Iliad is just the whole of Thucydides later [laughs]. Just – but again the feeling of progress that you really knew more and understood more, almost week by week, especially to begin with was great. And then of course I think at university one makes some really firm friends, and long periods of talking with people in the same year and same class, or in different years and different classes, that was … a wonderful experience.

Any friends in particular?

I have an old friend, John Race who lives in Abingdon now and he's a very – was a very close friend and still is and he takes a considerable effort to keep a group of us together, and we will – we meet at each other's houses every now and again and renew acquaintance. And he studied classics and went into computing like I did, and went into industry first and then into university. So our – our careers tended to match as well, have a lot in common with him.

Interesting. What year did you actually enter Oxford?

1952, '52 to '56. And then again, I went back to study statistics in '58, '59.

What was your social life like, you've mentioned these discussions with friends and –

Yes, I was quite active in – in a few societies. I played chess for my college, I was a member of the Oxford Union Debating Society and I took an active part in the Experimental Theatre Club which used to arrange weekly readings of plays, and I didn't act so much as produce these – these plays. I was – I acted in the college play, and I think twice in all. So that was – and I – did I play bridge, yes I did play bridge I think once or twice, even for the university, you know, minor match. I used to play bridge a lot during the vacations at a club in – close to my home in Kent and got quite good at that. But I gave it up in 1959 and never looked back, never took it up again [both laugh], I read the weekly bridge column in *The Guardian*, that's all.

Why did you give it up?

I went away to Russia for a year and just never took it up again, and didn't play cards in Russia so much [both laugh].

I have ask as well in what sense experimental theatre, that's –

Well there was a more serious dramatic society in Oxford, the Oxford University Dramatics Society and they – they took things a bit more seriously. Experimental

means doing experimental plays I think and doing things in experimental ways. I produced a reading of Plato's Symposium with Nevile Coghill as Socrates and I used to very much enjoy typecasting. And a – a production in translation of Plautus' comedy The Captives, those are two that I remember. And – and I failed to produce – cancelled I think a performance of Samson, Samson by Milton, I've forgotten, anyway things conspired against us and had to be cancelled.

Were they well attended?

Oh adequately, yes yes. Yes, as well as – as well as the size of the room allowed, you know, the room was reasonably full, there was perhaps twenty or thirty people.

Interesting that you were producing, it sounds to me like classics, sort of –

Well I suppose that was [both laugh] not a coincidence. I produced a reading of a Pirandello play I think one time, which I don't think I quite understood [both laugh].

What other interests did you have, is that just the societies, it all sounds very sort of structured, are there any things outside that?

No, I don't think so, no, that's perhaps more extra curricular activities than at school.

What are the –

Drinking of course [both laugh].

That's interesting actually, people sort of try and convince me there was so little of that in previous student days, but your experience of it, was it still a factor in student life?

Oh yes I think so. I used to go out for a pint after finishing homework and before going to bed, or – I suppose not every day, and then occasionally a binge which [tuts]. Sometimes suffered from afterwards, or even during.

[18:39]

How did you actually take to college life, were you staying in college or?

Oh yes, we had the privilege of residing in college for the first two years and then the second two years one had to move out to digs, in those days there wasn't enough room. The very first term I took up with second year mathematicians, in a late night study group studying logic. We got hold of a – an essay or something by the logician Quine, probably his methods of logic. And tried to understand what it was all about, not sure that we succeeded but it certainly introduced me to logic and nourished my interest in the subject, and later in my philosophy course I was definitely interested in mathematical logic and logical foundations.

[19:45]

What did your university course actually consist of in your first year?

First year was Latin and Greek language and literature, the language included translations both of prose and of verse into and out of both Latin and Greek. Which was quite a challenge, and the literature included translations and demonstration of the knowledge of whole of *Homer*, whole of Virgil's *Aeneid* and other, and one or two special books, *Satires of Juvenal* and *The Trojan Women of Aeschylus*, was a Greek set book, so that was there was something like fourteen papers in all. Then in the last seven terms we moved to philosophy and ancient history and studied Roman and Greek history from the original sources. Erm, would we be reading, did we read Livy, I'm not sure, and Thucydides, and Herodotus, lovely, and philosophy, both ancient and modern, and Aristotle, studying his Nicomachean ethics. And modern philosophy including, well it was a bit eclectic when one could choose a count [ph] for example, and study the current – current philosophy of – of the Oxford school, which was specifically linguistic school of philosophy at that time, I was very – took classes from Gilbert Ryle who was the philosopher, wrote a very influential book called *Concept of Mind*, which impressed me a lot. And as a graduate student I attended lectures also by Austin who was an even more austere linguistic philosophy than Ryle. And I think they had an influence too. Well the – the papers included trans – included the papers

to test our continuing knowledge of the Latin and Greek languages, as well as the set books written in Latin and Greek and otherwise sort of philosophical essays on impossible questions [both laugh].

[23:00]

What would you think your favourite parts of the course were?

Well the – the – I like Greek better than Latin and I liked Greek, I think Greek history a bit better than Latin, I really wasn't interested in the history. But the best part was the philosophy that – and the best part of the philosophy was more logically mathematical philosophy in which for one term I had John Lucas as tutor, John Lucas went on to make his name in mathematical and indeed computational philosophy. But that was after I'd left, he was a very very junior fellow when I was his student.

I was going to ask actually, who were your tutors?

Well him I remember, I actually gave the after dinner speech at his retirement dinner so we had some contact. There was a Professor Walsh who came from Edinburgh originally I remember quite well. His wife was the producer of a play, a Moliere play that I was – acted in. My tutor for the first five terms was Robert Levens, I think quite – quite a clever teacher really, very good record of high honours in the examinations. One had a – I had a – I had some more tutors but I don't remember them so well.

Are there any that you think were particularly influential in your own ways of thinking?

No, I don't think so [both laugh]. Well they did make me read the famous article by Alan Turing on incomputability of termination of computer programmes, so I remember reading that and again I found it pretty [laughs] tough going. But I have understood it since, occasionally shall I say [both laugh].

[25:38]

Interested, I was just wondering if in terms of making this interview accessible for other people who don't necessarily know that much about philosophy, I was just wondering if you could define philosophical logic?

Philosophical logic is sort of logic as investigated by philosophers. I'm not particularly skilled in that although I'm still interested. In fact I've quite recently, I think the last year has been to two seminars organised by philosophers, one of them in commemoration of Russell's logical work, Principia Mathematica. So what philosophical logic tries to do is to investigate philosophical questions by the use of logic and that's what I would like to do too, investigate any questions by the use of logic. But of course computers were really very new in those days and the implications of – I was explicitly interested in the implications of computing and – and philosophy, questions like could computers do mathematics were already prime – uppermost in my mind. But it was considered a very recherché [ph] topic in philosophy [laughs], until I think John Lucas made it respectable and showed how it could – how the two subjects could be brought together.

Did you actually have any first hand experience of computing as an undergrad?

Not as an undergraduate, no. John Race, my friend, did used to make logical machines in cigar boxes which did a little bit of elementary logic for you, which I took an interest in, he was always more practical than I was [both laugh].

What sort of logical machines?

Oh you'd – you just deter – I mean they were just little tiny binary computers, and so you could press two buttons and find out what – five buttons and find some logical function of those five buttons that would light two or three lights, just for fun [laughs] and people still do it for fun.

What was there for you to actually find out about computers available to you?

Erm, I don't remember finding out anything very much about computers, until – but I definitely had an interest in them. In fact the – I think perhaps the only job I've ever

replied was to LEO, the computing branch of the Lyons' Corner House company, which was very advanced in making and programming their own computers to organise their supplies and their finances of this chain of – of coffee houses. And they were – I saw the advertisement and go along, but I wasn't seriously interested in taking up of [laughs] – that was during National Service.

Oh right.

And similarly when I was actually – the first job I took was in computing.

[29:50]

Seems interesting considering you've got this classics background, I was wondering if – I'll pop this off in a second, I was just wondering if you could reflect for a second on how the two are actually linked because to me as, you know, a layman it doesn't seem necessary that obvious?

I think possibly an interest in languages, an interest in grammar. I took a specialist course in my last year under Professor Palmer in comparative linguistics which involved looking into the Indo-European [ph] routes of the similarities between Latin and Greek and studying ancient inscriptions. So the same kind of analytical – analytical bent seems to be illustrated by quite a number of my otherwise outside interests. That's – and in language in general and I very quickly gravitated towards computer programming languages as my area of specialisation, so that that in a way was part of a continuum of interest in language. Language is a vehicle of thought, is a vehicle of reasoning, as well as just for communication and for all the other purposes we use language for.

[End of Track 3]

Track 4

I think the point at which we'd finished off last time we were talking about the link between – actually can I just move your mike ever so slightly.

Yes, it's a very good microphone, I gather that [ph].

Yes, it's surprising the things they actually pick up [laughs]. Last time I think we'd sort of reached a point where we were talking about the links between a classical education and computing and I was just wondering when you first actually encountered a computer?

I went on a computing course in 1959, early in the year I think, while I was studying statistics at Oxford and it was run by Leslie Fox who came from another university to serve as the computer director of the computing laboratory. A post which he retained until well after I'd returned to university as a professor. In fact I was working in his department when I first came back to Oxford [laughs] in 1977. Anyway, he was running this course on a new Ferranti Mercury computer which had just been installed in the computing laboratory and I attended the course for a week and wrote my first programme, was very much taken with it.

What was your first programme actually about?

I was – happened to be reading a book by von Neumann and Morgenstern called *The Theory of Games* which contained an algorithm for solving a two person zero sum game, quite a famous algorithm so instead of doing the set exercises I thought I would do that instead. And I wrote the programme and watched it working for the first time with some excitement, and it did work apparently, at least it got to the end but I'd forgot to put any checks in the programme itself, so I never found out whether the answers were correct [both laugh].

What do you actually see when you run a programme on a Ferranti Mercury?

You don't see very much, a paper tape goes in towards the beginning and it makes a lot of – does it make a lot of noise, no I don't think it does actually. It sort of whirs for a bit and then perhaps a paper tape comes out, which is what happened in my case.

[02:45]

And this was when you returned to Oxford to study statistics?

Yes, after my degree at Oxford in 1956 I did National Service in the Royal Navy, I don't think we talked about that.

Oh no no.

I was accepted onto a naval Russian course to study Russian for two years and after a short period of basic training put on civilian clothes and attended a joint services school in Scotland, in Crail, running it there and after six or seven weeks we took an exam, which selected those who were linguistically qualified for a more intensive one year's course in the language which took place actually at London University, in Russell Square as part of the – well I think officially affiliated to the School of Slavonic studies. And in fact there was a course organised solely by the navy, employing its own tutors and giving them intensive language course in modern Russian, both literature and naval terminology. So we learnt a lot of Russian for bollards and prouse and sterns [ph] and things [both laugh] which I've forgotten.

What did you actually think about the prospect of doing National Service?

Well it was accepted that that's what one did, and if one was lucky one got a cushy number like [both laugh] learning Russian in the Royal Navy. And certainly it came in useful later.

How did you actually turn up in the navy as opposed to the other branches of the armed services?

They had an entrance interview, qualification, and I said I was familiar with nominative, qualitative, genitive, ablative and they said, 'Well Russian has one more case than that but we think you'll manage it,' [laughs], I think knowledge of Latin and Greek. But I did also quote as one was advised in those days that my uncle was a full captain of the Royal Navy, I didn't know him very well but it [laughs] also came in useful later as I might tell you.

Did you actually see active service at all or was it just training?

No, no active service, it was actually during the time of the Egyptian war so it would – if we'd been in an appropriate branch of the service we might very well have at least embarked on the – on a ship to go there [laughs] before it was over, but no it didn't have any affect. We did every now and again spend two weeks of ordinary naval training, mostly in shore bases and had one or two short trips aboard royal naval ships, a minesweeper once, that makes one very sick and [laughs]. A destroyer once on I think they called it two third speed trials but it was fast enough [laughs] and the speed with which the boat rocked up and down was certainly seemed to match the speed of which it went along [both laugh]. Was like being in a high speed lift going up three floors, down three floors, up three floors, down three floors [laughs] and it was definitely an experience, but very good for us, we slept in a hammock. Not actually at sea, I think we went into port for an actual – for the night.

To what end were they actually teaching you Russian?

It was an intelligence services course and the intention was that – well we did have a short training in interrogation, put it that way, but our exercises were all in the assumption that we were friends with the Russians and fighting some other unnamed power [laughs]. So we learnt to interpret.

Seems an interesting way of looking at it, friends with the Russians despite the fact that the Cold War was very much on at the time as –

Oh very much so, yes yes, indeed. But I mean I think that all the exercises were reds versus blues.

And which we were you?

I think we were blue [both laugh]. Paradoxes involved.

[08:03]

Did you consider actually continuing in the navy after?

Oh no no, that was – in fact I went back to Oxford to study a one year course in statistics which I decided that … I would have to get a – an interesting job and rather than go in for sort of management trainee scheme that the Oxford University Careers Advisory assumed an arts student would go in for and do something more interesting, statistics had been an interest of mine and probability theory ever since school, when I happened to read a book called *Mathematics for the Million* by Lancelot Hogben, who sort of excited my interest in mathematics and had a chapter on probability theory. So I was interested in that and thought that would make a good career. So I registered for a one year course, intending to use my savings to pay for it but actually I managed to get a state scholarships for the year, and got my only engineering and scientific qualification, which was a certificate in statistics.

Is that at masters level, diploma or?

No, it wasn't – a diploma would have taken two years, and a masters wasn't on offer, but I think nowadays it would be called masters. I didn't need a mas – everybody who gets a degree at Oxford automatically qualifies for a master of arts if he pays the fee and attends the ceremony, which I did during the year, 1958 '59.

[10:00]

I'd like to ask you some more questions about the statistics course but there were just one or two other things that had occurred to me about National Service as well, I was just wondering what were the other recruits like on the course with you?

Oh they were very good, we had two people who were native Russian speakers, although not native Russians, and a third – a third one who was just very very clever, Peter Oppenheimer, and they all got distinctions on their final examinations [laughs]. They were both – well as far as I know they both made very successful careers afterwards, as indeed did most of the graduates of the course. I have been – I have met them occasionally afterwards, there's a club called the Frinton Club, Frinton Society which has three or four meetings a year and we gather together at one of the homes and have a meal or maybe go to one of the shore establishments of the navy in Dartmouth or somewhere and have a good meal, but I haven't done that for many years now.

Did you all take the idea of National Service seriously, it's –

Yes, I think we – in fact we were treated very well and although we did drill and so on, it was all – I don't know whether it was the navy or just they did treat national servicemen well, but you know, even the sergeant majors were assuming that they – that you just needed them to help you and they were very willing to do so. So one of my colleagues seemed to live about three quarters of a second in the past [laughs] and so when you're doing your drills he was always the last one to get his feet together [laughs]. But it all went off well.

Did you enjoy it?

I think so, yes yes, I mean the company was very good, got on well with the teachers, and we were – when we went back to Crail after the one year course for a more intensive course in naval Russian, sort of finishing course, we were officer cadets so we even had slightly more comfortable accommodation and tea served to us every morning in bed [both laugh].

And what do you think actually got out of the experience?

Well a good knowledge of Russian certainly, and what does one get out of an experience that's [laughs] … it's a sort of culture that, naval culture in – we used to go back for reserve training for a couple of weeks every year, not every year but on

some years. So we would stay in the officers' mess and attend classes. And again that's – that's [laughs] an interesting experience.

What's naval life actually like?

Naval off – well National Service, I –

What was your experience of naval life I think might be a better way of putting it?

Well a bit like boarding school really [both laugh], sleep in a dormitory and eat institutional food and every now and again go ashore as we used to say, which must have meant walking out of the gates [laughs]. That – drink in the NAAFI or listen to the radio, television I suppose, don't remember that very much in 1956 but –

[14:30]

What sort of place is Crail, I've never actually heard of it?

It's a – or it was then a fishing village, I don't know quite how it's grown since. We were in a disused air – I think it was an aid base originally which has its wartime huts still up and available for accommodation and classrooms. It's a long way away and every now and again we would have two weeks off, sometimes to go on a naval training course, and sometimes to go home. And then we would assemble in Kings Cross and take the train to Edinburgh and beyond Edinburgh an all night trip, two miniatures of whiskey [both laugh] to see us through.

When did you think about going back to study statistics?

I … I don't know when I first thought of it. I did – I think I only considered one job before doing that, might have been afterwards with United Steel, and I either wrote to them or saw that they were interested in recruiting and visited for a day or so, basically to work in their computer department on automation of steel mills. And I met Stafford Beer, at that time he was quite a famous cyberneticist, at that time. I

think he came to grief later as a – when he was employed as a consultant by some South American government with a brief to automate everything.

Chile I believe wasn't it, was it Project Cybersyn?

Yeah, cyber is the word that he certainly used.

When did you meet him?

It was – I can't remember exactly. Could have been even in '56 before the National Service, and as I said last time I – I visited LEO computers on occasion, really just to see what it was all about. And, er, but at … so I was definitely thinking of a computing career and there were no computing courses in those days so a statistics course on which I learnt computing, well I happened to attend a computing course but I also learnt to use a calculator by hand which was very useful …

What was it about computing that actually grabbed your attention in the time before you'd even used one?

Yes, I was – got an interest in philosophy while I was still at school, chiefly through reading some of the works of Bertrand Russell that I remember but also Professor Joad was a sort of populiser of philosophy at that time. And I took an interest in logic and the foundations of mathematics, I've just recently bought copies of two of the books that I think I read at about that time, *Principles of Mathematics* by Bertrand Russell and a slightly thicker tone [ph] on *Human Knowledge. it's scope and limits* and re reading them slowly. But that – that gave an interest. There was a bit of speculation, certainly in my mind, about the light which computer intelligence, they used to call them intelligent machines before they became better, but computer intelligence and human intelligence, so words like artificial intelligence were beginning to go the rounds. And so that it was the sort of philosophical implications of computers that attracted me to the topic in general. And of course programming itself was a lovely puzzle solving and great fun [both laugh].

[19:45]

You mentioned your first programme on the Ferranti Mercury, I was wondering, interestingly enough we've interviewed the chap who actually designed the thing but it would be interesting in a users perspective of actually programming it, what was it like using?

Right, well we had what was called an autocode so we didn't learn the machine code which presumably your designer actually designed. We were using an autocode which had been in – designed and implemented by Tony Brooker, who was later a professor at Essex University, so it wasn't as challenging as [laughs] – as it had been for many people. And later on when I got a job I was also in the business of implementing an autocode so … yes the programme was only about ten lines long so it wasn't a great – great challenge.

What sort of things would fill those ten lines, it's –

What sort of?

What does autocode actually look like to see written down?

You – it looked fairly like these codes look nowadays, you write, 'A=A plus sign of B,' and it – it computes the expression and stores the value in the variable A. The autocode had some unusual instructions, one of which I remember was Hoot, which caused a one second blast on the machine's hooter [laughs] and one was called Read More Programme, because in those days the stores were so small which meant you couldn't get the whole programme in at any one time, so if you called RMP, the – your programme would disappear and a compiler would be brought into the computer again and it would read and compile some more programme.

Did you learn any other languages apart from autocode at this time?

Not at that time, no no.

[22:00]

How much comp – how much is computing actually an element of the statistics course you did?

Well it was only using – using hand computers and we definitely learnt how to not apply matrices by hand, well using – the great luxury was one that would do automatic division, otherwise you'd have to wind – wind the – wind the handle backwards in order to do division.

What were the other components of the statistics course?

Oh the probability theory, which is quite elegant mathematics, and the conduct of statistical – statistical significance tests to do – see whether the experimental results were – were significant or not. I studied in – in the unit of biometry, and the … most of the examples were taken from agriculture or forestry …

Was that one of the uses they thought you might put it to, was there any sort of application in mind for the teaching you were given?

Well would – presumably the start of a qualification as a statistician, which is a – a recognised speciality in – certainly in the civil service and industries would also – and agriculture was also – agricultural research was very much dependant on statistics.

Who were your teachers?

My supervisor was somebody called Scot who I think shortly afterwards went to New Zealand, and the head of the department was Norman Bailey who was – specialised in epidemiology, spread of disease which was a nice branch of probability theory.

How did being a postgraduate – were you in the same college in Oxford?

Yes, one normally keeps to ones college for the rest of your – at least your student career. It's … you're allowed to move if you get a job in the place, which I did eventually. And well it's – it was quite nice being a graduate student, not quite so

carefully looked after and [laughs] a bit more independent. I don't remember being very closely attached to the college at that time, the department – for graduates it was mostly the department that – particularly graduates in the engineering sciences would be mostly members of their department and associate more with fellow students rather than their college.

What was the workload actually like?

I don't remember it as being exceptionally onerous. Interesting, and so one did what was necessary. I do remember having some time for reading on the side, for example the book on – on game theory, of which I only read very – very few chapters, but also read again maybe the introduction of a book by Martin Davies on incomputability and that I think gave me some insights which I was grateful for about how computers could arrange how to repeat certain instructions, so they could actually execute many more instructions than you'd actually written in your programme, was rather an important characteristic of computers, particularly when they operate as fast as they do at the moment.

I was wondering what sort of activities actually take up a statistic student's time?

Yes, I wonder. We used to do I think a dummy paper every week, or every fortnight, I've forgotten, to try and answer questions. We used to attend a few lectures, and – and practical classes on using the calculating machines. But, er [pause] yes I mean it wasn't excessively arduous. And it was quite interesting [laughs] so –

What does one actually do in a practical class with calculator that?

Oh you learn to multiple and divide and how to actually do – calculate standard deviations, it's really just getting finger – finger exercises for doing it reasonably accurately and fast.

[28:00]

Were there – what were the – how shall I put it, facilities like for computing machines, calculators and so on?

Well they were a scarce resource so I think – I think that there was enough to give the students electric machines, if it wasn't electric machine it would be a hand comptometers which you had to wind the handle, but I must have done some handle winding too. Some of them were automatic and actually did division automatically which was an advantage. But those, I mean those – I remember thinking, oh we'll – we'll never have enough of those for everybody [both laugh].

Who else was actually on your course?

I don't remember very well, there was a – a colleague called Michael Bulmer who did extremely well, and in his subsequent career and also ended up as a fellow of the Royal Society and – but I never met him again [laughs].

Were there many of you?

On the course? I think between ten and twenty, reasonable.

What was the balance like between men and women?

Anywhere between 100 per cent and a little below [both laugh], yes I think at that time the preponderance of men was quite dominant.

Did that ever seem unusual at all?

No. And I'm afraid it still doesn't, but … I think – I think the proportions are getting up a bit.

You mentioned a little bit about how doing your postgraduate course was different to being undergrad there and I'm just wondering if there was any other changes?

Any other changes in the university in the two years I'd be away, not I think that I would notice. It is a change of course moving from undergraduate to graduate and from arts to science, or mathematics. But I – I don't seem to dwell on that, take things as they come [laughs]. Accept what I – what I get rather than what I expect.

Did anyone ever comment on it being unusual at the time?

Me making the change?

Hmm.

I had to convince them that I would be able to do the course and so they interviewed me fairly extensively and recommended me to learn – learn a bit of how to do arithmetic, it was multiplication, division, square roots kind of thing which I did out of – out of a self help manual, that's proved fairly useful. I can still add up columns of figures two columns at a time.

[31:30]

Had you had much thought about what you actually wanted to do after you had done the statistics course, you mentioned the civil service as an option in passing?

Yes, no I hadn't. And I didn't really look around, the course was expected to be a two year course leading to a diploma, but it did – had got this subsidiary qualification after one year. And I did quite well and got a distinction in it. But towards the end of the course I saw on my college notice board that the British Council were advertising for to recruit exchange students to visit Moscow, the Soviet Union for a years exchange studentship, and I thought that would be fun and exciting [laughs], I can use my Russian and so on. So I waited until the last minute and then – then posted a letter of application, went for interviews and was accepted, so that – I took leave of my course and went off to Moscow.

Who actually interviewed you to go?

Oh the British Council was – was the organiser and interviewers. There were probably some people from the Foreign Office there as well, or for – from security or something. And those chose twenty, most of them studying arts or – or geography or something connected with the actual Russian territory, or language, or literature or whatever. I was attracted to go to the Department of Kolmogorov who was a very famous Russian probability theorist and mathematician in general. He was a – eventually at least a foreign member of the Royal Society, a very nice chap actually [laughs]. I only really met him once, he entertained at – entertained perhaps – perhaps the English students or just me with somebody else for Easter, a cup of tea and a – and an Easter cake that they make in Russia. But I was attracted by probability theory which I thought was a beautiful subject, and also by the philosophical interest of probabilistic and statistical reasoning, how can one – what does it mean to say something is only highly probable or ninety per cent probable, because if it turns out that you're wrong it doesn't really count [laughs], you're allowed to be wrong [laughs]. So I had my views as to – as to what that might mean, from the philosophical point of view, 'cause philosophers at Oxford at that time were very interested in meaning.

What did you think it might mean from a philosophical point of view?

I actually wrote a paper and read a paper at the Graduate Philosophical Society in Oxford which explained that and I've looked it up since. I think it – I connected it strongly with a willingness to make a bet, that if you said that you thought it was ninety per cent certain but refused to bet on it at shall we say fifty per cent odds then you were being inconsistent. It just, you know, as inconsistent as it would be if – if both said something and its negation. Then if you … so now if you are actually in the habit of taking bets, if your judgements about probability are seriously wrong you'll lose money, in the long run, over a long series of bets, which will be independent of the subject matter of the individual bets that you're making. So you're sort of as it were survival of the fittest, the people who make good estimates of probability will end up richer and have more children or whatever the [laughs] – whatever it is, whereas those who – who make bad bets will suffer for it in the end.

[36:33]

It's interesting how you described probability as beautiful a moment ago as well, just wondering if you could expand on that and bear in mind I'm a historian, I don't find [both laugh] any particular branch of mathematics particularly pretty at all but –

Well you start with a real world situation, somebody playing a game or playing two games or making a bet of some kind or another, or a disease which in each unit of time you have a certain probability of either dying or of passing on the disease, which might be dependant on the density of the population in your immediate district and so on. And then you set this up as a set of equations, you write down the characteristic, you know, the relevant characteristics for the real world situation and then you solve the equations and you say, 'Well with a probability point three the whole population will be wiped out, probability point five it will die out very rapidly, and actually the changes of it – well the other alternative is it becomes endemic and you have a permanently – a ratio, a certain proportion of people that will be infected,' so problem solved. But you need to do a little bit of calculation to solve the equations.

Which part of the – that situation you've just outlined do you think appealed to you, the application of maths to some real life problem or the maths itself?

I think probably the maths itself [both laugh]. I remember being at – already at school, I was impressed with a paradox about if you have twenty-three people in a room the chances are that two of them will have the same birthday, so I wanted to see if I could make that – how many would you need to give you a reasonable chance that three of them would have the same birthday, or four. So I calculated and I worked out up to six and it turned out there was something like 300 people would be needed to get six people sharing the same birthday. And there were 300 people in my school so I looked through the school register [laughs] and found a day on which six of them had their birthdays. So maybe that – that was what turned me on.

I was actually going to wonder if you'd ever considered a career in operational research as well with that sort of –

Yes, in fact operational research would have been the – the title of the job with Stafford Beer at the – at the United Steel.

[39:45]

Stafford Beer is one of those chaps I've sort of encountered largely through the cybernetics side of it and thinking about the Chilean economic situation and the computerisation of that, I was just wondering what was he like when you met him back in the '50s?

Oh fairly extrovert I think and very enthusiastic [laughs]. And, well, I don't remember a great deal, he was – he – he described the process of automating a steel mill as you have to decide what parameters really matter and make sure that the computer can read them and calculate from them and then use them to actually control what goes on. But if there are any aspects of the situation that didn't matter very much you'd carefully build in a facility for the management to take the necessary decisions [laughs], which doesn't quite accord with my current philosophy of the subject [both laugh].

What's the difference between your current philosophy and the Stafford Beer view from the '50s?

Oh great admiration for people who can make judgements of the kind that computers are just totally incapable of approaching. Well once you know that the computer only does what the programme tells it to then you realise that programming something, well it's a bit like the mathematical problem, you've got to make up a set of rules, like the rules of the grammar and natural language and attempt to make the rules so that they make the right decisions at the right time. But the situations that most of management face are not subject to rules and they don't recur often enough to be able to generalise from experience and so the actual decision has to be made by the seat of his pants. It's getting a feeling for the situation and deciding whether to press the button or not.

Do you think that Stafford Beer's ideas were realistic shall we say then?

I think they were later discovered to be [both laugh] rather up the wall. But then we were all very optimistic in those days about what computers could do. Strangely of course they are now beginning to do it. But computers that are shall we say a million times faster and bigger than the ones we had in those days.

[42:30]

When do you think, you know, that optimism actually faded for you?

This was when I was in – in Russia, I got a letter from the National Physical Laboratory offering me a job as a senior scientific officer at – to work on a project to translate from Russian to English, and this was quite attractive, take advantage of my Russian and pander to my interests in computing, and so asked my neighbour and he said, 'Senior scientific officer, wow!' so I said, 'Well I'll go for that,' [laughs]. And so while I was in Russia I actually studied what the Russians were doing about machine translation of languages, so I met some of the – some of the workers there, some of whom subsequently became quite famous. And actually read one of the early works of Noam Chomsky on syntax of languages, and had to go to the Lenin Library to do it in Moscow. And then I thought, you know, how would a machine ever acquire sufficient vocabulary to perform the translation, 'cause every word had to be looked up in a dictionary, how could one construct a dictionary of science, 'cause science was a subject that people were translating when the actual language of science changes so rapidly, in fact every scientific advance tends to be reflected in a new set of technical terms. And then I thought of the other – the real killer is that the individual words, either my – might get away with 100,000 of them but it's the combination of words that actually carry meaning, every – every word has three or four meanings and it depends on the context, you know, which meaning is right, how would you ever get a dictionary with enough entries? So I was feeling a bit disillusioned with it and when I went back to the – the National Physical Laboratory interviewed me for a job and … I had already sort of thought that it wasn't going to work.

How was the actual interview at the NPL?

Well I think they were basically trying to attract me, I mean as all good interviewers should, because not many people had – with the knowledge of Russian [laughs] actually looked like being computer programmers. But unfortunately there were several things standing in the way; one, I wasn't actually senior enough to be a senior scientific officer, in fact I wasn't even senior enough to be a scientific officer so I could be recruited as an experiment officer except for one thing and that is I didn't have a science degree so it would only be a temporary experimental officer and I would never get a permanent employment in the scientific civil service. So I didn't have much difficult in turning that one down [laughs]. My interviewer was Donald Davies, who is quite a distinguished – or did quite a lot in – in what do they call it, message passing systems.

Packet switching?

Packet switching, that's right, yes. My wife says that she met him shortly afterwards at a party and he'd said how they just lost a very good recruit [laughs].

When did you actually meet your wife?

At – when I got a job with my employers Elliott Brothers started – I actually, ah, met Elliott Brothers while I was still in Moscow, because towards the end of my stay, my uncle wrote to me, the naval captain of course, and invited me to serve as an interpreter at an exhibition that he was organising. He'd retired from the navy and he'd become secretary of the Scientific Instrument Manufacturers Association in Great Britain and he was bringing his member companies to an exhibition in Moscow and would I spend a couple of weeks with him helping with the exhibition and interpreting for the exhibitors and the public. So I said, yes – oh no paid me forty pounds for this which was a lot of money in those days, so I came back and met one of the exhibitors, was the – my eventual employers Elliott Brothers, who were exhibiting a computer. So I made friends with them and spent a lot of time on their stand and at the end of the stay they invited me to – they offered me a lift back in a van which had brought the computer in, back to England, which I accepted and we

spent a few days crossing Europe with them and then they invited me for an interview for a did, which this time I did accept …

I've got a few more questions on your time in Russia actually before we move onto Elliott Brothers but we've been talking for about fifty minutes, would you like a break for –

Yes please.

[End of Track 4]

Track 5

You mentioned that the British Council had been behind your trip to Russia, how did you actually approach them?

British Council advertised for students to go and interviewed us, and briefed us of course when we'd been selected … and put us I think under the tutelage of the cultural attaché at the British Embassy in Moscow.

Did you actually choose a subject or was it an opening there in the statistics branch or did you actually suggest it?

Sorry, were you talking about the British Council?

Yes, I was just wondering did they actually offer a position in – hang on [look at papers] … where you were actually in Russia, was it actually an advertised position to go there or was it an open offer for you to choose somewhere you wanted to go?

Oh right, yes, definitely you could choose – you could choose your subject, couldn't actually choose where you would end up. And some of our colleagues ended up in Leningrad rather unexpectedly. The … a group of serious looking men in black hats and in large black cars came and took them away [laughs], it was rather frightening, but I ended up where I wanted to be. So the choice of subject was very much – one of the students that the British Council selected Nicholas Slater who was the nephew of Boris Pasternak and at the last minute he couldn't get a visa and so he didn't go.

When you said that the British Council briefed you, what about?

I – I remember that we were briefed about security, I'm sure we were warned that our rooms in the – in the dormitory would be bugged, and that we weren't to engage in black market dealings or currency dealings or indeed get involved – well get a Russian girl pregnant, those were no no's. And I think on the whole we – we kept to those guidelines [laughs]. Although in subsequent years I think they had some trouble.

Where were you actually based?

We had accommodation in the big skyscraper building on the Lenin Hills which is where the science faculties were which by Russian standards was extremely luxurious. A – a two bedroom block with a shared facilities, and shared with another English student. And access – and we were given what became by Russian standards was a very generous stifehand [ph], 1500 rubles a month, which was much more than we could spend and …

What does one actually spend ones rubles on in 1959?

Well there was – it was actually quite difficult because it was quite a place of shortage. And … I bought some books, brought them home. I remember I got my first attack of piles when I was there, I had to go up to Russian doctors who told me what it was and either advised me or read that I shouldn't sit on too hard a chair so I thought I would buy myself a cushion, and I went around Moscow, all of the shops, none of them had cushions, so in the end I wrote home and got one sent from England which was [laughs] very nice, by which time I didn't need it [laughs].

Which department were you actually attached to?

It was called the Chair of Probability [ph] [inaud] …

And was that based in the skyscraper as well?

That was based in the skyscraper as well and lectures were in the skyscraper and the science library was in the skyscraper. But I must admit that my mathematical knowledge was not anywhere near adequate to really follow lectures in – in mathematical aspects of probability theory. I think we must have thought it was really rather suspicious what I was doing [laughs] so when – when the opportunity came to as it were re-specialise in machine translation of languages that's what really took my fancy.

[05:50]

Although I did – did study a book on measure theory, which I remember in fact and was quite good background for what I – well what I'm doing now actually.

And when you say measure theory that's not a term I'm familiar with?

It's the – it lies at the foundation of probability theory, and is a – a branch of topology where the sets – every set has a measure which is a real number as it were, perhaps corresponding to its area.

[06:35]

I've actually seen pictures of the skyscrapers in later years but I was wondering if you could actually describe what they were like in the 1950s?

Well they were – looked I think identical to what they [laughs] – what they do now, they don't change shape very rapidly. And so they have a – a general form of a main block which is a high – high building, what twenty, thirty storeys perhaps, then tapering off in sort of irregular pyramid shape and sort of one or two spires. And perhaps a single spire in the middle with a red star on top and then some wings which are lower, perhaps six storeys and spread out a bit from the centre and maybe branch a little bit. And also have roof decorations of some sort or other, they're still there.

How was it decorated inside?

Oh lots of marble, really quite luxurious and very spacious … yes, no shortage of space.

How did the teaching facilities you found there compared to what you were used to in Oxford?

Well the lecture rooms were well appointed and the – I had regular tutorials, it wasn't all that different. I never saw a Russian computer, those were still pretty secret in

those days, although the university did in fact build one apparently, I heard it was called a Setun and was a ternary computer with three values for each digit rather than just two [laughs], didn't last very long.

[08:45]

What was the – who actually taught you when you were there?

Who? My tutor was called Sevastyanov and I remember there was a lecturer called Dynkin. Kolmogorov gave lectures too, very nice. But that's all I remember.

Did – were you treated any differently because you were a foreigner?

No, not really, no. They did have exchange students from other countries, in fact the Americans had been exchanging for some – a few years before British Council came in on the act. And they had a lot from China at the beginning of the year and I think that was probably the main lot. People from Eastern Europe, Egyptian I met. And when I talked with my fellow students in the evening if they were – quite often the natural language to use was English [laughs].

[10:00]

Although also spoke Russian to our Russian friends.

What was the social life actually like there?

Social life, I socialised with the diplomatists in the embassy which would throw parties for us or to which we were invited. I also got in with a group of poker playing journalists, and met quite a few ex-patriots, people who'd perhaps married a Russian wife or for maybe more political reasons had decided to change their abode. And that was very interesting because those three communities did not mix at all, you never [laughs] – the diplomatists and journalists obviously have different interests and [laughs] everybody tended to shun the ex-pats [laughs]. I think we were very lucky that year and subsequent years, I think we were quite a new experience and since

those three groups never really met each other, we had a certain cache of novelty [laughs] which was very nice.

I was wondering if you could give me just a little illustration of what each of these three groups was actually like to meet?

Perhaps we didn't – well I met the journalists as a group and the journalists were as you would expect, quite jovial, quite hard drinking and quite keen poker players [laughs]. So … that was the – used to have fun with them and the … perhaps with the ex-patriots one felt a little reserved but I did spend – I was entertained once by a man and his wife and it was very pleasant, he was doing military work, I've forgotten, compiling a dictionary or editing a dictionary or something. And … the diplomatists I think were mainly on business, sort of their job entertaining people [laughs]. We mostly would socialise with each other 'cause we were all together at a diplomatic party so … gave us a chance to meet our fellow students, fellow English students.

[12:50]

I was wondering, you mentioned, you know, worries about your room being bugged and that sort of thing, how much was the Cold War actually in evidence?

Well it – it was quite in evidence because that was the year in which the spy plane was shot down, at the beginning of the year Kristov visited Eisenhower in the United States and there were book published about the friendship between America and [laughs] Soviet Union. And then this incident occurred and Eisenhower was caught out telling a lie and everything shut down, the invitation was – returned invitation was resended [ph] and I think people were more careful after that. We did make Russian friends and we all accepted the situation as we found it, shall we say [laughs]. But each of us might have been spies, or whatever, but didn't really, you know, sort of left in the background. Actually the effect of the bugs that had one effect and that is that absolute rule not to talk about our Russian meetings with the Russians in our own rooms, because what – the Russians were interested in who we were meeting. And the same thing – same rule applied, do not introduce your Russian friends to each other because each of them thinks the other is the informer [laughs]. Really, quite

spectacular Frost [ph] [both laugh], so we learnt not to do that. And I got quite a shock when I got home and talking about my experiences, I caught myself not mentioning the name of my friend in my own home in England. Oh, but yes, that's alright [laughs].

Do you think actually being trained as an intelligence – well to go down that intelligence route in the first place actually gave you a degree of insulation to that sort of thing when you were in Russia at all?

I think no, it was pretty – associated the, you know, interrogation is a specialist thing and the tricks of the trade, whatever they were, I've probably forgotten now [both laugh], were not really relevant to anything we did later I'm glad to say [both laugh]. Never been employed.

Did you actually talk about – what did you talk about with ordinary Russians?

What life is like in England? What do you think of your Queen, very funny thing this royalty business. Do your peasants get pensions? Which [laughs] one has to still take two or three steps back and explain [both laugh] about absence of peasants in our society [laughs]. They were in and perhaps still are a very recognised class in the Soviet Union, you had workers, intelligencia, intelligent [ph] and peasant and that was your registration, that's what you put on the form when they asked what your social level was [laughs]. And the peasants lived on collective farms and they were I think very poor and worked very hard and really had a pretty miserable life. And obviously they were talking about the possibility that they might have pensions, they didn't really get a salary, they got – they – an allowance for a day's work which could be cashed in the shop perhaps or whatever.

Did you meet any other preconceptions that Russians had about life in England?

I think perhaps they were too polite to repeat the [laughs] Dickensian, on the whole they had a very rosy view of what life was like in America and the west, they weren't – they weren't being taken in by any manner of means [laughs]. But on the whole we just kept off that sort of issues, we didn't complain about what goes on in Russia, they

were your hosts and you don't talk politics anyway because you – Russians wouldn't talk politics and it could be very boring and tactless to do so. And – but that, you know, as occasionally with close friends they'd discuss a serious issue like membership of the communist party, two friends were – who knew each other beforehand, discussed – they felt that their society needed change and should one actually join the communist party to effect that change or try to work for the change outside the communist party, I think, you know, serious question and I think they disagreed what – what the answer should be [laughs].

And it's Russian friends or?

Russian friends, yes yes.

[19:00]

Where would you actually put yourself politically at this point?

I was left of centre, *New Statesman* reader and in fact I got the *New Statesman* sent to me each – each week or two weeks or whatever. And I got very annoyed with it [both laugh] criticising what was going on in Britain, they should come out here and see what it's really like [both laugh], so perhaps I came back a little more appreciative of the … organisation of our own society.

I was going to ask as well you mentioned this move from looking at probabilities, statistics to in machine translation of languages and I was just wondering how did that actually come about, that switch, was it just through the NPL or were you already interested in it?

It was I think primarily through the NPL, off – offer, so amazing how one ends up here even if it's not organised in the civil service [both laugh].

Had you had any contact with them before or?

No no, quite out of the blue.

If you had to sum up what you learnt in those – that year in Russia, what would it be?

[20:45]

I suppose again a very different – very different way of life and my interest in computing was I suppose increased. I did in fact make perhaps my most famous invention while I was at Moscow State University as a result of thinking about problems of translating languages. The first thing a computer would do on reading a sentence in the foreign language was to sort the words into alphabetical order because in those days the dictionaries and other language would be held on magnetic tape which clearly would be scanned from the beginning to the end. And if you sorted the words into order in a single scan you could pull the articles for every word in the sentence rather than scanning the whole tape for each word, so I thought, it's a nice exercise, how would I programme sorting the words, and usually very small main store of a computer, that … and I thought of one method and thought, no no, that's a bit slow because it would take – number of words you'd have to square it and you'd have to do something for every pair of words. And then I thought of a method that was better than that and that was called Quick Sort. I tried to programme it in Mercury autocode which was the only programming language I knew at that time, and I couldn't quite organise it, I thought, oh something like this will work [laughs]. And – and in the end that's how it turned out and now when I go to China or Russian or anywhere that's the thing that they all know that I'm famous for.

I was wondering if you could briefly just explain to me, once upon a time many years ago I couldn't actually code a Quick Sort but I have actually forgotten so [both laugh] –

Do you think I've remembered [laughs]?

I'm just wondering if you could very briefly, you know, for the purposes of someone who may not know how a Quick Sort works, if you just explain the basic functionality of one?

Yes yes, well the idea is to split the job into parts, and so the splitting is done first, and you split the words into two groups and the ones in the left group are all smaller than the ones in the right group, and that can be done quite efficiently on a computer. And then you sort the left group and you sort the right group. Well you sort them using the same method that I just described for sorting the whole sentence. You split them into two sub subgroups and sort them separately. And when you put them all together they're all sorted. I see you've drawn a lovely picture of a tree which is exact description of how the whole thing works. So it illustrates a basic concept of problem solving which is divide and conquer, and it uses a computing technique known as recursion which is used to get the computer to use the same method to solve the smaller problems as it – as you have told it to solve the bigger problem. And it works fine provided that at the end you recognise that the problem doesn't need solution or can be solved by some other method, because if you go on forever then the computer goes on forever, and we've all done that many many times [laughs].

[24:40]

It's interesting the way you – you said you invented this idea, I'm just wondering, you know, this process of invention sometimes it can just be click [clicks fingers] and it's there, other times it's more of a thinking things through and working it out, which was it?

This was a click, amazing [laughs]. Start of a career in computing [laughs], just the right thing at the time.

Do you remember where you were?

Yes, I was lying on the sofa bed in my room in Moscow State University, that's probably the piece of paper in my hand and pencil.

What do you do once you've had that click, where does it go from there?

Well try and work it out in greater detail which I did by trying to programme it in Mercury autocode, but Mercury autocode didn't have this wonderful recursion that

makes it all sound so easy, and the administration of the tree was more than I could quite manage. But I must have stored it up and then when I learnt a language which had recursion I used it to write the programme and actually publish it in a western journal.

When did that come about?

Early 1960s when I was working for Elliott's. The – more or less the first job I was given by my supervisor at Elliott's was to write a sorting programme and he said, 'Use this method,' a method that had just been published by a programme known as Shell, was called Shell Sort and it's quite a complicated process, and fairly effective. And so I programmed that and I showed my programme to Pat Shackleton was his name and he – he was – thought it was okay, and rather timidly [ph], 'I think I know a faster way of sorting that,' 'Oh I bet you don't,' he said, [laughs], so I described it to him and he said, 'Oh yes,' and he programmed it himself, because he'd previously programmed the Shell Sort for a different computer so he programmed it for the same computer and found indeed it was faster.

So taking a step outside of, you know, your own little narrative in this, I was wondering if you could sort of situate Quick Sort more broadly, how important was it as a development?

Well I don't – I haven't had it confirmed but people tell me that it's still the most widely method – widely used method. It becomes more and more important as the main memory of the computer gets larger because the difference between N squared and N, something close to N itself, gets very large when you've got a thousand billion of them. And then so it's – it's really quite effective and it's quite effective in – even the extending backing stores that computers use nowadays which are getting more and more random access and so I think the basic – basic technique is still very applicable.

And how old were you when you actually came up with the idea?

This would be 1960 so I was twenty-six.

Did you think at the time that this would be the thing that people would know you for half a century later?

No, I did not [both laugh]. I did have a vague suspicion or ambition that I might be an academic and that in order to be an academic I should publish things. And I suppose that caused me to write it up for publication, which I – I did first in an American journal and then I wrote a much fuller account of the method and its performance which I'd managed to analyse using techniques that I'd used on the – learnt on the statistics course. And I published that in the British Computer Journal and the referee was Tony Brooker [both laugh].

What sort of response did you actually get to those articles?

Tony Brooker was quite impressed [both laugh]. No, I think as I say it was sufficient to get the people who were writing sorting programmes interested and excited about it.

Did you actually tell anybody else about it in that space between actually coming up with the idea on your Moscow sofa and implementing it at Elliott?

I didn't implement it at Elliott's, no, the implementation of the other routine was the one that was actually published and there was insufficient demand for – for it to – to actually change it, but it was implemented later on – on subsequent machines. No, I think by that time it had been published and people could read about it.

[30:20]

I think it probably seems a good time to move on to talking about Elliott Brothers and –

Oh right, yes, well we are more or less.

How was your interview for it?

I don't remember my interview. I think they might very well have made the offer even before my [laughs]. But … no, going there was … of course my first job, I'd made a – quite a conscious decision that I didn't want to be a perpetual student so I abandoned the statistics course in favour of getting a job. And indeed at that time the gender balance was reversed, there were more women in computing, programming than men, and that was very nice. Including Jill who became my wife shortly after in 1962.

How did you meet?

Well she was – was she – no she … how did we meet, we just met socially I think and I took her out, as one did in those – well [laughs] in those days and I suppose we fell in love or something [both laugh].

Was she a computer person?

She was a computer programmer yes, oh yes she was much more experienced than me, and she had actually written an autocode for the company's previous computer and so she was an obvious person to join me in implement – in doing what I was doing, which was implementing a more advanced autocode called ALGOL, ALGOL60, as they said for our next computer which was going to have the same autocode as this one. And I was leading a small team of two or three people implementing that language between 1960 and '62 or '63.

[End of Track 5]

Track 6

Elliott Brothers, where were you actually based?

Borehamwood, right in the sort of north boundary of London, next to the green belt and we lived in a small house in Barnet, quite close by.

Could you describe to me what – what the building you were actually working in was like?

Yes, a very sort of basic modern factory building with concrete beams, bridge – sorry beams and bricks and windows, three or four storeys high and with a single storey factory built out on the back. So, very standard, not – not very far from the studios at Elstree, and I had digs there, I used to walk past the studios on the way to work.

What was your actual job title or role?

I was a programmer, and then I suppose a senior programmer, and then I got promoted to being assistant chief engineer and then chief engineer. And eventually I was moved to the research division as a researcher, senior researcher, up to senior researcher. So I have had jobs as an engineer [both laugh], which is nice to look back on.

I was going to ask as well actually 'cause programmer in one of those words that the meaning of has actually changed quite a bit over the years.

Indeed, yes.

What did it encompass when you were actually a programmer for Elliott?

Well we would design and write library programmes for our customers. Where did we get the ideas from? I don't know. I – after the sorting I wrote a routine for – a device – called device routines now for looking after peripheral devices, organising transfers between tape and main store, I wrote a package for that. And then I moved

onto working on, as they put it, designing a new language, new programming language for our new computer. But we had a little computer library down in the – the ground floor of the building and I found there a small grey leaflet called The Algorithmic Language, ALGOL60. And I read that and – and took it as a model for the language and tried to put into the language those parts of the ALGOL60 language that I'd understood and which I thought our customers would be able to understand, and the bits that I thought I knew how to implement [laughs]. So it was quite a small subsets as a language to begin with [both laugh], but eventually I went to – on an ALGOL60 course in Brighton, I think, you know, in 1960 itself. With the manager and the sales manager of our division of the company and after that course we sort of decided well why don't we just do ALGOL60? Very fortunate decision 'cause that's what I then had to implement [laughs], not quite all of it because it was – it would have been too inefficient on our machines but quite a substantial –

[04:30]

Including of course recursion which is most important facility of language [laughs]. I used recursion actually in order to structure the compiler itself, it gave a way of splitting up the task of – of compiling each component of the language, could be compiled by a separate subroutine and then they would call each other recursively to – to compile a complete programme.

Just for the benefit of people who don't know what a compiler is would you mind briefly defining it for me?

Yes, the task as a compiler is to translate from a mathematical language which is somewhat comprehensible to human beings into the machine language of the computer which the machine can understand and execute but is not really suitable for human consumption, or production for that matter.

What are the advantages of using recursion within it as opposed to other methods?

The advantage of recursion is that the whole language was defined recursively in the sense that the individual commands of the language were made out of expressions,

and the expressions were made out of sums and products and the sums and products were made out of the expressions, and so as you analyse an expression you see the same patterns occurring on a smaller scale within the expression as you see for the whole expression. And that's the basic idea of recursion, that the parts are similar to the whole.

So are there advantages of using it in that way?

It meant that we could split up the complete task among different people writing different parts of the – of the compiler and we could get the parts of the compiler working separately from each other and then put them together. So at all times during the implementation you were able to actually compile larger and larger parts of the whole language, until eventually you sort of thought, well maybe this is all we need to do [both laugh].

Right, I was actually – my other question was how would you go about implementing a language but it sounds a very sort of step by step process building up to a whole then?

Yes, I mean none of us knew how to do it at all, it was all completely new. I did actually read an issue of the communications of the ACM in which people who were working in compilers described how they did it and so I'd had some – some guidance. And – but this method of using recursion was for me at least quite new. Most people use other techniques which involved translating into intermediate languages. In those days the stores were so small that you couldn't get the whole of a compiler into the store together with the programme that it was attempting to compile and so you had to split the compiler up into parts and then each part would translate the whole programme into a language which was nearer to the machine code of the computer and everyone would regard that as a very difficult way of doing it [laughs].

[08:20]

What computers were you actually using at this point?

What?

What computers were you actually using when you started at Elliott's?

The computer I was using was the Elliott 803, and the computer that I was designing compilers for was the 503, the next computer which was going to be, and was in fact, sixty times faster than the 803. So while the 803 was quite reasonably fast at compilation, the 503 could actually compile the programme that you give it at the maximum speed of the input device, which was 1,000 characters per second. It was great fun watching the [laughs] programmes being fed in that much faster.

How did you actually feed them in at this point, was it –

They used the Elliott paper tape reader so they were punched on sort of teletype punches, as each character was represented by five or up to eight character – up to eight holes in a piece of paper tape and then the reader would read these rows of holes one row every thousandth of a second.

803, 503, actually compatible at all or?

They were very compatible, yes, yes the programmes that run on the 803 ran on the 503 without any problem. But we were able to actually deliver a useable compiler also for the 803 and it was quite widely used by 803 customers, particularly those in universities.

How much contact do you actually get with the people who are using your software at the end of the day?

Well I used – we used to run courses, programming courses for our customers and I'd do some of the teaching on that. And after that, well not – not very much, much the same as it is today, you launch your brain child onto the world and if all goes well you don't hear anything. Things start going wrong you might [laughs] get some feedback that isn't entirely welcome.

Interesting in the way that you said you'd be asked to write a computer language for the 503 and you thought, oh ALGOL, this looks a lot more sensible, how much freedom do you actually have in this job to actually make that sort of decision?

Well that that was what I was asked to do so that was the job. Programmers these days – well they also have quite a bit of freedom, particularly if they have the imagination to think of what their customers are going to want, the management probably mainly prioritising things rather than actually designing or instructing or delegating. It's quite a sort of democratic profession.

Interesting point there about what your customers want, who did you consider your customers to actually be, who was your end user, who was in your mind?

In those days?

Hmm.

The main market – we had a commercial market the commercial market our machines were sold by the National Cash Register Company so we didn't meet any commercial customers. They were mostly industry and engineering, agriculture to do statistical agricultural research establishments and universities because we would – essentially came in at the low end of the price range of computers in those days, we could sell our complete basic computer for 23,000 pounds which would be somewhat over probably about half a million today. And it was a – it would actually execute nearly 2,000 instructions per second. And nowadays you get 2,000 million instructions per second [laughs] in a mobile phone, it's ridiculous.

Did it actually feel like a small number at the time?

No, no it seemed amazing, compared with – compared with the use of the comptometer which I knew about, it was hundreds of times faster than you could get – people used to publish books called *Faster than Thought* [both laugh] which it certainly was.

[13:25]

As someone who's actually working in the computer industry, I was interested you mentioned Faster than Thought, I'm just wondering what you made of the wider perceptions about computers that existed in popular culture?

At that time?

Hmm, before people actually had them?

I – the – the most … I summarised it in 1977, that in 1977 still most people had never seen a computer, and never expected to see one. Because of course they were rather hidden away anyway in computing centres and fairly closely guarded, even in those days and – and that certainly changed [both laugh]. Well I remember Iann Barron talking about micro process – he was the person who persuaded Callaghan to go into information technology, and indeed support INMOS, his company, with government money. And so he was – he was the chips with everything man in those days. And he said – he predicted the day in which the ordinary person would not know how many computers he had in his house, he says, 'How many electric motors do you have in your house at the moment?' this was in '77, and most people wouldn't know. And we still don't some – our computers have been like that for some time.

Did you actually think that situation could arise in the 1960s?

I have always been sceptical about the amazing development and – of computers and the prediction that they would continue to improve at the same enormous rate as they were, doubling in – in both speed and size and capacity, storage capacity every two years or so. And it – it really is a) impossible to believe that it would happen and b) impossible to imagine how you would use all that extra power. Of course you don't realise that until it actually happens and in fact more or less until it's on the market, there's really been no development in the propagation or the innovation in computing that I've been able to foresee. And the people who do foresee it and actually make it happen of course make a lot of money.

While we're on the subject of money I was wondering how well paid is a job as a programmer in the 1960s?

It was quite – I thought quite well paid, I was paid 900 pounds a year which was 100 pounds more than the standard graduate salary, because I knew Russian, and every year or two they used to send me back to Moscow with a computer in a van to exhibit the computer and sell it to the Russians afterwards, so they got some value. But the thing is that the salary would be expected to go up every six months for at least two years and if they wanted you it would go up quite quite fast, so that's how they kept people. It was quite normal to recruit people and then for them to only stay six months because the market for jobs was so buoyant that anybody with six months experience was way ahead of the field.

Why did you say for eight years?

Well my salary kept going up [both laugh], no the work was – I had no reason to move, no, it was a very good environment.

[17:40]

Can you describe what that environment was like to me, on two levels if you would actually, both sort of the physical environment in this modern factory where you're working, and maybe the atmosphere as well.

Right, well to begin with I had a partition – my office was a partition in the corridor and I soon graduated to a desk in an office with about ten programmers. But then as I I suppose moved up the management scale I got into an office and had a secretary and [laughs] – and looked after other people. They were people that I had myself recruited and that I liked and respected and that has really been my good fortune during all my – all my career, that I started small and recruited people that I liked and enjoyed working with and in those – those circumstances one doesn't feel like leaving. I thought when I came into the industry in 1960 that I'd really missed the bus and that the main – main wave of expansion of computing and programming was now over, and I had a long haul, my boss was only four years older than me and it might be

a long time before I was promoted [both laugh]. That's unbelievable how it's still – still expanding.

How long was it before you were promoted?

Erm, I suppose I was put in charge of one or two people in the project group quite quickly. I mean in charge of is sort of [laughs] … no very great managerial [laughs] directive. It – moving up the next stage and being in charge of several projects, that was when I was promoted to assistant chief engineer.

[20:00]

Actually looking after all the software of the company, things began to hot up, got an office and a secretary, and made my big mistake. The project that I was working on failed completely, this was on the 503 computer, the – the success of the ALGOL compiler project gave us the confidence to attempt to implement an operating system, and operating systems really necessary on faster computers because the operators manual operation would just be too slow. So I sort of designed a – an operating system and set a team of people, eventually a group of about thirty people to work on implementing it. When the time came when we promised delivery it wasn't ready, so – and it sort of passed without anybody noticing and some time later we sort of thought this was a poor show or some [laughs] more senior managing pointed out that this was a poor show and so we had to assess the progress that we'd made so far and make an estimate of when we really might deliver it. And came up with a figure six months ahead, and then started work on a reduced specification. And everybody worked very hard, nights and – and daytime, and you know, well to begin with I made everybody estimate how much they were going to do each week and at the end of the week I would have a progress meeting and found that they couldn't [laughs] – they couldn't do it, they were actually working slower than they'd thought. But in the end we got down to a realistic estimate and the thing was ready and unfortunately when it was demonstrated it was just incredibly slow. The compiler which under the previous system was working at 1,000 characters a second was now working at two characters per second, which actually made it undeliverable. Well we continued working for a month or two and by immense labours we managed to get it up to six characters a

second [both laugh] before we decided that we weren't going to be able to do it. So my boss called our customers, all our customers together, fortunately I think there were only about eight of them, and told them that this promised software was not going to be delivered, and they were all from universities and research establishment and so on and they didn't take it too hard. But I was sitting there [laughs] listening to this chapter of woe from my boss at a lunchtime, they were – realised I was a bit depressed and they comforted me by saying that they never really expected it to be delivered [both laugh]. So one begins to wonder how thirty people working hard, very intelligent people, could work for two years on a project that was absolutely doomed, from the start. And it was doomed because we didn't have enough memory, the decision that the new machines should be compatible with the old machine meant that its addressing range was only 64,000 words and that was therefore the size of the main store and the programmes would not fit into that store and they had to be taken from the backing store which was amazingly fast, but not fast enough. And so it spent all its time transferring information between the two stores rather than doing useful work. So prob – so the problem was one that afflicted I think everybody who tried this method of enlarging their main store, including even IBM, it's called thrashing, and the store thrashes rather than doing any useful work, and we learnt it the hard way. Now that – the story of that … failure was recounted in my Turing award lecture in 1981 where it struck a resonant note among the [laughs] many others who'd suffered similar failures. And of course it set the challenge for how should one write an operating system, writing a compiler seemed to be easy, why were operating systems so much more difficult, and that gave me my first interest in research question when I moved to the university. And I'm still working on it [both laugh].

[25:50]

I wonder if I could take you back to those two years spent developing the operating system.

Yes.

I was just wondering if you talk me through how one actually goes about developing an operating, even one that doesn't necessarily work that well at the end of the day, you know, where do you start?

Well there were plans to produce a second version of the ALGOL compiler and produce a symbolic assembly language which was the – what most people were using instead of machine code, a sort of interm – a language which was intermediate between high level language like ALGOL60 and the machine language, gives the programmer more control over the way – efficiency of the storage and – and computing of the machine. And then the operating system was – the purpose of the operating system was to look after the peripheral devices, magnetic tapes, drum, disks, we were hoping for line printer and input devices, plotters and so on, so there was a fair amount of work there. But the main thing was to enable more than one programme to run at the same time, and that raises problems of sharing the machine doing more than one thing at the same time, nowadays known as concurrency, which is quite difficult to manage and control anyway, but essential to the efficient use of the computer in an operating system. So we had programmes which looked after the – what did they call it, spooling, where the magnetic tapes would provide input in advance of what was needed, that's input spooling, and where the output to the magnetic tape would be stored if the magnetic tape was not ready to receive it, so output spooling, so that was one of the components of the system. And having split it into components you then get a team of people to work on each of the components. I didn't concern myself very much with the details of what they were doing, so taking a rather stand off view of management. But when the – when the crash came I really had to delve down a bit and get – get things working again. So we threw away that code and took a very much more step by step approach to improving the software that we had already delivered successfully and doing small bits of – that our customers really seemed to want and not inventing a whole new software system which is what I had done before. I think – well I sort of admire myself for actually [laughs] getting down and really working at – digging the company out of the hole that I had dug for it before [both laugh].

I was wondering, as somebody who's managing that team of thirty people, how much detail work do you actually have to do?

Well really not very much. I did do a lot of progress meetings, getting people to predict how long things would take and in learning how to estimate better, gradually. And the second thing was really almost part of the company philosophy that I put the programmers in direct contact with our customers, and so they would find out what needed doing, what the customers really wanted, and they would report back and I would moderate, or prioritise shall we say, what they were asking for and make sure that our programmers didn't make too many promises to too many different customers. That was the management style that I adopted.

I was wondering if you could give me an idea of what life is like as a manager in Elliott's, could you perhaps talk me through what a day working there was like as a manager?

[30:40]

Well it was very varied of course, there was a lot of administrative duties, project proposals to request development funds, recruitment took a fair amount of time, there was customer support, sales support, and talking to the troops. I was actually – had quite a wide responsibilities which I think at – I was never responsible for production surely … I'm not – I used to walk around the factory every day to see what was going on. But not because I had to do anything about it but just I felt I ought to know what was going on with – that was a sort of [laughs] – I think managing programmers is – you have to be really quite gentle because they – it's so easy to get another job, so you have to make sure that life is – that the programmers are all doing what they want to do and understand how they're contributing to – to the company and sort of keep moral up, which was important. I did ever seem to – once I'd – once I'd recovered from the [laughs] error I seemed to be quite successful as a manager.

Could you give me an idea of maybe just one illustration of how you'd actually go about incentivising programmers and trying to keep them?

Well the most important thing is to talk to them and find out what they want, that's – you do a lot of comforting, people feel a lack of confidence and worry about things

and just have to be comforting, that's – I was, yes, I think every manager knows that that's part of the job.

This is going to sound like a facetious question but who do you have lunch with?

As a manager?

Hmm.

Erm, what did I do, I used to lunch in the – in the canteen for a long time … I think it was sort of fairly random. We used to go out drinking with our friends, became, you know, it was a weekly out [ph] on Friday evenings which was a more social occasion than – than lunch. And I think after a while, when I was married, I used to take sandwiches, at least some of the time and … I didn't – there was a senior manager's canteen which I was occasionally invited to but usually the food was a bit too posh, I mean a bit too [laughs] – a bit too much for lunch, I was getting quite fat. Well after Moscow I couldn't – I was very thin in Moscow, sort of not terribly tempting food [laughs], so I needed a bit of plumping up.

[34:40]

And we've talked a little bit about the time as a manager in Elliott's, I was wondering if you could give me an idea what was life like when you started there at the other end of the scale as a programmer, and what was, maybe again looking at what you would do in a typical day perhaps?

Well of course it's much much less varied, you just come in and design or write a few words of code or you run a few tests or whatever it is and then the next day is very similar. And then you – then you write it up and document it neatly and get the documents circulated in – in a loose leaf folder to distribute to your customers and then go onto the next thing. So it's – it's fairly concentrated, you don't want distractions very much when you're writing a programme [laughs]. And I tended to continue to think about better ways of doing things, when I – when I left work as well, which probably wasn't good for me but still do it.

So do you spend most of your time working in that little cubicle or are you talking to the people around you as well?

I think there was a fair amount of talking around. I moved into a smaller office, sorry an office with three or four people and then we would – we would chat about what we were doing and I think that in the – when – a cubicle in the corridor I didn't have any neighbours and in the larger office it was antisocial to chat too much, but I think we were just three people and perhaps the third one wasn't there you could talk quite a bit.

So what sort of things do you talk about?

Erm, anything, we talked about our work … oh [laughs], I'm not very good at small talk [both laugh] so I'm sure on the whole what we – I think we talked about politics and … a little bit. I don't remember, sorry.

[37:20]

I've got one other question as well which I thought I'd pose – ask you about programming as well, you know, to me programming now means sitting down and just tapping something out on a computer, but obviously you haven't got that option in the 1960s.

Well that's right, programming is writing a lot of symbols on a coding sheet very often with – if you're programming a machine code the columns are laid out for you and then you hand that in to be punched by the punch girls, and so you might be waiting a little while for those to come back. Then it is punched on one machine and then verified on another, that is a second typist types the same thing and the machine is set to check rather than to punch, that the holes that it reads are the same as the holes that it was asked to punch again. You get that back then you have to get a slot to run the programme into the computer and actually test it and that could take another little while. Then as a result of the test you find an error so you have to change the programme, the programme is changed on the coding sheets, and then it is as a whole

punched again. Now these programmes were comparatively small of course and so the cycle repeated. And so it was usually a good idea to have more than one thing going on at a time so that you were writing new code at the same time as you were waiting for the punching to come back and test the old code.

Is reliability of the computers you're actually running it on an issue at all?

Yes indeed, the – particularly for machines that hadn't even been delivered to customers yet, we ran the programmes on the prototype computer; or well of course for the 503 we could run the programmes on the 803 as a preliminary, so that wasn't so much of a problem. But when we got peripheral equipment that would be fitted obviously to the 503, and it would be fitted to the prototype, peripherals would be fitted to the prototype 503 and it wasn't always reliable. And that was a constant cause of complaint, I did – I did once get the hardware engineers rather than maintenance engineers to make a list of what it would take to bring the prototype machine up to production standards and the list was so long that [laughs] it just couldn't be done. Yes, it was quite … but you certainly had a – it was a small company and you certainly had a feeling of belonging and contributing and seeing what you'd done really make a difference, that was great.

Shall we call it quits for today then?

Yes, certainly.

[End of Track 6]

Track 7

I was wondering if you could tell me a little bit more about your time at Elliott's, were they a good company to work for?

Oh, I think everybody acknowledges them as being among the best, the – they still seem to have the reputation they had of hiring very bright people and doing innovative things. I meet them – I meet them occasionally even now, a little group of us who meet two or three times a year for lunch or – and of course there is quite a bit of interest in the Computer Conservation Society in – in that side of computer history. And there's a book been published recently by Simon Lavington, he's worked on it for decades and it's a very comprehensive history of Elliott Brothers which I'm afraid I haven't bought but [both laugh] comprehensive I think is the word.

What did you like about working for them personally?

Well I liked programming, and somehow – well I liked the people I was working for and later on I liked the people who were working for me, and although there were periods of considerable stress and failure [laughs] they always treated me extremely well.

Are there any colleagues in particular you remember well?

Yes, Jeff Hillmore was a colleague write – in writing the ALGOL60 compiler. He worked more with Jill while I smoked my pipe and thought deep thoughts [laughs], he did the actual work. I still met him occasionally. Roger Cook was my boss, he was head of division at the end and I still meet him, very nice man. Laurie Bentall, chief engineer, hardware man, was my boss for quite a time. And one or two others who are perhaps closer friends now than they were at the time. So it's very nice meeting them every now and again.

What was Roger Cook like as a boss?

Very non interfering I should say. He had an amazing gift for coming to demonstration of a new computer or a piece of software and poking random buttons and it didn't take him many minutes to cause the system to crash, 'Oh dear,' he says.

How much did you actually test items of new equipment and software?

I didn't test the hardware, but the – it was accepted every programmer still has to spend quite a long time testing software that they themselves have written, so testing is probably still takes half or more of the total time of development. particularly of general purpose software where you've got to deal with a wider range of possibilities than – than a piece of software that is more special purpose.

Are you looking for anything in particular in that testing process?

Yes, you – it's quite an art, you try and write tests that are going to find any faults that there might be. But of course even random testing is better than nothing and sometimes just sort of wandering around and noticing any unexpected seems to me [laughs] a necessary part of the process.

Were there arrangements in place as well for other people to test your code?

No, I don't think that's really – well it's widely practised in Microsoft at the moment where there's a whole profession of testers who are not line managed by the project team itself, the sort of quality control group, which on many projects numbers more staff than programmers. And they tend to be independent, but the reason why the programmer really has to do his own tests is that he's expected to correct the errors that are discovered and so that is part of the same process.

[05:20]

I was wondering about, sort of on the software side of work in Elliott's and you mentioned Laurie Bentall as the chief hardware man, how much contact between the two halves is there in the process of developing something?

Very little even then, probably would – developing a new computer was something where hardware and software tended to come together because the hardware people where interested instruction counts, which were the most frequent instructions, are there any instructions we could leave out next time, so we collected statistics of that. And I think there was some thought even then that the writers of the compilers should have the ability to say, 'Oh no no, if you put that in we would never be able to use it,' but I don't think – unlike today, I don't think very much notice was paid [laughs] to the requirements of software at the time that the hardware is being designed by hardware engineers.

Why do you think that is?

Well for one thing software people can never agree, so – and the second thing is hardware people have to build it and they have to build it to be as cheap and as fast as possible and those are objectives that they know how to achieve. Any advice on – on the – from the software people is confined to things that the hardware people don't worry about very much, like how do people use it [laughs]. [Break in recording?].

We were talking about hardware and software weren't we, that's a –

Yes. The present situation is that on certain critical questions like security and some of the sort of basic low level software, the colonels of the supervisor and so on, there is consultation on new developments between Intel and Microsoft and indeed other manufacturers of hardware and software where it's important to establish a – an industry wide standard in order for the – the protocols and security to work. But on the whole I think that – in spite of all we said at the time, there isn't a great deal that the software people can tell the hardware people. Both of – both of them are so constrained by what already exists, enormous legacy of – of millions of lines of software, already written by manufactures and basic teams, Microsoft and Google and IBM, and even more written by the customers, it all has to work on the next version of the hardware or it – their sales will be zero so they've got to do the same as they'd done before. But if there's a – a real new application like graphics or security, then at the edges they're willing to – and they do consult the software writers on how to ensure that there are no loopholes in the security systems.

We talked a bit last time about being the 503 and the 803, was the worry about the legacy system and ensuring compatibility with that something that existed back in the '50s and '60s.

[09:55]

Yes, I think around that time all the manufacturers realised they couldn't afford to go on and developing their own software from scratch. Of course for the smaller manufacturers they didn't have such a large customer base anyway, and they would – they did not have a long experience of existing customers buying the next machine. But of course IBM had that experience and something like eighty per cent of the world market so they knew the legacy problem and they introduced a range of computers, I think around the time that our big software project was collapsing.

You mentioned the problems with the operating system project [laughs] last time, and also the ALGOL compiler you developed, I was wondering what were the other big projects you works on at Elliott's?

I think those were the only ones, the ALGOL compiler I worked on with a small team, of which I was the project leader. And the operating system was a larger team but … the – the only other software I wrote was sort of practice and a sorting routine right at the beginning and a magnetic tape drive device routine, to look after the peripheral equipment, storage equipment. So neither of those were as big as the operating system or the compiler.

And what's the chief challenge for someone like yourself writing software in a commercial context at this time, is it …?

Commercial suggests business use of computers that we weren't so concerned with. But I presume it – I mean in general scientific and industrial, what were the main concerns? Hmm … I don't think we ever really thought in general terms like that [laughs], one did what one had to do. You know, things that really hadn't been done before and so you more or less have to be driven by what – what's going on and

customers that you've actually got if you meet them, and the applications occasion – the applications that the individual programmers were working on, usually at the bequest of a customer.

Is there any particular thing you're optimising that software for though, ease of use, reliability, speed, those sorts of concerns?

Yes, I think for the ALGOL compiler the goals were – well the usual mixture, the speed goal we didn't pursue actively, the criteria we used that it shouldn't – it should be as fast as a normal – normal machine code written by human beings, or not much slower. And the size of the – size of the code was very important because the stores were limited to about, well eight or 16,000 instructions, well – and so that the generated code had to be reasonably compact. And the other thing that I was very keen on was that the effects of programming errors should be diagnosable without knowledge of the machine but only knowledge of the programming language, so you never got what they called binary or hexadecimal dumps trying to find out what's going wrong by looking at the actual raw contents of the store, it could all be predicted from the programme itself. This meant that our compiler checked all subscripts of all the arrays on every single access, which did of course make it quite slow compared with the norms in which these things are – well a programmer makes a mistake that's his fault and it's not our job to help him [both laugh] and that's of course in a way – presages [ph] my interest in correctness of computer programmes, verification and correctness.

Are very formal methods in place then for actually ensuring those things?

No, no formal methods. Relevance of mathematics and logic to the subject was – was not – not really thought of and indeed isn't very often thought of even today [both laugh].

I was wondering if you could give me an idea of what you think your style was like as a manager of programmers?

When I was – I think throughout it's very *laissez-faire* and didn't interfere very much and I looked on the job of a manager as creating an environment in which the team can – can do its best, and forming an interface to the rest of the company, or onto customers and so on. So it was in – I think, I mean perhaps without knowing it I designed – chose the subset of the language that we were going to implement and I wrote the basic pattern of how the store was to be laid out and the run time routines, storage allocation and so on was to be done. But basically let people get on with it. We had no budgets, no deadlines, no development appropriation requests, at least not in the earlier days, we did later on. So it was a bit like Microsoft research is now, free and easy. But at the same time very effective.

[16:35]

I was wondering, you mentioned your sort of career path in Elliott's last time of programmer to senior programmer to chief engineer to researcher.

Yes, assistant chief engineer first, yes. And then translation as it were to researcher, and basically they justified it to me by saying, 'We think you'll be happier there,' and I think they were right really [both laugh]. I was … perhaps not – not terribly interested in the meetings and the managements and the policy and so on, and was very interesting work and interesting colleagues in the research laboratory.

I was going to ask as well, what does the engineer – the chief engineering part of this actually involve, sort of sounds like you were working with machines themselves and designing them?

Yes, I think that – I think that sort of meant I'd looked at the prototype machines and things like that [laughs], occasionally talked to the logic designers, it wasn't a very large team of design engineers, and I think the title of chief engineer was one that shouldn't – even at the time I felt was a little … of an exaggeration. Of course nowadays we use the word engineering for software engineering a lot more and recent awards have sort of made me more used to the idea that I might be a sort of engineer. I've always felt it a great honour to be an engineer, perhaps you do something useful and deliver products and so on, but apparently even working on theories that are

useful in the delivery of products is good enough, so I'm – I'm now a fellow of the Royal Academy of Engineering as well as the Royal Society, and just recently I got an engineering award from the Institution of Electrical and Electronic Engineers in the United States. And also election to the National Academy of Engineering in the United States which is perhaps the highest honour one could have [both laugh], as a foreigner it's sort of one above the native members [laughs]. But there are quite a few of us, they're very good at recognising contributors from other countries, particularly Europe of course.

[19:35]

What would you mark out as the difference between what you might have thought about as engineering, at the time when you were at Elliott's and what you were actually doing?

Well the – I've written sort of philosophical papers on the differences between engineering and science and I put myself fairly squarely on the side of the scientists at the moment [laughs]. But acknowledging that the engineer has a more important and apparently more difficult task in the sense that not only has he got to do good science, but he's got to deliver products on time and on budget and satisfy real clients or markets out there in the real world. And the trouble is the scientist is to abstract [ph] as far as he possibly can from the real world, to control all irrelevant variation [laughs], bring everything down to the result of time and controlled experiment which will decide – decide between two theories [laughs]. So the scientist looks for certainty, engineer doesn't have time to do that [both laugh], constantly flying by the seat of his or her pants, possibly to say his in the circumstances. And scientists seeks perfection, accuracy of measurement, best the engineer can hope for is controlled chaos [laughs]. But what happens of course is that the engineer turns the constraints of budgets and timescales and so on to justify always making the second best choice and never going – never going for anything that's good enough will happen, will be what he decides on. And as for originality, it's the life blood of science, but anatoma [ph] to the engineer, because originality nobody knows what's going to happen. You want to use things that have been tried and tested by everybody else before you. So that's … I don't think I saw it in quite those terms at the time [laughs], in fact we

tended to use the word engineer for people doing hardware as you were inclined to do yourself. And is still somewhat current.

At the time was there any difference you noticed between the sort of chaps who were doing the software side of things and the sort of chaps who were doing the engineering side of things, the hardware?

Well the hardware designers, the logic designers my boss told me were really intellectually that the cream and you couldn't afford to have software design designed by anybody except the cleverest person you could get and – but you don't need very many of them [both laugh]. He was a hardware designer himself at one time. Well basic reason is that because every transistor saved is profit to the company, you know, you have a limited amount of space in a cabinet and on the board, and a limited budget for the price of the machine, and you've got to fit as much as you possibly can onto the space and finances available. So – and of course you mustn't make a mistake, that's – those are a lot more expensive than areas in – in software which can be cured by a patch …

[23:48]

Were there many women working at Elliott's?

Yes, I think the majority of programmers recruited before I arrived were women, but unfortunately that changed and pretty permanently shortly afterwards, most of the people I recruited were men I think, but quite a bad gender imbalance which is still with us.

Why do you think the situation changed?

The … introduction of computers to schools I was told was the reason for it but there weren't very many computers and the boys all crowded round, and played computer games even in those days and the girls weren't so attracted to either the competition nor the type of game that the computer could play. We had computer addicts, people who really spent all their time, day and night, programming or doing something with

computers. And there was a reputation, a rumour that in fact your working life as a programmer was only two years 'cause after that you'd just go mad. Fortunately [laughs] it was a complete – complete fabrication. But I did meet one or two people, indeed interviewed one or two people who were obviously – programming was not good for them and wasn't – a good thing not to employ them.

What do you look for in a good programmer or someone you're interviewing in the 1960s?

Very difficult, I suppose one could – one could propose a logical puzzle of some kind or other, and – but basically I never felt that recruiting or interviewing was anything but a black art [laughs]. Fortunately I'm … always been able to be able to choose people that I enjoyed working with and vice-versa I think. And – and been pretty effective at weeding out the ones who are going to click and those that perhaps wouldn't.

I was wondering as a computer scientist in engineering, how much contact do you have with say computer scientists in universities?

I still have a lot of contacts as it's part of the Microsoft objective to encourage relevant research in universities, to link with it and of course to maintain – maintain a level of scientific industry – activity that matches the best that universities have to offer.

How was the situation in Elliott's?

I – in Elliott's was a small company and so we didn't have a specific policy favouring university connections, except that most of the machines we sold were sold to a university environment and so one did talk to the purchasers and occasionally gives them and talk at their universities. Or indeed run courses for them to come and attend to learn programming.

Were there any universities you were close to on that score?

No, I don't think so, none that I can single out. We were close to Hatfield University physically [both laugh], but I don't think I visited there anymore often than anywhere else.

[28:15]

When were you moved to the research division of Elliott's?

That was two years before I left, 1966. And the division was working on the design of a new and advanced computer, that is to say there was at least one – well [laughs] a person working on it when I joined, and he – he was working on virtual memory and cache memories for speeding up the computer faster than the basic store speed of the machine would allow. Quite groundbreaking research in those days.

Who was the other researcher?

Mike Melliar-Smith whom I've been in contact with occasionally since and he's – he's still an academic and quite a – has quite a respected reputation in the field. And his wife too.

Under what circumstances did you actually move to the research division?

I'm not sure, as I say they sort of approached me and said, 'We think you'd be happier in the research division,' [both laugh] but shortly after I moved there the company was taken over. Now what was he doing, he was trying to excite interest in a new computer that we were proposing to develop, so we would go around to universities and to ascerne [ph] we went once, to try to describe these sort of architectural properties and the cache memories that we were proposing to use, and some rather vague grandiose expectations about what the software would do [laughs] which we would never have been able to fulfil. And, er, that's right, that was before we were taken over by English Electric, and I think we were trying to get government support to bring out a – more powerful versions of the computer that we were currently selling which was the 4120 and the 4130, so we gave new names 4140 and 4150 I think to the – to the medium scale and large scale computers that we were proposing to develop.

But when we were taken over by English Electric and it was very clear that the English Electric range of computers would be the – the future of the company. And not so long after that English Electric and us were taken over by ICT as it then was, to form ICL. And then it was obvious that it was the ICL computers that were the future of the company, after – some time after I left it was taken over by Fujitsu and now it doesn't make computers at all [both laugh].

Were those changes, you know, from joining in IEE and then joining – turning into ICL eventually, does the company itself change that very much?

No, we were left very much in situ, we were involved with the development team for the software of the new English Electric computer for a while, mainly in an advisory capacity and when I left – when I went to university ICL continued with a consultancy for me, again working on their new operating system for their new range of computers … the 20900 it was called.

How did your duties in the research department actually compare to those you'd been doing previously?

Well I didn't have a team working for me, and our brief, I suppose as far as we had a brief, was to conduct investigations that might be of benefit to the company and these tended to concentrate on this new machine project. In which I and Mike Melliar-Smith were the main – well our main job it turns out was selling the idea rather than [laughs] actually doing it. And we were especially coached by an outside coach in making presentations and we learnt quite a lot of skills from there which I still put into practice [laughs]. We prepared our slides and our script and one place we – we gave a talk and the audience were really quite restive [ph] and then – until the end and then they started asking some, you know, slightly sort of sneering questions. Which were very very good questions, I mean they actually hit the nail on the head and my colleague was able to answer them. I was perhaps able to answer some others and then turnaround in the audience was amazing [laughs] and afterwards over tea they said, 'We thought you were actors,' [laughs]. So it doesn't pay to have too slick a presentation.

What were your – what were the top tips you were given to actually sell computers?

Well we were selling ideas really rather than computers, basically I think about the layout of the slide, constructions which I don't bother with anymore but he recommended that the slide should always ask with a question and then have not more than six bullet points. One of the most valuable things he said is, 'Always turn up at the place of the talk at least half an hour before the talk,' it's amazing how often that really turns out to be good advice; something doesn't work. In one case they couldn't even find the key of the room [laughs] but fortunately they allowed us to see the room before lunch and by the afternoon they'd solved that problem [both laugh].

[35:35]

How much actual research did you do in the research division or was it all selling?

No no, I think there was quite a lot of speculation and discussion between us, a lot of which took place in aeroplanes to and from the place of – place of the talk. But it was very speculative and quite unrealistic [laughs] in the circumstances, but we – you learn a lot by thinking about things and working out better ways of doing them.

Where was the research division actually based?

In Borehamwood, quite close to the Elstree Studios, and we had a company just by the A1 I think.

Was it the same sort of facility you were in previously or was it different at all?

Previously from?

Previously from when you were talking last time about the Elliott factor in Borehamwood?

That is the Elliott factory, yes, the factory and the research division were – and the software's was all done in the same place. In fact the whole of – the whole of the

computing division of Elliott Automation Computers Limited was situated at Borehamwood. They also had factories at Rochester, and Sydenham I think, but doing other things besides computers.

When you'd sort of moved over into that what almost sounds like the computing equivalent of blue sky research to some extent, am I reading that correctly?

Yes, oh yes [laughs].

I was just wondering how other people in the company saw that sort of research?

Hmm …

And did people's attitudes towards you change for instance when you moved over from being a chief engineer to being a researcher?

No, I don't think so. Obviously didn't have so much day to day contact and … the head of the research division was very helpful and pleasant, I got on with him. No, again I take things as they come [laughs].

[38:10]

What was life outside work like when you worked for Elliott's?

Yes, what was I doing outside? Er, a bit of social life, drinking, wasn't playing any sport, no sports no. Was I played bridge, no I think I'd given up playing bridge, wasn't playing chess. I was married, I had children, so family life I think was the most dominant factor.

When did you get married?

In 1962, coming up for our Golden wedding in January.

How did you meet your wife?

At work, she was working for me as a programmer on the Elliott ALGOL project, so didn't have to go too far [laughs]. And we had a whirlwind courtship and short engagement and got married quite quickly in a registry office, with … a friend from Elliott's as best man and both our sets of parents there, they put on rather a splendid party for us in the summer.

Where did you go to your honeymoon, or did you go on a honeymoon?

Brighton, yes yes, just for a short week, it was the middle of winter so we didn't – but we – again in the summer we took a holiday abroad together in – in Corsica which was warm and nice.

Did you travel much overseas before that?

Travelling overseas, I did – taking holidays overseas, I think mainly France, not much further than that. And I did once go to the United States to attend a world congress of computer science in New York to give a paper, so sent by Elliott's. And took Jill with me and spent a few weeks visiting her sister and family who were over there at the time.

[40:50]

I also went to Russia quite frequently, I think I've said to sell computers at exhibitions in Moscow.

How successful were those trips to Russia to sell computers?

Well we always sold it.

Sold it, that suggests there was one of them [laughs]?

Just one, yes, we took a complete configuration of a computer and negotiate – well they – the Russians picked the chosen customer, and then we negotiated for a discount

for used goods, fourteen per cent, did I tell you [laughs]. Well fourteen per cent of what we marked the price up before we took the computer over there anyway [laughs]. Yes, and I managed to meet some of my old friends who I'd made in the – in the state university …

Are there any sort of security or commercial concerns with selling high tech equipment to Russia that you had to contend with?

Not – not personally, but I think one of the difficulties about trade with Russia was the US embargo, which meant that if the US suspected that your company was exporting sensitive US equipment to Russia they would stop buying from that company. And we definitely wanted to stay on the right side of that regulation. Of course a lot of – nearly all the components in our computers were sourced from the United States and the peripheral equipment as well, so not quite sure how close to the wind we sailed on that [laughs]. On the whole we weren't at the leading edge, we were selling workhorse machines, nothing particularly advanced, and almost certainly nothing as advanced as they were making themselves anyway.

How does one actually sell a computer under those circumstances?

I never engaged in negotiations of that kind, but no I can't [laughs] –

So what do you actually do there, when you are over in Moscow?

Oh I was, I suppose a chief interpreter and I would answer questions from the general public and also when previous customers came and wanted to consult about technical questions of how to maintain their current machine I would interpret that as well, so I was sort of stand manager rather than exhibition manager.

[44:10]

When do your children actually arrive on the scene?

The first one arrived two weeks – one week I think before I was on – went on one of my Moscow trips [laughs] so that one I think my – got my company to pay for quite – some long telephone calls [laughs]. That was Tom, and he's now working in Coventry in telecommunications. And Joanna arrived a year later and after 18 months our third son Matthew, which made a sufficient bunch. And shortly after Matthew was born we moved to Belfast.

I was wondering did becoming a father change your outlook on life at all?

Probably not [both laugh] – yes of course it did. I suppose I – one loves ones children in quite a different way but … I suppose looking after the house and providing for and so on would have loomed larger if it had been more difficult but fortunately I was pretty well paid throughout my career, and buying and selling houses I suppose is about the most nerve-racking thing one did in those days. And I didn't do it too often.

Can you give me an idea of what family life was like outside of work with this new family that's arrived?

I doubt that it's very different from everybody else's. The … Jill obviously left work and so she was mostly concerned with looking after them. We used to visit quite a bit with other member of the family, my brothers and sisters and Jill's immediate family as well. So there was quite a bit of carting around to do.

Where do you go for family outings?

Where did we go?

Hmm.

[Pause]. Seaside [both laugh], pretty invariably yes. Choose a place that has a hotel that is good for children and a beach nearby, and just enjoy a seaside holiday, which we still do occasionally.

How does your work actually fit around your family life?

Here, now?

No, back in the 1960s?

I used to tend to work in the evenings, just thinking and writing, and on the whole I think I'm – Jill has to put up with [laughs] a fairly absentee if not – mentally absent husband even if not physically absent [laughs]. I still do it quite a bit. Holidays are always something that sort of one has to work at planning rather than coming naturally [laughs]. Make sure you don't take too much work with you on holiday [laughs] but I think I'm getting better.

Shall we take a short break?

Yes.

[End of Track 7]

Track 8

You were mentioning hardware and software at Elliott's.

Oh yes, one of the main hardware designers at Elliott's is Roger Dyke, a very clever man obviously. And when we were designing the new range of computers known as 4120 he consulted software people as to what the most important instructions were because there was a limitation imposed on the size of the computer, chiefly by the size of the cabinet. For a curious reason the – we had to use the same cabinet as was already being used for a different device, because the design and ordering and production of a cabinet was the longest part in the design of a new computer. And unless we wanted to delay the first delivery we had to use an existing cabinet. So there are only so many boards that would fit into the cabinet and that dictated the size of the, and complexity of the computer and of the instruction set. So they consulted the – when they ran short of space they consulted what the most frequently used instructions were, particularly the complicated instructions, the two most complicated instructions were automatic hardware subscript check, which of course was rather important for our Elliott ALGOL compiler 'cause our company was unique in checking all the subscripts, and floating point divide, which is obviously an arithmetic operation of great interest to scientists and mathematicians and engineers who are prime users of the computer. So we conducted statistical surveys and we found to our surprise that by far the most important instruction was the floating – was the – not the floating point divide but the subscript check. And while we're willing to accept the scientific evidence the sales impact of not having hardware floating point divide might have been a bit distressing so we discussed this in committee hardware and salesmen, managers, designers and so on for a little while and at the next meeting of the committee the hardware designer reported, 'Well actually we've found a new way of doing floating point divide and we've simplified the implementation of the structure of the whole control matrix which implements these instructions, and we can – we do find that we can fit the floating point divide in together with the subscript overflow check and are there any other instructions you would like to add?' [laughs] So that was why you needed really good hardware designers, solved that problem nicely.

[03:30]

I was wondering how did your time at Elliott's actually come to an end?

Well when the company was taken over for the second time it was obvious that the centre of gravity of the company was moving away from Borehamwood and clearly the junior partner in two separate takeovers, because English Electric which took us over was the minor partner in the formation of ICL. And so I thought that really there wouldn't be a great deal of interesting research to be done and not very much prospect of promotion. At the same time Tom Kilburn from Manchester asked me on some occasion privately whether I would have agreed to have my name go forward as a candidate for a chair at Manchester. Now that tickled my fancy considerably [laughs] 'cause somehow or other really I think I had the idea for a long time that academic life was the one for me and so I said yes. And they didn't – they didn't follow up shall we say and they made a different and I think very successful appointment. But when I saw an advertisement for – oh sorry what – yeah something more complicated than that. I thought that the difficulty of – of getting an academic appointment, if I applied to some other university, would be that I didn't know enough people in the computer science community in England, and this motivated me to change my job to join the National Computer Centre in Manchester, which was quite a quixotic choice really and –

[05:45]

They were an organisation set up by a previous government as it were in the white heat of technology, to indicate how with it they were, I never really found a role in life but I was – got a job as a consultant and went up to Manchester. Tried to buy a house in Manchester, and went into work every day and sort of looked through – look through old files and found an awful lot of unfinished business [laughs] that they had – which I mostly sort of stopped off. And I began thinking about the topic of research that had interested me most in my days at Elliott's, which was formal definition of programming languages, which I now call the theory of programming. So I had a fair amount of time there, there was never anybody in – in the office, everybody was out visiting, our official titles were consultant and so on so we were the – the boss of the

establishment, Professor Black was not very often there and my immediate boss was very seldom there, so there wasn't a great deal that – and furthermore the person that we were buying the house from kept on delaying. And then I sort of came to my senses and said, 'Well really if my ultimate objective is to be a professor at a university, I really ought to try and see,' [telephone ringing].

Shall I pop this on. [Break in recording].

[07:35]

We were talking about the NCC.

Yes, so –

And you were talking about your ambition to become a professor and wondering how to –

Indeed, I saw an advertisement for a chair at the Queens University Belfast and so I decided to apply, or rather I made a sort of conditional decision that if I managed to post the application by six o'clock on the last day [laughs] as late as possible [ph] I would apply, so I did. And was invited to an interview shortly afterwards and went to interview and to my extreme surprise they offered me the job straight afterwards, so –

Straight after the interview there in person or?

Yes indeed. So I said, 'Oh I think I better consult with my wife about that,' [laughs] and she said that her impression of Belfast was it was a terrible place and being run by an extreme right wing government under – called Faulkner I think it was in those days, and she was very much in two minds whether she would come with me [laughs]. However, she didn't make – make any fuss at all and gladly decided to come with me and fortunately the person who was selling a house to us still hadn't confirmed the purchase at the other end, so I rang him up and he was … very sympathetic, in fact he said [laughs] – he was a professor just actually moving down to Southampton so he was sort of realised and he said, 'Oh well, yes of course, of course you must do that,

it's my own fault,' and there was no recriminations there [both laugh]. And shortly afterwards – we'd only just bought a larger house in Barnet at that time, and done it up a bit, moved into it and my youngest son had only just been born so it was not a terribly propitious time to move, but we upped sticks and moved into a rented house, being rented by the university. My predecessor was an American, Jim Brown, and he'd resigned to go back to his original uni – state anyway which was the University of Texas at Austin and so we moved into the house that he'd vacated.

[10:30]

It was a beautiful house, in a lovely Victorian – actually sort of early Victorian terrace in a little enclave called Mount Pleasant and within walking distance of the university so we were very … pleased to move in and really dreading the time at which the university would tell us, as they said they would that there was a limit of two years on the tenure of a temporary accommodation. Fortunately in – they didn't – they didn't actually write that letter [laughs] and in the letter that they did eventually write in about '71, '72 it was to offer us the purchase on [inaud] the house at valuation. Which was I think at the time 9,000 pounds, so my [laughs], we scraped together all the money we had and bought it. And we were very happy there.

What was it like?

Well it was big, very big rooms, high ceilings and very nice neighbours, and it had a … it didn't really have a front garden, the front gardens were all in a central reservation surrounded by one – well we made it one way access road around it, so the front gardens were sort of open to each other. There was small back gardens as well, garage, and it was walking distance to university and schools. And very close to the river, nice walks on the river, and even closer to the Lyric Theatre, which it was sufficiently close that one could go back home for ones specs in the interval [laughs]. So we were very happy there.

Did you go to the theatre much?

I shouldn't say a great deal but it was certainly very inter – a very good reparatory company and visitors and they played Irish plays quite a bit, and it was lovely hearing the Irish accent [laughs] and so we did enjoy going to the theatre there.

[13:30]

I'd like to ask you some more questions about Ireland but I feel I have to ask you just one or two questions about the NCC as well, so what does a consultant actually do at the NCC?

I don't think we ever found out [both laugh], it was just a job title. I think that it was sort of basically they fitted in with civil service grades and I expect the grade consultant was the one that was closest to what we were doing and which had an adequate salary to attract computer scientists.

What did you actually do there?

I – what did I do, for goodness sake. As I say I opened up some old files and finished some old business, I did a bit of research, and I was only there for three months. In fact of which I spent half under notice [laughs], so the – the director of the – the director of the NCC was one of the referees that they consulted on the appointment and when I got back from the interview he was waiting for me and he said, erm – he was vigorous and – it was alright, I wasn't going to get the job anyway, there was a much better candidate than me [laughs], to which I kept my counsel [both laugh], and we negotiated quite a – well quite a favourable agreement that the initial expenditure, extra allowance for expenditure on recruitment would be paid until the end of my notice period. Oh no sorry, I think half of it would be spent – would be chargeable. And I left shortly afterwards. I was doing a weekend commute, I had a bed and breakfast in Manchester and came back home for the weekends. That was quite nice to stop that [both laugh].

[15:45]

How was the interview in Belfast?

I – I enjoyed it, I suppose I would – had just read a – an article by Peter Naur on the education of computer scientists, and his views attracted me quite a lot so I based my answers on what I was interested in and what I would be doing very much on that article. And they – I was quite enthusiastic about it [laughs] and that obviously made a good impression.

[16:30]

What aspects of Naur's thinking actually appealed to you?

I can't remember, he was the designer of ALGOL60 effectively, and so – and a very good computer scientist, so I suspect it was the treatment of programming as a serious profession was probably the main message that it's quite difficult to put over in those days. But industry were very interested in deskilling the profession of programmers so that they could programme and would be sufficiently easy that they could recruit school-leavers, and they would do what they were told, as opposed to these terrible programmers who kept on having their own ideas [laughs]. And that the manufacturers and sellers of the computers were very keen to say how easy their machines were to programme and you get programmers of the street, and here are we saying the opposite, no you want to re-skill programming and take advantage of the very cleverest people to do your programming for you. And it was quite interesting, that's the view that Microsoft takes, that's the first company that really respects programmers, oh yes, and other companies – well at the time. I once was invited to be the proposer of a motion that – or at a debate organised by the professional association, the British Computer Society, to the motion that the universities are producing the kind of graduate that industry wants. Now, so I put forward my views on what an educated computer scientist should be and do and contribute, and the opposing views were put across and the debate occurred and a vote was taken at the end, and nobody voted in favour. Well I wasn't going to be the only person to vote in favour was I [both laugh], it was really quite a – a standoff between the universities and industry. We had a visit once from … was it big – chemical company, ICI, they said they recruited all their programmers from school leavers, and they all used

COBOL not ALGOL of course and so I think – I think we've actually made quite a bit of progress since then.

What was so controversial about your view and what computer scientists – what sort of education a computer scientist should get, a programmer?

I don't think it was all that controversial and one of the nice things about being in Belfast is were close enough to industry and to government, total population of something like one and a half million, I would meet civil servants, senior civil servants and teachers and employers, so more or less socially, and somehow one could get much more – much better speaking terms with them [laughs] when you knew them socially. And when I had the degree programme in place we would give the – all our honours graduates a year off, a year out in industry, and so we had to make friends with local industry and industry abroad, England mainly, to take our students after three years of study and they would come back after their fourth year, it was amazingly successful.

Sandwich course sort of arrangement?

Yes yes, sort of extended sandwich and at an advanced level. And we talked quite strange things like proving correctness of programmes, not very successfully at that time I think, but the students came back a great deal more mature and really buckled too to their honours year studies and the industries knew much better what sort of contribution could be made by a bright young university student.

How are you actually meeting, you know, the civil servants, industry people?

I seem to remember that there were receptions organised by the university and by the civil service to bring leaders in the community together.

[22:15]

We were – it was more easy to network than in a larger country.

How did you feel about the prospect of moving to Ireland, this is '69 the army is sent in isn't it so this is on the cusp of –

Right, this was in 1968 and it was the – two weeks before some rather small and insignificant riots in Londonderry, so we didn't really know what was going to happen and we were shocked and frightened by the developments since then. But Ireland was so lovely to live in and it was, you know, we thought, you know, how bad do things have to get before we pack up and go home. But – and however bad we thought they always got as bad as that, but we never packed up. The worst occasion was the Ulster Workers Council strike, which switched off the gas and electricity and really was pretty vicious, they – they closed the shops by threats if necessary and – and of course with power sharing government, which was the brightest thing that we saw, fell and moved back to direct rule [ph] again and the violence continued. Although actually at a lesser – on a lesser scale, from about '72 it started getting better. And as soon as – as long as it's getting better, you know, you don't really have that threat hanging over you [laughs]. But even so I think one of the motivations people had and it probably affected us as well was getting our children educated, not in that atmosphere, so we moved back to England just for sort of – so that when they become teenagers we don't have to worry so much where they are [laughs]. No, we were – I mean it was like a very minor version of the Blitz, we were moved out of our house one night 'cause of a bomb planted in a paint factory over the road, didn't go off, all a threat, and a lot of threats and more threats than actual incidents. And one of the houses which my department has taken over was destroyed in one of the early bombing campaigns, so we had to find new accommodation, so it was – the main thing really was that so many of our – so many of my colleagues – not so much family but colleagues, wouldn't come to Belfast. You know, we live there twenty-four hours a day and they won't even come for two hours and [laughs] – however we kept our contempt for them a little in check and –

Did you ever feel threatened living there yourself?

Well the strange – no not really, no. Strange thing was that having left Belfast in 1968 when things were better, I thought twice about accepting the invitation to go back, just for a sort of short visit [laughs] somehow or other. And it's not so – it's – I

mean a rational assessment of the danger I could make and I could certainly follow a rational assessment, it's not that, it's that if anything did happen people would say it you're your own fault, and there's just [laughs] that feeling – it would just be too ironic to spend eight years there and then [laughs] finally succumb to an attack and – but I did go back quite frequently [inaud], but it just did worry me a little bit more.

[26:55]

What did you like about living in Ireland so much?

The – I like Belfast, the architecture was all of a piece, it's sort of Victorian architecture. The people were so nice, everybody – everybody we met, very good colleagues, very good neighbours, and the countryside and the sea and the coast and the mountains were so close. I mean from almost everywhere in Belfast you could see a mountain, the black mountain was there, well you know, down the end of the street, you needed a clear line of view, half an hour and you're at the seaside at a resort, an hour and a half and you're at the north coast, the Giant's Causeway or at Newcastle by the Mourne Mountains, and the sea, it was just lovely.

I think we should stop in a moment but I've got one final question for today. I was interested in the – you haven't held an academic post before and suddenly you're a professor.

Yes [laughs].

How did that prospect strike you?

Oh a bit daunting, in fact I never really thought I was worthy of being a professor, even after – well I was first called a professor by my schoolmates at school because I was sort of so learned and [laughs] always knew the answers in class and I think – I don't think – I mean that wasn't an altogether friendly nickname, Prof [laughs]. But then the – the till ladies at the staff canteen would call me Prof, sort of a [inaud] [laughs] deserve to be called Prof do I, but one does get used to it, it's – if people want to call me something that's still what I prefer to be called.

[End of Track 8]

Track 9

We were talking last time about your arrival at Queens in Belfast and I was just wondering if you could describe what the university was actually like when you first got there?

The university was I think a very – very friendly place. The environment was [laughs] fairly normal, I mean fairly normal, the departments scattered in a number of buildings around in South Belfast. And I was director of the computing service as well as professor of computing science, so the workload was very heavy, especially to begin with when you're getting used to it I was – the university grants commission conducted a survey which involved sending all members of staff a diary to fill in for a whole week. And I filled that in rather – slightly peculiar 'cause I was away in the States for a while and so I had to mark the time shift differences as being these seven hours do not exist. But anyway it showed – I managed to clock up seventy hours a week and I think that was roughly speaking what I was doing. After a while they – well actually it was a slightly longer and more unpleasant story, the one real problem was, being director of the computer laboratory, I had a manager of the computing service, very competent and pleasant person called Jim Brookes, who was reporting to me, and he didn't think he ought to be. And the chairman of the university computing committee thought the same and he was – became my *bête noire*, and I don't now wish to malign him in any way [laughs], I really thought he was out to get me. He was attacking me through my secretary and I felt really badly – as though I didn't know what I was – you know, what I should do and that I was incompetent in the job. So I went to see the vice-chancellor and the vice-chancellor said, 'Leave it with me,' and he looked into it and mulled it over and he said, 'Yes, you're right, what we'll do is we'll split the two jobs, and have a separate director of the computing service.' And I was naturally very very relieved and most universities at that time were splitting off the job from being a normally full time professor, but the director of the – sorry the manager of the computing service saw that this was the end of his ambitions and he left and the chairman of the computing services committee also resigned, so it was – I was left as it were the victor in the field [laughs]. However, the director of the – the manager – sorry the chairman of the computing services committee was persuaded to return to his position but fortunately I was of his orbit at that time. So

that was the one unpleasant matter. The other thing that really shocked me more or less when I first arrived is that I was asked to submit to the faculty my plans for the next years teaching which wouldn't happen for another 12 months [laughs] and the comparison of that with the timescales of – of industry was quite startling. I mean we didn't know from month to month what was going to happen, we could never plan further in advance than that.

[04:45]

So anyway I had at the time two good lecturers, Mike Pengelly and Roy Nelson, and two programmers working for me, Jim Welsh and John Warne, in fact I think I had four programmers working for me, one of them was Fred McBride. Now all of these people actually made quite a good career for themselves afterwards, including Jim Brookes, the … manager of the computing service went to be I think the secretary of the British Computer Society after that, he – the supremo of the employed staff. And they were all very nice, and very helpful [laughs]. But after a year, maybe two years, Mike Pengelly was really my right hand man and moved to the Open University and very shortly afterwards Roy Nelson did the same. And at the same time Jim Welsh left, I think it to take up his career in Australia, and so that was a pretty low time and I realised I'd got rid of all my staff really, was I [laughs] – was I any good. And of course at the same time the troubles were brewing.

[07:00]

The – we arrived in Belfast and moved into our new house just two weeks before the first demonstration and – and struggles in Londonderry, and we couldn't understand what was going on at all. Anyway they persisted for a while, but we thought, oh well that's in Derry, that's 50 miles away, and doesn't affect us. We used to, on advice from the locals, take every evening the *Belfast Telegraph* which was quite a good paper and we used to read the headlines and find out – and the articles and try and find out what was going on both on the streets and on the political scene, and we had the greatest difficulty in understanding it, we couldn't really see what it was all about at all. I remember one evening I read an article and I suddenly realised I was beginning to understand it, until I got to the end of the paragraph and saw the closing

quotes, there was a quotation from that morning's *Guardian* [laughs] just dramatic demonstration of how different – anyway we did catch up and after about a year the troubles moved province wide including Belfast, so one began to feel a little bit worried about that. And [laughs] –

Had you been expecting any trouble along those lines before you'd actually moved there?

No, there were no signs that we could see. Faulkner was prime minister and he was notoriously – or at least in my wife's view, or my wife's mother's view at least, notoriously reactionary politician. My wife's mother was a member of the communist party so she was expert in this kind of thing. And this was … and it was a bit – and she was worried about moving to Belfast, only two people she'd heard of were Faulkner and the Reverend Ian Paisley who was if anything [laughs] a little bit more extreme and religious to boot. So her procrastinations were not – were not favourable. But she's always been very supportive of me and my career and my work.

[10:15]

So she agreed to move and we moved into this lovely house which was owned by the university, rented it for a supposedly limit of two years, and it was a wonderful little enclave called Mount Pleasant which had a beautiful shared – beautiful garden in front and very nice neighbours. And after a while it was, you know, that was – we were really won over by the friendliness of the people and the very – and the nearness of the countryside. Living in London you sort of don't expect to visit the country very often but here it was just five minutes out on any road and you were in the mountains or the – or the agricultural land.

What sort of activities do you actually do for fun in Belfast?

Well we used to do a lot of walking and we used to drive around the place. We had quite a – quite a social – well not – I mean not a – not a spectacular social life but dinners and neighbours and friends and other professors, quite common, and we made

a lot of very close friends, erm, Professor of Russian and his wife, Professors of Economics and his wife, some of the family of staff in the department, Don Fey, Mike McKay all retired now of course, we still keep up with, Christmas cards you'll see just over there are being addressed [laughs] almost as we speak.

That's quite a large pile of Christmas cards.

Yes, well yes it is indeed. Well having moved from – from – we still keep up with people from Elliott's from Belfast, from Oxford of course perhaps most of all and then there's Cambridge crew and a lot of people that we met on our travels. We've spent sabbatical periods in the United States for example, both in Stanford and in Austin, Texas.

We're interested in this, the two hats you have to wear, there's professor of computing, one of them professor of computing and the other director of the computing service, what's the actual balance like in time between the two posts?

I should say probably fifty-fifty, yes, I didn't discriminate very much, so loss of half the job was a great advantage, bringing me down to thirty-five hours a week, which of course also crept up.

[13:20]

And what does a computing service actually do in the 1970s?

One of the things of facing us was to buy a new computer, so we – we had to go out to tender and consider all the alternatives, and in the end we bought the only alternative that was actually available to us, the only one that would be funded which was an ICL computer, British computer. But the other thing is we have a certain amount – we had responsibility for the fair allocation of computing resources and computing time, and it was sort of generally agreed that – well it was in the committee agreed that the departments would have to have their time rationed, because otherwise the load will just go up and within a few weeks you'd totally saturate the new computer again. So I – I tried to work in – help work out a scheme and – and I got the suspicion, which

may or may not have been justified, that the chairman of the computing services committee was trying to use this to get me to make a mistake or become unpopular because of the unfairness failure of the rationing or the complaints about the inadequacy [laughs] of the ration and so on. But I – that might have been my paranoia. Anyway that's sort of quite a delicate situation which has to be really resolved by a committee representative of the academic interest.

Can you give me an idea of what sort of, you know, who were your actual users at this point?

Mainly the scientists, the Department of Applied Mathematics, and the chemists. So they were – they had to be prevented from [laughs] too much appropriation of the resources.

I'm interested in this idea of having an actual committee to decide on who gets what computer time, was that common do you know?

Oh in the universities everything is done by committee [laughs], because it's very much a participatory management. Basically everything that happens has to be agreed by everybody who makes it happen and so under the – of course that's a recipe for total stagnation unless the chairman is good and effective, which on the whole they get to be, yes. They have to be elected of course but people will respect an effective chairman.

How do you actually decide on what the priorities are to spend computing time on?

Well you have to make a proposal based on some principle or other. So the [laughs] director has to find some principle which he can recommend and then work out the consequence of the principle and then adjust the principle as needed [both laugh].

Can you give me perhaps one example?

Oh one easy principle is that your proportion of the new computer's time should be based on your actual usage of the old computer's time, which certainly helps to avoid too much screaming [laughs].

Why did it have to be an ICL computer?

Oh the university grants committee that was allocating the funds, through a computer board had a definite buy British policy and you would need to, er, have some very strong reasons or perhaps better strong political connections to reverse that [laughs] policy.

I was interested when you mentioned this, your workload diary of seventy hours a week, what sort of activities actually take up your time, sort of as a –

It's mostly reading and writing, just ordinary I – I must have attended quite a few meetings but it wasn't – I don't think meetings dominated the issue.

[18:48]

I mean I had to lay plans for the academic development of the department as well, and after a while – I had a … an ambition to set up an undergraduate degree in the subject, so we had to plan it first as a join honours school with other departments including pure – well mainly pure and applied mathematics and statistics, forgotten whether there was a statistics department. So we started out offering first year options for – sorry first year basic courses to be taken by any students, in fact any students of the faculty of science, or arts for that matter who were in both faculties, but we – our basic financial structure was dominated – was through the science faculty, so I didn't really participate in the faculty of arts very much. And the courses were designed, the first year courses at Queen's University had a tradition that every student took three subjects, and the third subject would be outside the main courses that would be taken subsequently, so that gave us an entry when all we could offer was a one years course, we could start up without having a commitment to give a whole three year course. Well the system of options it was quite a modular course, the system of options continued into the second year, so we were able to gradually infiltrate options into the

mathematical and scientific degrees. We were very much helped by being members of a school, the school was really sort of informal grouping of three department, three or four departments in mathematics physics and computing and the professors of those departments were quite cooperative in nurturing this viper in their bosom [laughs]. And what happened was that the science faculty adopted a scheme for allocating new resources to departments in proportion to their student load, so if our courses were popular and each lecturer had an average of twenty, twenty-two students, that was quite a high figure, and if that was the highest figure in the faculty the next post made available as a result of increased funds went to my department. And some years even after – with that additional member of department, we were still the top of the list of the lead and we got two members of the department in one year, but if we got two members of the department that would mean that in the next year we were overtaken by psychology, which had a similar sort of – had really vast numbers and so they – they topped the bill roughly every alternate year and got – in fact got one or two extra hosts [ph] and [laughs] our turn would be the year after that. But gradually using that mechanism we were able to ratchet up to being able to give a cautious in all four years, 'cause it was a four year course in Belfast, which –

[23:40]

No, I remember more correctly now, the science faculty, it was three years basic and most of the good students came in what they called year one. We missed out year nought which was a feature of – of the university, brought into enable universities to take students who weren't so well prepared by their secondary schools. Again it was argued that secondary schools of the Catholic denomination were less capable of producing university standard entrants. So it was [laughs] a sectarian dimension to the problem [laughs], anyway I never got involved in that I'm glad to say.

Does that sort of sectarian divide in Northern Ireland actually – does it actually function on a university level as well then?

Well the university is one of the few institutions which were completely blind to – I say completely, I mean obviously pockets of – of bigotry were available if you looked out for them [laughs], but we didn't really discriminate. Or at least if we did, if my

colleagues did, I didn't notice [laughs]. Although I'd got a pretty good ear, Catholics tended to talk with a slightly more southern accent, it was not [laughs] – I mean I would never bet my house on it, but of course the locals knew immediately they saw you what school you went to, that was a giveaway, but I didn't know. I knew – I mean I know some – obviously the names of the main schools but not the lesser ones. Yes, no we were fairly – fairly free. I was caught up in one … well I suppose two really, one was a – a one day strike called by the Catholic students, in which I gave the same lecture again, which I shouldn't have done really. And one was the Ulster Workers Council Strike which occurred in 1972 and in which the buses and the trains were stopped, and the cars and the roads were stopped by road blocks and the students had to walk in, some of them many miles, get up at five in the morning, walk into your exam at [laughs] nine, so everybody was asked to be especially lenient on the marking of the papers [laughs] as you can well imagine. But my experience was that the performance of the students was better than usual and on the whole I think it had that effect. The troubles meant that people wanted to study, either to take their minds off it, or in order to at least have the option of leaving the province and getting a good job outside. On the whole it was the norm for graduates to take – take jobs inside Northern Ireland, to be with their families, and that was reinforced by the trouble. People weren't itching to get away, they wanted to be at home and see that everything worked out okay, but nevertheless they might have been thinking that they should keep their options open for going away.

Did the troubles affect university life in any other way?

Well we weren't immune, in fact my department lost one of its buildings through a bomb, and in fact it was – what did they call it, the Black Friday bombs? Sorry, memory wasn't one of the – I don't think it was one of those. And we had to – we must have moved in other temporary accommodation. But on the whole there seemed to be a general understanding that the university was to be immune, the – the student's union which might have been a hot bed for dispute and complaint and demonstrations actually also felt [laughs] that they were on their best behaviour. And when – after a year or two they decided that they were – instead of electing a – what used to be a Catholic president of the union or a Protestant one, they chose a Welshman [laughs], of course didn't – didn't [inaud] say that I was an atheist and the joke was that the

supplementary question was, 'Are you a Catholic atheist or a Protestant atheist,' [both laugh] so there wasn't any –

[30:00]

I've always wondered, living in Northern Ireland as an Englishman, did you ever encounter any hostility?

Almost none, I was – I mean from the people in the university and the neighbours who were of course senior civil servants, doctors, there was a certainly none at all. On the whole the attitude was that we're glad – delighted that you agreed to stay here, through the troubles. And you got – I got that from my hairdresser and taxi driver, in fact after [laughs] I came back, after I'd left and I was visiting Belfast I took a taxi once to the airport and I talked about my experiences in Belfast and so on and the taxi driver, who was an Indian, knocked ten per cent off my fare, I've never been tipped by a taxi driver before [laughs], I was able to return it as a tip. But I did only once meet somebody who said, 'Yes, the English always come over and pinch our best jobs,' and I was told that that would be the responsive and so I was prepared but nevertheless it was a shock.

Under what circumstances?

Oh, I think almost a social – social occasion, it was no particular provocation on my part I don't think [both laugh].

[31:45]

Interesting in building up on your comments last time about your preparation for the professor's interview reading Bower [ph]?

Peter Naur.

Naur, thank you, I've had Neils Bower [ph] in my head all morning for some reason and I was thinking it's one of those names a bit like that [both laugh].

Yes, he was a Dane, still is, he's still around.

I was interested in when you were setting up or thinking about setting up the undergraduate course and you talked last time about sort of orientation of university computer education, I was wondering what was your take on the direction it should take when you were setting up that undergraduate course?

I don't – I didn't have quite the same philosophy as I did at Oxford. Er … I can't quite remember what the first courses that we taught were. We had – I think the standard syllabus for computing science was at that time and beginning to – to become reasonably widely recognised. The first courses were on software and hardware, learning to programme in a programming language, high level programming language, actually one which had been implemented by my colleagues in the department. And that was the first course and the second course was a course on hardware and machine code programming which sort of gave the – a nice balance between low level concerns of hardware and higher level concerns of programming principles or whatever. And then in the following years there would be a course on operating systems and a course on compilers, how did the high level language compiler translate that language into the machine code. I did have a course on programme verification which was the subject of my research and my – well my fame perhaps I should say [laughs]. But that was definitely a final honours year option and wouldn't have spilled over into the undergraduate courses particularly. And then the … I instituted a practice for the honour students, people who are graduating in, specialising in computer science by itself, that they would have a year out in industry, a secondment, an internship for a year or so. So we put quite a lot of effort into recruiting local industries and even industries in the UK and further afield, I think one time we sent a student to Switzerland and they – they learnt – learnt the job on the site. And it was very effective, the students came back for their honours year quite determined to learn something about the theory [laughs], they really saw that things weren't all roses out there and that they really needed to know what – what was – what were the principles behind it and it was great fun to teach them after they came back.

Why did you see that industry year as important?

I guess partly because I – one is looking to make sure that the students are employable by industry and a year's experience of course gives you an enormous complimentary boost to any actual courses concerned. And I suppose quietly as a sort of insurance to make sure that we ourselves had some contact with the industrial deeds, perhaps I was influenced by that debate that I told you about last time, zero votes in favour of [laughs] recruitment from university.

What was your uptake like for new students?

You mean for recruitment or –

Yeah for recruitment for –

Eventual places?

Recruitment for the undergraduate course?

Well I think it was of course to begin with it was sufficient to bring us to the head of the league tables, staff student ratio, but throughout we always had enough students, we were okay. Even in the times we sort of weren't the worst in the faculty. And the students got jobs. Oh another effect, we sent a student out to a local industry … and the … manager who he was working for had previously said that he thought – he had never employed a graduate and he thought he never would, but after two weeks with this chap, he was very bright, changed his mind completely, he said, 'Have you got any more of those?' [both laugh].

What sort of things were they actually doing in placement?

I think they – very much as an intern today, learning something about perhaps the programming environment, programming languages that were used in industry were very often different from the ones taught in the university. So they learnt that you didn't have to always use the same language. And then they were given an

assignment to programme something that would be useful, potentially useful, to their employers.

[38:40]

On subjects of careers and computing here, I was thinking when you said that you lost three staff in quite quick succession, how do you go about replacing them at this time?

Well it was getting difficult because people from outside weren't falling over each other to – to come to Belfast. So the people we – we recruited people who weren't previously academics, and that turns out to mean very successful. The – we recruited somebody, Don Fey who had been a manager at Fords, a computing manager at Fords for example, and he knew quite a lot about hardware so he took our hardware courses. And … we recruited one or two people who were already in the department as lecturers, one of them was a lecturer in applied mathematics whom my predecessor had made a commitment that he would employ him in the first available post which I honoured [laughs] and he was very good, he was – he was never really a computer scientist but he was a good, very good member of staff, he was experienced in the university, he was native to Northern Ireland and he was very loyal. He stayed throughout until I left myself and then he went off to … the Virginia Polytechnic in the US and made a very successful career there as well.

Shall we take a short break?

Yes, let's do that.

[End of Track 9]

Track 10

I was wondering if we could talk a little bit about your research at Belfast. What was your main interest at this time?

Well one of the – the reason I went to university was that I got interested in a topic which … I would characterise as the axiomatic definition of programming languages, that I had always had an interest in mathematics and I read mathematics books for intellectual excitement, and I got this view of mathematics that – that a mathematical subject was characterised by the axioms or postulates which the mathematician studying that particular subject chose as the basis of all their proofs. So I thought that a set of axioms might be a good way of defining the meaning of a programming language. The thing that attracted me about axioms is that they weren't necessarily a complete description of what they were talking about, but they just told you enough to be useful in your proofs. This was a property that I wanted of a programming language definition because in those days programming languages were implemented by computer manufacturers for their own architecture and design of computers, so the language in which each manufacturer's compiler translated a high level language, even the same high level language would be adapted to the peculiarities of that manufacturer's own hardware which were sold by that manufacturer. This meant in those days that there were a great deal of variety between the architectures. For example the length of each word in the computer, the length of the standard operand or the computer operations varied between twenty-four and sixty-four bits. Standard now is that it is either eight, sixteen, thirty-two or sixty-four but in those days anything would go, the IBM – main IBM scientific computers of the day had thirty-six bits in the word and Elliott's was much better at that, thirty-nine bits, whereas the ICL computers had forty-eight bits and there were plenty of – this meant that the arithmetic on the computers was very different and even in high level languages the actual results of the calculations on the computer would be different because the word lengths were different. Nevertheless one wants to have a description of the meaning of the programming language which was somehow independent of the word length and other characteristics of the hardware. So that programmes could safely use the – the programming language, and manufacturers would have some freedom to make choices in the implementation which were not prohibited by the axioms.

For the benefit of –

So my slogan was that the – whatever method you used for defining the meaning of your programming languages, it's what that method allows you not to say that is the most important thing.

Do you mind briefly just defining axioms and postulates for any listeners who may have no idea what they are in the future [laughs].

Yes certainly.

And for me to be honest it's [both laugh] –

Every branch of mathematics is based on certain assumptions, all the proofs, the first line of every proof has to be either an axiom or a reference to an axiom and references to other axioms will occur at many places in the proof. And the mathematician is allowed to assume, or postulate the truth of these axioms in constructing the proof and establishing the truth of the theorem as it were based on the axioms. So later proofs can appeal to previous theorems as truths without proving them. But eventually you have to get back to something and that's called an axiom or a postulate, or an assumption or a hypothesis or something for which it is agreed that – that you will not be asked to justify, this is because the set of postulates is agreed between the two mathematicians who are writing and reading the proof.

[06:00]

So the definition of a programming language as I – needs to be strong enough so that the programmer can construct proofs of the correctness and validity of the programme, and weak enough so that the implementer has some freedom in the method of implementation. And that was my view of what a programming language definition should do, it's a sort of contract between the user and the programmer and the implementation who's – which is going to execute the programme.

How widely held was this idea at the time?

Oh it was unique I think to me [laughs]. Although it attracted – so I first put the view forward at a workshop or meeting in Vienna, with the title of Formal Language Definition Languages. These are languages for formally defining languages, programming languages in particular. And I put the same view about the merits of axioms in being able to not say too much about the – what's being defined, and I think the remark was applauded, although nobody else put forward this view at all, they were all putting forward different views about how to define programming languages, and none of them was – was actually consistent with the view that I put forward. And that's roughly speaking the situation today [both laugh], although I'm going back to it and I find that the message is very popular. It really gets across if you can talk to somebody and it looks very attractive again.

[08:20]

So from that first announcement and talk, where did you go from there?

Well the real – I wrote a long article about it when I was at the National Computing Centre, which was never published and never widely distributed, and was rather complicated. In fact I've seen a copy recently and really couldn't be bothered to read it, it was only too detailed [laughs]. But when I got to Belfast I was unpacking the books – the boxes full of books and papers that I'd packed up in England, and I came across a jellygraphed reproduction on – you wouldn't know, this was 1968, in those days you could use a cyclostyle perforated stencils and a machine to reproduce things, or locally you could reproduce them using a dye which could be sort of offset process, could be placed on a jelly which you could then later press – press your copies from and it was one of those. It was called *Assigning Meanings to Programmes* by Robert Floyd and it put forward a different – a way of proving programmes by use of assertions. And I'd – I had looked at that article before and sort of put it on the side, it was published in a mathematical journal and I put it aside as being too technical for me but I read it over again and suddenly realised that that was exactly what I wanted because it was useable directly to prove the correctness of your programmes in your high level language. Whereas my previous work which I'd done at the NCC was

based on reasoning about an execution of a programme rather than the programme text itself, so it was more indirect.

[11:00]

So as part of my seventy hours a week in my first year of my ten year as a professor at Belfast, I wrote a paper called, An Axiomatic Basic for Computer Programming in which I put – expanded Floyd's ideas under – in a slightly different notation using what are now called Hoare Triples, and that paper has been – was really the basis of my academic reputation after Quick Sort. That was the one that everybody referred to, in fact it was sited again in a recent award of distinguished achievement award which I'm going to collect in Philadelphia in January [laughs], it's still remembered. And now I think it's the wrong – it was the wrong way of doing it but [laughs].

What was wrong with it?

What was wrong with it, it was adequate for its purpose, but it was both more complicated and less powerful than the way that I would now recommend, which is even more axiomatic, exploits the power of axioms but what I'm working on, I've been working on again for – after – for the last four years is going back to algebra, the way to express the axioms is to write algebraic equations, equations of exactly the type – type that every schoolboy or schoolgirl learns about the operators being associative or distributing through each other like multiplication distributes through plus, or associative like plus or indeed multiplication. Those are the kind of axioms that we can actually apply directly to programmes and prove – and the – the rules of Hoare logic can be derived very easily from them, but the algebraic axioms are both simpler and more powerful. That's what I was doing this morning [both laugh].

What form – actually if I were to write it down, what form would this notation actually take you are talking about?

I would use the notation, now I would use the notations of the programming language itself, so an operator like semi-colon in a programming language connects two sub programmes, one of which is executed before the other, that's what semi-colon

means, it's called sequential composition. And the axioms about sequential composition say that it is associative if you execute three actions one after the other, it doesn't matter whether you execute the first two first and then the third, or the first and then the second two. And that's exactly an expression of the associative law for semi-colon. There is a – there is an operation in high level language given various names like – like skip or do nothing which is you compose that sequentially what you were doing before makes no difference, so whatever I do, if I do nothing afterwards it's the same as what I was doing anyway. Or the four, so this is a property that zero has with respect to plus, if you add zero to something it doesn't change it. But –

Were you actually expecting this paper to go on to be such a hit?

Yes [both laugh]. The reason why I'd – I moved from industry to university was that I had this idea that work in this area was not likely to be of immediate concern to industry for many years to come, and – but nevertheless the use of mathematical and axiomatic methods to prove correctness of programmes was an ideal occupation for an academic. Because it will be done in order to understand the programme better and in order to make sure it would always work, so as an academic pursuit it seemed to me that it ought to become quite popular. But I realised that would take some time, I was prepared to – I was – and it would take even longer before the work was actually applied in industry. In fact I thought this is a splendid subject for a person who still has thirty years to go as an academic because if industry doesn't take it for thirty years it means I don't have to compete with industry in my research, I can keep this subject going for thirty years, and so I did. And indeed when I moved on retirement in 1999 from university back into industry, in Microsoft, I found that my prediction was correct, that indeed nobody was using it [laughs] – using the results of the research. But by some very great good fortune along came the virus and the virus or the worm or the malware that infects our computers, and can bring them to a halt, or do worse, caused a very dramatic shift in the attitude of Microsoft to verification, or verification technology perhaps I should say, because the virus can attack errors in the software, which you would never detect by testing. And so the only way to make sure that there were no vulnerabilities in the programme is to prove that there are no vulnerabilities. I use the word prove in an industrial sense now, it's not absolute proof but it's – it's a very meticulous analysis that gives one confidence that there aren't

many of that kind of error left anymore, and although the errors are only a very – absence of error is only a small part of the correctness of the – of the programme in terms of its serviceability, you actually use the same technology to check the absence of these – of these errors as you would in the verification. So the last ten years have seen a complete change around, yeah, industry is very keen on – keener than the academics on actually applying the technology, and the ideas, the concepts not, you know, not the details but.

[19:20]

It's interesting that you began talking about this problem in – by referring to that industrial issue, about different programming languages, different computers.

That's true, yes.

And yet it's taken forty years to get to that point which is [both laugh] – it's interesting how you've sort of gone from a practical idea to thirty years of abstract academic work. How did you actually feel about it, doing those thirty years, after sounding like you're starting with a very firm idea of that application and then a long period of not really working on the application itself but on the theory of it?

But that's the reason why academic research works, it's the very essence of it, you have to – you have to be inspired by problems that you see around you, otherwise you might just as well go out for a drink. And then you have abstract from them so that you don't have to be totally immersed in the details, keep away from any practical application which of course would involve you in meeting a deadline of some kind or other and making a profit in the end, to pursue the – you need to pursue the academic research for its own sake, for – for a long time, just as all scientists have had to do and must be capable of doing and it's the additional – it's the additional contribution that they eventually make to industry that justifies any funding that they've achieved in-between. I mean how long was the gap between the discovery of the theory of gravity by Newton, to the time when it was first employed in real practice? I can tell you 1918 it was used in practice, was the first time that anybody used Newtonian mechanics to calculate the trajectory of a shell, it was no good with cannonballs

because they weren't going to be accurate enough anyway. But some enterprising junior officer in a – a battery in – on the western front in the First World War, decided that he would fire the last shell in that war, and he calculated the trajectory so that it would land just before the armistice came into effect at eleven AM, hmm [both laugh]. And that was a – of course a precursor of the much more serious uses of Newtonian mechanics in – in warfare, which is very often the place where discoveries find their first application I regret to say.

Is that a position you've ever had to defend over the years?

What of –

Of pursuing academic research when the end result is so far away?

To my shame I have never used that excuse, I have always pretended that what I was doing was rather industrial interests. And I fear that this was – if I had – if I had [laughs] taken it more seriously it would indeed have – or it could very well have diverted my research, or it might have inspired it, who knows because I have maintained industrial contacts and from every one of them, every one of them I say exaggerating, I gain some insight, some idea that I would not have had before that was both I could see as being a both academic interest now and eventual industrial interest later.

[24:00]

I was wondering as well, just go back to the [ph] 1970s, in terms of actual doing research on this, how do you actually do it? I as a historian sit down with a pile of dates, you know, I'll browse for dates on the internet, I will make notes, eventually through this horrible rough exercise some sort of document will come together, how does computer research compare?

Yes, no my method of research is [laughs] sort of more self-contained than that; I don't look up books, I try to start writing the paper. I say wouldn't it be nice to publish the proof of a programme that people could read and understand and see why

that programme worked and how far it worked and what the assumptions were and all the rest of it and what would you expect I used a programme I'd written myself, in fact it was the main part of the Quick Sort programme [laughs] as an example. And what happens is you find, I found that the proofs get very complicated, and so I try and think of some way of simplifying it and occasionally, and in this case too, I draw in my objectives a bit and don't try to prove quite so much about – about the algorithm as I might have done. For example in the – in the first paper I published containing an actual proof it was a proof of a subroutine of the Quick Sort algorithm called Partition. I had perhaps successful proved that I wouldn't hit any of the boundaries that computer – machines place on the length of the words, so it would work equally well on machines with short word lengths and long word lengths and so on, but that part of the proof was rather tedious for the normal reader [laughs]. Interesting that now actually that's part of the proof that industry is most interested in doing, overflows and underflows are really – can be really really costly, buffer overflows were the main vulnerability of Microsoft software until they mastered the technique that I described of detecting them at compile time. And numerical overflow caused the crash of the first Ariane 5 space vehicle in – launched by the European Union, oh some years ago now. So they can be very expensive [both laugh].

Did you ever think that you would go back into industry and actually look in the implications of this when you started off?

I actually had … thought of a possibility of ending a career in, you know, just through sort of aesthetic reasons since I'd started with eight years in industry but it was quite a surprise to get an offer from Microsoft in, actually in 1997, the – the director designate of Microsoft research in Cambridge, Roger Needham, invited me to … well invited me I think to discuss employment prospects [laughs] and I thought I should finish off what I was doing in Oxford, in fact my last two years were a bit of a come down, I should have taken that. But when I really reached retirement age and I felt that my work for Oxford was done it was a wonderful opportunity. And the thing that really attracted me was the freedom that this supposedly industrial research organisation actually gave to its researchers, which I had exploited.

[28:40]

To go back to your time as an academic in the 1970s, how much freedom did you actually have to pursue your work as you saw fit?

Oh I think there was no compulsion on any academic to choose any particular area of research or pursue it in any particular way. What is the pressure comes through – at that time through getting grants from the research agencies and they had varying degrees of intensity pressure to support industrially relevant research. But every now and again you could persuade them, I could persuade them, that my research was so and my contacts within industry helped me to do that and on occasions industry actually supported my research directly with grants.

Could you give me perhaps an example?

IBM supported a research assistant for a couple – two years, at least. And, sorry yeah I'm – they supported two research assistants for I think two years before that, so there was quite a lot of assistants going, but of course the advantage is that indirectly through the assistance at least, I had contact to industrial – know how industrial interests, industrial – we could discuss problems with people actually working at the coal face.

How important do you think your own industry experience was in pursuing full definitions?

Well as I say there was the original inspiration, and I suppose when I was making a claim that my work was relevant to industry I didn't totally disbelieve it [laughs], I thought that eventually this would be the way things that went ahead. And since I didn't have to put a timescale to it that was okay. And then again the – the … I've always been a – a believer in not being wholly rational about what I do, which is do some things that don't seem to have any particular reason why I should do them but it's like sort of going to schools or – or talking to industry or going to a – a lecture in a subject that I don't know anything about. Just so often it kicks your thoughts just a little bit away from the well trodden path and you think of something new just completely unpredictably.

Do you often go to lectures in other subjects?

No, not now [both laugh]. No, not – one doesn't do this too often, it's just every now and again you do something quixotic as it were. And a great friend of mine would never do that [both laugh], he always had – he always wanted everything he did to have a good reason.

Could you perhaps pick out maybe just one occasion when you've done something completely different and got that inspiration?

Well I wouldn't say it was completely different, no not that. Erm … I suppose it … it's happened twice recently in the last couple of weeks, but they were both occasions I was giving a talk and somebody in the audience who had – obviously has a different background has asked a question or made a comment, come up to me afterwards and said … said something which … surprised me. I was giving a lecture, a talk on … Friday of last week, and the theme of my talk was really look how simple the algebra makes it all, and this fellow came up at the end and he made a suggestion that made it even simpler [laughs]. Just lovely, mind you he's a colleague of mine in Microsoft and he's really brilliant, really brilliant.

[34:25]

On the subject of colleagues as well, I was wondering do you form a research group at all when you were in Belfast?

In Belfast we'd – ah a research group? I don't think we had enough funded research to form what we would call a research group. We – we could get research council funding, but that became much more generous when I moved to Oxford [both laugh] and that certainly had a research group there.

Do you have any PhD students?

I do indeed, not as many as some, but I had my first PhD student in Belfast, I remember well, Michael Foley. He … enabled me to – he'd … did we have joint authorship in those days, publish a paper on proving recursive programmes, which was a class of programme that you would think would be much more difficult to prove, and indeed it is because it requires an inductive proof but with his assistance I formalised an inductive proof method for recursive programmes and applied it of course to Quick Sort which is a recursive programme [laughs] and published a paper. Unfortunately he … I think he got badly beaten up in a sectarian attack and he decided to move out to London and I haven't been in touch with him since but I hear his name as a poet, I may be wrong, Michael Foley, perhaps I should try and check and see how it goes [both laugh].

Shall we take a stop for the day as it's nearly half three.

Yes, I think so.

[End of Track 10]

Track 11

What do you think were the most significant events of your time at Belfast?

Well at the time of course the troubles gave rise to most of the [laughs] most significant events. It was a – we didn't suffer physically very much but it was a shock to see armed soldiers going around in jeeps the whole time and going around in pairs one after the other and you could easily get your car caught between the two of them [laughs]. However, of course they all treated us very well and probably also treated most people very well. We did – my department lost one of its outbuildings in one of the major bombing days, which was – had to replaced, was a bit of a – a bit of excitement. One day we were turned out of our house because there was a threatened bomb in a nearby paint factory, but we went to the big house at the end of the road and we were well entertained, that's the whole family of course, three children. And [laughs] I've spoken about the Ulster Workers Council Strike. The most really worrying time was during that strike, because we'd felt that the power sharing government fallout strike had been a ray of hope, this is in 1972. And the strike was sort of well orchestrated and was supported by a fair amount of threatening behaviour as well as a certain – religious, you know, sentiment. But you know when they turned the gas off and then they were going to turn the electricity off, that is quite a [laughs] – quite uncomfortable and then the government fell, and were taken into direct rule again. There were about 300 people killed that year, directly by terrorist activity. And since – after that it began to get better, and shortly after we left the armed – armed soldiers stopped parading the streets, fully – weren't fully armed I meant – I mean [both laugh]. So we really lived through the build up and the – and the slow down of the troubles. Of course they dragged on and on, we followed the news with some interest after we left and it really wasn't until 9/11 that it really died down. And I think that was because there was a lot of American money coming in up till that point and it just dried up. I mean got people who were experienced terrorists and somebody offers them money to let bombs off, you'd have to be very – a very reformed character to refuse the money [both laugh].

Living through that difficult period in Northern Irish history, how much do you actually talk about what is actually going on, I wonder what it's actually like living through it and how much what's happening is a topic of conversation for instance?

Well I don't think – it wasn't an overriding topic of conversation, I think among our neighbours who were sort of upper middle class and clearly not going to participate very vociferously in the controversies [laughs], it didn't really feature very much. And in the university you didn't talk about it with other members of staff because you weren't sure that some of them might not be Catholic or Protestant, as the case may be. And whatever had happened, terrible thing had happened the previous day that you might want to talk about, there were always two sides to the story and they wouldn't e reconciled and so you just ignore it.

As someone living through that, do you have an opinion on it or are you a neutral party?

I was, I think as they say, neutral on the side of the Protestants [laughs]. I found it difficult to believe that the police and the Protestants were as bad as the opposition was making them out to be, and I suppose that's reasonable because you don't really know what the aggravation was with the other side. So, er, as I say we didn't discuss it, we didn't participate and so effectively neutral.

[05:50]

What happened to the computer building that was blown up?

Computer building that was blown up.

You mentioned you'd lost a building to the bomb?

Oh yes, no it was just a departmental building, it didn't – I don't think we had computers in our offices in those days [laughs]. It was – let's see was it caught in – I think it was caught in the blast of a shop next door. It was … one of the visitors on my staff, actually a Frenchman from Wren [ph] called Jean Bezivan [ph] took a

photograph of the bookshop, over the way, happened to take it the day before the explosion, and when he came back on the day, he took it the day after the explosion and then – then he took his – his negatives to be developed in the chemist, and when he came to collect them there was a gentleman from the army waiting to interview him [laughs]. Anyway they looked – he managed to persuade them that it wasn't [laughs] – that it was just chance and they said, 'Yes, and if you ever want your photographs developed again, please we'd be delighted to help you,' [both laugh].

What was it about the council strike that worried you more than other events?

I think the contrast of the hopefulness of the power sharing and the reality of the grip that the Protestants had on the economic life and therefore political life of the country, they were prepared to use the full right to strike in order to get their way in the politics. And it was very much more successful than the terrorists who were trying to use other methods to get their way.

What were your feelings about the change to direct rule?

Oh we'd been on direct – I mean we're direct [laughs] – was no different from here you know [both laugh], even Cambridge has gone direct rule.

[08:25]

You mentioned that your children are born around this time as well, when did they appear on the scene?

They arrived just before we went, so I think our youngest son was only six months old when we – when we went there, so the oldest son Tom went to school there for the first time, in a local primary school, which was a state school and therefore Protestant of course. And he – the accent of course was a little bit off-putting [laughs] when he … he – one day he said that the headmaster had come in to speak to his class and I said – I asked him, 'What did he say?' and he said, 'I don't know, I didn't hear it,' [laughs] and that's how it was. Even towards the end of our stay I was talking to the dustman about our daughter – no our son actually went to a state school, at one of the

good grammar schools that they had which was a little unusual in that time, and our dustman was quite impressed with it and we were talking and I couldn't understand a word he said, three times he said it and then we just had to smile and say [both laugh]. So that was … but I like the accent of course when speaking the sort of standard English [both laugh].

What do your other children do?

Now?

Well then?

Then well the middle girl is Joanna, she went to the – well they all went to the same primary school and she was – took the entrance exam to the paying – paying grammar school, or scholarship as they called it, we paid her fees, independent school. And she got it but we were just leaving, so in the end they all went to a middle school in Oxford.

And your third child, is that a daughter as well or?

No, two sons and a daughter in the middle. And they were, you know, sort of beginning to be out and about, I mean prospect was that they would – they would be more away from home and was I think some feeling that it was a good thing to get away from Belfast, even in – even at that late time, one wouldn't worry so much having the children out late.

How do you balance family life with that fairly gruelling work schedule you described last week?

Well very tolerant, I could work at home and I did ease off after a couple of years, I gave up the [laughs] directorship of the computing laboratory. But I've always been a bit – a bit inclined to do unpaid overtime right from the beginning.

Why did you eventually decide to leave?

I think it was opportunity. The Belfast – I'd developed the department and developed an undergraduate course, developed a graduate course, took doctoral students, but what I want – wanted to do was to develop a graduate course that would attract people from industry to learn about modern programming methods or really I meant theory. And that just wouldn't have enough clients in Belfast and so that was the first thing that I did on – on getting to Oxford, so to start a masters degree.

How did you actually get to Oxford?

Well the trigger was that Christopher Strachey who was one of our great computer – British computer scientists died, tragically prematurely and so his post became vacant and I actually applied for it, one of the few jobs I actually applied for [laughs]. And didn't hear anything for a very long time, in fact it was nearly two years before they eventually sent me a letter offering me the post and inviting me to come for interview [laughs]. They didn't – they didn't sort of interview candidates in the way they do now. I had had a similar experience in – with Imperial College, did I tell you about that last time? I got a letter from the rector saying, 'I'm pleased to inform you that [laughs] Imperial College has elected you professor of computing and we'd be very grateful if you'd come and talk to me,' so I did and in the end I declined the offer. I think mainly because somehow they seemed to have a lot of I thought personal type problems in the department, and they just were problems that I wasn't particularly interested in spending my time with [both laugh]. And Jill was very relieved and she was more worried by the prospect of going back to London than by the troubles [laughs]. So we were very happy in Belfast, exciting but – but really it was a wonderful place.

[14:50]

So during those two years I kept hearing rumours that I had been appointed, 'cause everybody thought, 'Oh he's a natural replacement,' and I suppose I did myself really [laughs]. But I think what happened was that they – they advertised and they got a number of applicants and then what they do is they try to think of the most distinguished computer scientists in the world, and offer him the post, keeping all the

[inaud] in abeyance [laughs] while this gentleman makes up his mind. And the gentleman not unnaturally starts enquiring, 'How big is your department, what are the pros,' 'Well two people including you,' 'What are the prospects of growth?' 'Well we did once pass a resolution that this should be an additional post in this department,' this was at a time when in Belfast we had nine members of staff and in most leading universities there would be at least double that number. And Oxford couldn't make a commitment to allocate a third post. So probably that person did not pursue the [laughs] – take up the invitation.

Did you ever find out who it was?

No, no no, that's very secret of course, I might ask now whether my colleague knows. That's … but I certainly didn't at the time.

[16:35]

In fact when I arrived at Oxford, shortly after I arrived I managed to invite some visitors and indeed some research staff, I was just beginning to get the research going there and the vice-chancellor paid us a visit and not – not unannounced so I asked all our visitors and everybody to be there while the vice-chancellor was calling. And our main visitor for industry, [inaud] the vice-chancellor and said, 'I do hope that you're thinking of expanding this department,' and the vice-chancellor turned to me and said, 'That's a challenge for you isn't it Tony?' [laughs] hmm, and indeed it was a challenge.

How big was the department when you first got there?

Well there was me and Joe Stoy who was the lecturer in the department, there was – there were two programmers and a secretary. And the – I thought that what I would have to do was to be to set up a masters course, now there was a joint masters course with mathematics when I arrived but that was just being cancelled so I had to start again from scratch, setup a masters course with just two members of staff teaching it which would not really have been a very – but then if either of us went on sabbatical we'd have to cancel the course for that year, and that was my original plan. And then

the government decided that information technology was a necessary subject and that we needed more education in the subject and that they would allocate some posts to the universities to fill and to develop their courses. And what was it, I happened to be visiting the university offices at the time and had a letter arrived, and so I was able to put in an early bid [laughs] and we got one more post, which was filled by Peter Henderson and then I planned our – our masters course on that – on that basis, again it would be very tight. And we'd hoped to have guest lecturers from other departments and from industry and so on. But in the end we didn't have to because two things happened, first of all there was a big squeeze on the universities, Mrs Thatcher gained her anti scientific reputation by making big cuts and particularly the number of place – student places was being cut, which affected Oxford very badly, because Oxford was primarily an undergraduate university and the colleges all made their money from undergraduate fees and so reducing or restricting their intake created howls of protest. But at the same time Mrs Thatcher decided to give yet further support for building up the staff of the universities in computing and we were invited to submit a case for recruiting more staff, and in the first round – we didn't know there was going to be a second round but I think we got three members of staff and suddenly transformed the scene [laughs] and I started planning an undergraduate course.

[21:10]

And furthermore each member of staff came with eight student places, so that meant that the colleges were – who are primarily responsible for the teaching of the undergraduate degree in Oxford were motivated to employ – to take up joint appointment and appoint the lecturers as tutors, because in Oxford the salary of the dons is made up partly by – from the colleges, paying for their undergraduate teaching, apart from the university paying for the lecturers and examining and administration and so on. Without the colleges we wouldn't have got any students accepted anyway so it had to be distributed around the colleges. And the colleges were notoriously conservative, you know, like new subjects and so business studies [laughs], I don't know, computing, but this really broke through and that meant I could start planning an undergraduate degree. Of course everything had to be approved by the faculty of mathematics, faculty board of mathematics of which I was

a member nearly the whole time that I was there. In fact by the time I left I was the senior mathematics professor at Oxford University [both laugh].

I was going to ask when does computing actually fit into Oxford?

It fitted in as very much part of mathematics, I did the same thing as in Belfast and developed the course as a joint course with mathematics for – well for the foreseeable future at the time, at the time that I did it and that built up the strength so that we could eventually offer a full degree in computing. I think the … I mean there were people in the faculty who had fairly negative views about computing [both laugh] which I'm sure justifiably, they were very very clever and good mathematicians.

What sort of negative views?

I never really heard anything expressed directly at … one of the problems was that when we expanded we obviously couldn't fit into where we were – started out in 45 Banbury Road, just a single semi-detached Victorian house and we would have to move and the possibility is that we would be just given odd houses that as they came free in North Oxford, or the university departments were just clearing out from four lovely large – a row of Victorian houses in Keble Road which was allocated to the faculty of mathematics. And I don't know that I ever suggested it but it did seem that it was a possibility that they should move us into that and force the mathematicians to continue in very cramped accommodation for the indefinite future, in fact they've only just just moved out after twenty years, that's thirty years nearly into a new site which I haven't yet seen in the Radcliffe Infirmary site. So I think there must have been quite a bit of ill will about that [laughs].

[25:35]

Yes, I … when we got the six members of staff I thought it would be a good idea to actually plan to start the undergraduate course so I made this proposal to the faculty board and … the faculty board as usual referred the issue to a subcommittee or setup an ad-hoc committee to consider it including – well I think consisting mainly of members of the sub faculty including myself, and we had a meeting in the faculty

president's – the chairman's office and the faculty secretary took notes and the other members of the committee were I thought moderately negative about it, I think some good reason, you don't start up an undergraduate course with only six tutors in the subject 'cause you need a tutor in every college, all proper subjects have. And there were well nearly fifty colleges [laughs]. So they sent a – sent a report, the secretary drafted a report which went back to the faculty board which was totally damning, it was incredibly negative, although I thought the meeting hadn't gone well I had no idea it was quite as bad as that. So I objected and said, 'Surely it wasn't as bad as that,' and the chairman said, 'I'm afraid it was,' [laughs].

What was so bad?

And the secretary agreed [both laugh] and as a result the faculty board rejected the report and I was convinced that this was a plot by the chairman and the secretary. I never checked, it really does seem to have been a ploy [both laugh]. So in fact we didn't set it up immediately, in fact the first undergraduates were taken in nine years after I'd been there nine years.

What was the particular criticism that stopped it happening then?

Oh I don't – there were so many [laughs], I don't know that I can – I can remember in detail. I should think it was mostly impracticality, no evidence that there was any demand, and I'm sure it was all couched in the fact, you know, sort of phrases that there was no evidence that, rather than any direct assertion of imminent failure [laughs]. But as I say one heard the same arguments when they wanted to set up a degree in business studies [both laugh].

[28:40]

I'm curious as to why, you know, one of the largest universities in the country, you know, computing science should be such a small subject compared to Cambridge for instance?

Well Cambridge started earlier and had a strong departmental head, Maurice Wilkes, and I think it sort of just got under the net. The department at Oxford had been set up by the – the Science Research Council in order to provide a post for Christopher Strachey who had been working in Cambridge for Maurice Wilkes and they didn't get on, Christopher was a bit sort of flighty person and more interested in imagination than ideas and Maurice was very practical engineering, let's deliver it, let's do it kind of person. So they didn't – they didn't fit – fit very well. So it had been set up with outside money, as part of the computing laboratory, which was still at the time that I was there, a joint computing service and academic department. The head of the department was Fox, Leslie Fox, who's a distinguished numerical analyst and he'd built up a strong – well he's built up a team of four numerical analysts, and he never – he always said he never understood the Strachey stuff and that couldn't understand what the fuss was all about, being very much a numerical mathematician. And in fact not a very computational one, he liked the intuition of doing it by hand. And was a bit notorious for being theoretical and numerical analyst which I couldn't complain about 'cause I was for the same reason a theoretical computer scientist [both laugh]. But he obviously wasn't really rooting for the department, he'd set it up and sort of as a challenge, as being a … to give the subject a possibility of proving itself, and very good for him too. But not what was needed to build up a – the post – one of the reasons for the two year delay in refilling Christopher Strachey's post was that the post was not an established post at a university, or it was established only as a reader and he had a personal chair and who was going to fund the difference, so that they would have to decide and fortunately they [laughs] decided right.

[32:00]

Was there any particular onus on you to take the department in any particular direction?

No, no that was entirely up to me, and I had a vision and that's obviously what was needed, and wasn't an altogether realistic vision but [laughs] it sort of gives one an encouragement and something to work towards.

We've talked a little bit about the teaching aspects of that vision but what were the other components?

The research, research was – in the early days was extremely successful and I had – we had two what were called special – special large Science Research Council grants at one time, one to look into sequential programming and one to look into concurrent programming, and they both produced outputs that are still quotable today, or becoming more so in fact. And we had no less than nine grants from the European community, we had some industrial grants, so we were, you know, perpetuating the Oxford tradition that an engineering or a medical department would have two researchers per member of staff, don't think we really kept that up but it was, that's the sort of ratio we were operating towards.

What sort of things were the European grants for?

Mostly formal methods, there was – the one that I was most interested in was called – there were two that I was most interested in, one was they were given initials, it was called ProCoS but it was about trying to develop a theory that would cover major components of a software system for a modern computer. That is it would include a compiler and an operating system, and it would develop the technology of proving those correct and in particular proving that the interface between them, defining the interface between them so that the two things would work correctly in combination. And I worked with some colleagues, chiefly in North Germany and also a couple in – in the Netherlands, people whom I still met and work and talk to, and the basic idea was to reproduce something that had already been achieved by friends in the University of Texas at Austin, which was we take all the stack, how do you build up the software in this standard way in which it is built up and at each stage prove that what you've written is correct. Well we did a – a pilot prototype of it in six years [both laugh].

What sort of actual activities go into that sort of research?

It's mainly writing papers, because we were working – in contrast to the United States effort, we weren't going to use computerised tools which I felt really weren't up to the

demands of checking the interfaces between the components and that was a challenge that I thought we should concentrate on. The American tools were adequate, were in the hands of a skilled experienced expert, capable of checking proofs, of the components, but checking that the whole system was based on a coherent theory was I thought beyond what they could do. Now tools are becoming available that are beginning to look quite useable and capable of tackling very major – major projects.

So if not with software tools how were you doing the work?

Just written proofs, usually an appendix to a paper but a lot of it was just definitions and conceptual engineering as I call it.

Shall we take a short break, just for –

[End of Track 11]

Track 12

I was interested when you said that your department included two programmers, what do programmers actually do in a department?

The department that I was leader of was called the programming research group and the – what they did was to actually implement compilers and operating systems for running the departmental computer, and – and for doing research on programming. So Joe Stoy who was the colleague of Christopher Strachey, was actually working on a publishable operating system, smallish in those days, which was written in a high level language, also designed by Christopher Strachey, and actually making it run the departmental workload. So that's what they were doing, of course as the department expanded there was always a lot of support work for them to do and I suppose shortly after I arrived that was the main – main responsibility.

What sort of computing facilities do you actually have?

To begin with there was a Modular One computer, a 16 bit computer which was limited to 65,000 bytes of main memory. And a big – big disc, enormous – very obviously rotating disc which holds two megabytes, and that we had to share among everybody in the department [laughs] so we used to have meetings every Thursday to decide how to allocate the space [laughs] on this disc. The backup was on paper tape and it was not a viable way of [laughs] running even a small department computer. Fortunately I managed to ask for an equipment grant, which bought a more modern computer, an Interdata computer, quite a sort of non-standard computer which seemed enormous at the time, had proper disc storage but again the backup was on paper tape. And it was micro programmable so it was possible to run the same software reasonably efficiently on the new computer that we'd run before. But still it needed quite a bit of work doing to keep the thing working.

When you say enormous is that in terms of its capacity or its physical size?

Enormous meant size in those days [both laugh], it certainly – the actual capability capacity and capacity in the sense of capability was extremely small, and quite

amazing. I mean the thing to be amazed at is how on earth did they think that was worth – I mean we were paying 70,000 pounds for these machines [both laugh] and really I mean I have in my pocket a machine that is far, hundreds, thousands of times faster and larger [both laugh].

When do personal computers come on the scene from your point of view?

They were coming on the scene more or less at the same time I was moved to Oxford. One of the early grants that we got from the Science Research Council bought us three or four personal computers. What did we buy? We bought Sun Computers I think at that time, yes. Again there was a – Mrs Thatcher set up a responsive research project called the Alvey Project, named after the chairman of the committee that had set out the – the plan of work for the project, and that provided money for grants and research and equipment. And our department won quite a few of these Alvey grants and I had a friend in the Alvey directorate, he – civil service which was part of the Department of Trade and Industry at that time and as is – seems quite usual in government departments every now and again they find they have a little bit more money that they hadn't expected but they had to spend it by midnight on March 31st [laughs] and so he'd ring me up and say, 'Do you think you could accept delivery next week?' and I'd say, 'Oh yes of course,' [laughs] so that helped equip the department.

[05:40]

What sort of things can you actually do on a small desktop computer compared to a monstrous mainframe or mini computer?

Nowadays?

Then?

Then? The main – main initial use is word processing, just drafting and printing of thesis and articles and – and that really for a theoretical computing department is very largely what we did. People doing crystallography calculations, the real number

crunchers would still use the central computer. Nowadays the central computer is itself made up of thousands of the personal computer [laughs] chips.

What sort of – you mentioned the Alvey programme a moment ago and I was wondering what sort of grants you actually got and to do what with?

Now that exercises my memory a little bit. [Pause]. Right, my colleague and ex-student Bill Roscoe, who's now head of department at the computing science department, as it's now called at Oxford, developed a computerised tool for analysing concurrent programmes using the communicating process model that we'd worked on together and he got support from the Alvey Project to support the programming of this model checker as it's called. And that – that was pretty successful. We – he later went on to win a Queen's award for technological achievement in collaboration in industry, INMOS, British microchip manufacturer and that was based on work that had originally been developed the Alvey Project. The … the Alvey Project was a typical sort of government – government led project in a number of ways [laughs]. First of all Alvey himself had recommended a ten years project and that was cut down to five, and secondly I think they spent nearly two years setting the project up, after everybody knew it was going to happen. And during that time of course the – the money available for computing science did not increase, it may have even declined a bit. And there was no preparation at all for example, oh we're going to need more researchers, therefore we should start by funding some more doctoral studentships, no, two years sort of, as it were, the tsunami went out rather than coming in, and then suddenly condition of the grant. You've got so much money, quite a generous amount, you start spending, you're not allowed to spend any of it the day before you start; you start spending at a constant even rate the moment it starts. And this is – I mean [laughs] not exactly industrial commonsense but administratively [both laugh] it was just horrible. And then it was a joint programme between the Department of Trade and Industry which was the government department and Science Research Council which is an independent quango and they all had different rules. At the time it was a five year programme but the grants were three years at a time, so Bill Roscoe got this grant for three years and did very large work and then he wanted to extend it. And there was money available in the programme because all being spent [ph] [inaud] so no difficulty about that. But the Science Research Council had made a decree

independent of the Alvey Project that they weren't going to extend the grants anymore. That the only way that you could get your grant extended would be to return all the money on your original – all the outstanding money on your original grant [laughs] and apply for a new grant altogether. Whereas the Department of Trade and Industry were running a five year programme and they had rather the opposite ruling, that they weren't going to start any new programmes because there were, you know, just two years left, but they were willing to contemplate extensions to the old programme. So we just couldn't get a decision, and meanwhile the people who – the people working on the grant were left with the prospect of a yawning gap in their employment record. And nowadays we tend to have a little bit of spare money in the departments that you keep somebody on for three months or six months or whatever to fill the gap but in those days we – I didn't have any slack of this kind, slush fund we used to call it, but not in public [laughs]. So – but Roscoe had to set up a company and he set up a spin-off company called Formal Systems Limited, with an American offshoot called Formal Systems Inc which survived for about ten years. And never grew very much, did further wonderful work on his – his model checking tools for concurrent processes, and – but – well interesting that a theoretical department could have a spin-off at all [both laugh].

[13:05]

This brings me onto I guess two or three different questions actually, I mean one is how important was actual Alvey funding at that time in the early '80s for the department?

Oh it was absolutely seminal, I mean it put us in the position in which we could realistically apply for nine European grants. And in fact this happened throughout the UK that the English uni – British universities took a lead role in a lot of these consortia which got Alvey grants. So although I think one would have to say that the programme didn't come up to the hopes of Mr Alvey [laughs] it certainly created a – quite a Philip [ph] in the computer science department. It was very non-cost effective because there were so many grants going to ad-hoc combinations of collaborations with industrial partners and academic departments, of not necessarily the best departments, I mean quite a lot of the new universities, ex-polytechnics were getting

grants which I have no objection to but I think as a result of that there were quite a lot of people who'd been doing research who really weren't cut out to be academic researchers. And we tended to discount experience on an Alvey Project in applicants for jobs and things like that, it was a bit – not cost effective, but – but effective in another and unexpected ways.

Such as?

Well just as I said the setting up the –

European grants?

European grants, yes. And I suppose in a way sort of creating a general understanding that computer science was a research subject at all, I mean when you've got academics who are regarding as sort of plumbing and changing fuses and so on [laughs] it's – and there wasn't funding, you know, there wasn't funding generally available for research posts in computing at universities at that time.

[15:45]

What did you see computer science as being if not plumbing?

Well I thought it was a practical subject like plumbing but based on a theory so it was more like engineer was more … a computer programmer was more like an engineer than a technician, that they had to do things, get things done, but at the same time what they were – they were able to put – bring a wider understanding to what they were doing and adapting it and thinking about it and choosing alternative – and innovating, which a well trained technician wouldn't necessarily be able to do.

Does the prospect of Alvey money actually help you in your own internal battles with the university?

Did it help internally in battles with the university?

Thinking about what you were talking about with the difficulties with the undergraduate programme for instance?

No no, the colleges weren't – the under – the colleges which recruited undergraduates weren't very much concerned with research. The important thing was that we got these initial recruitment, four posts I think it was, we got them filled with four very nice good hard working suitable people, and so they learnt that these computer scientists were okay. I think we'd been slightly … affected by the fact that the numerical analysts, some of whom were really really world leading, were all a bit sociopathic, they weren't what – really mixers in and they – they weren't interesting people, and the college is very interested in interesting people and we managed to recruit some very interesting people. But it wasn't easy, in fact one of the colleges actually withdrew their offer of a job after they had interviewed all the candidates, all the candidates for all four posts were interviewed at all four colleges and one of them said, 'No,' they were too old, they were looking for somebody younger, or some such excuse. And so we had to persuade another college to take on one of the chaps, the chap in question, who had been selected by the university, was Bernard Sufrin who was quite left wing I should say, very decided views and quite articulate about it too [laughs] and he was taken on by Worcester College which is not a left wing college at all. And he had a spectacular career and his success at the – in the undergraduate teaching was phenomenal, one year I think he – all four of his students got firsts, it was just – he was just so good, and in fact he's only just retired. And so it worked out very well but he was a little bit older and he'd been at Essex University, and so he was shunted in a different college. But as I say, you know, as soon as they get their personal – people realised that they are reasonable personalities and not all geeks recruitment to the colleges was much easier, well it was never easy I must say, you know, it was [laughs] had some hair raising experiences [ph], which I don't think I'll go into.

[20:10]

I was wondering if you could give me a little insight into what life in your department is actually like on a daily basis?

I probably didn't know actually sat in my office [both laugh]. I spent quite a lot of time answering mail, emails, a lot of administration, and lectures, I didn't lecture as much as most people did, and research. Well the days were different, some days one did – spent the whole day doing research, some days hardly got through the mail [both laugh]. Making out cases for various university bodies was to begin with quite a task, and you've got to design a course and recommend it to the faculty board and then get it passed by the general board of the university which was the effecting governing body. And I talked to the administrators, and they were – they were very very good, but on the whole it was their job to say no [laughs]. And indeed everybody's job was to say no, when I finally got round to setting up a full honours degree this had to be debated and it was approved by the faculty board of mathematics and kept being sent back by the general board and that was the only time I actually did some lobbying, I went and tried to find out what had gone on, and the people – perhaps they shouldn't have told me, they couldn't remember, it was just a – an item in a very long agenda, didn't have any prominence at all and what happened is that the administrators obviously did allocate their resources and time, and they had – must have very lightly decided this was a non-starter. And therefore they didn't sort of present it in a prime position in the thing and brief people to talk about it or, you know, the little things one can do to smooth the passage weren't being done. This is my interpretation of what was going on, so in the end I made an appointment with the vice-chancellor who was the chairman of the committee to find out what I should be doing. I was actually – the night before I was coming home from – from Paddington and there was the vice-chancellor on the concourse and so I greeted him and we started talking about this new course and I told him I could – there was a delay, there was a bomb scare at North Pole [ph] and all the trains were delayed, and so he – he listened and we agreed that we wouldn't need to meet in the morning so when people ask me, 'To what do you attribute your success in starting a full on school?' I say, 'It was a bomb scare at North Pole [ph],' so in a way it was [both laugh]. And that took I think six new posts out of university funds, all the previous posts had been out of outside funds, Mrs Thatcher's initiatives and whatever, and this was the first – since they upgraded the Strachey's post from a reader to a professor this was the first money actually passing over the counter as it were.

What did you say that was so persuasive?

I don't recall [both laugh]. I don't know at all, perhaps I just answered a few questions, he wrote – I think it just caused the item to be taken more seriously. And I think that's still going reasonably well.

[24:55]

As your department starts growing, from your point of view as the person who's at the top of it, how much control over it are you actually exercising?

Oh control is not quite the word we use in [laughs] – I've had the good fortune on several occasions to be in charge of a department nearly all of whose members I have myself recruited. Which actually I think must make a lot of difference, one does sort of feel comfortable with the people and then you just delegate everything and you deal with the – when things get troublesome, by exception. Occasional personal – interpersonal difficulties, very occasionally. So it's – oh the other thing is, even when I was in industry I was looking after a group of programmers who all knew that if they left they could get another job before their last pay packet hit the ground, it's [laughs] – so you're always very nice to people I've employed [laughs]. And that certainly makes life a lot more pleasant.

In selecting your own team of staff in that way, is there anything you're looking for in particular in them?

No, I can't think – I do – I do think and I just don't know how it is, that I do pick the right people, I mean I know people who don't pick the right people and [both laugh] you just feel comfortable that you can ask them to do something and they'll do it, that's the important thing. And then being a little careful, I think doctors have to do this too, if there's some false note in an interview with somebody, leads you to suppose just before they go out of the door that they're not quite happy, sit them down again and really try and find out what's going on. That is something I've sometimes failed to do and sometimes – sometimes found was necessary. And … so I suppose that's my management philosophy [both laugh].

Is there any strategic sense to choosing your own staff?

Well I did have obviously people who were interested in the same kind of formal methods that I was interested, same kind of ideals, very much in – in Oxford, less so in Belfast when my own – perhaps my own ideals hadn't been so well – well honed. But in Oxford it was necessary that everybody in the college should be able to supervise or tutor the students, undergraduate students who'd attended the other lecturers' lectures, so it really meant that it had to be a team and you couldn't really afford to have people who were not onboard as far as the general direction of the – and content of the course was concerned. So they had to be very homogeneous, much more homogeneous than – than was really very good for us in the long run. And this I think, this did cause problems before I had left, that the department was too homogeneous, and we didn't have people specialising in more application oriented subjects, more specialised subjects. Which the problem that my successor is now solving very successfully.

Shall we take another short break from –

Sure.

[End of Track 12]

Track 13

You've talked a little bit about sort of university administration duties within your department, do you have to take on other responsibilities more widely in the university as well?

I think most professors and teachers at the university do take on wider responsibilities, particularly at Oxford where they had duties to their college as well, so they'll be serving – serving on college committees. Each college is an independent legal and financial entity, so it has a lot of administration, both of academic and a non-academic nature, so people become wine stewards and [laughs] – I was a member of the library committee for a while, but on the whole I just didn't – I felt I needed to concentrate on building up a department which was a sectional interest and therefore I didn't really want to establish the – a lot of impartiality and [laughs] disinterestedness that a proper university – academic administrator should.

Which college were you actually part of?

It was Lord Wilson College, it was a graduate college in the North of Oxford which suited me extremely well, I was very well suited there. I was a little bit in awe of the undergraduate colleges still 'cause they have – well a very distinctive culture which can be a bit grating sometimes, and not quite sure whether you're going to be accepted or not.

Hadn't you been an Oxford student yourself though?

Oh yes, yes, I was a philosophy undergraduate at Merton College between 1952 and '56. So when I was a – an undergraduate, even the undergraduates used to frighten me [laughs]. And they recently elected me an honorary fellow which is nice.

As well as your university committees, do you have any sort of wider committee duties in the wider world?

I used to serve on the Science Research Council committees … when they had committees. More recent years they don't have committees anymore, they have what's called a college of assessors and they call meetings from a very wide constituency and the same person doesn't go to the series of meetings. In fact I've never been to a decision meeting [ph]. Refereeing – refereeing both personal and article refereeing, it is a – a scientific duty and sure [ph]. And organising conferences, chairing conferences, workshops, yes again a service to the scientific community.

[03:55]

What sort of SRC committees do you sit on?

At the moment I am a member of the select – of this college of peers it's called and I'm – I think I've been asked for times to write a referees report and twice I've declined so [laughs] – and that's in nearly ten years. But apparently that's not unusual, it's a very very broad constituency they consult. There was a time and obviously still is when the SRC felt that they had a reputation for being elitist, I think particularly when the new universities were promoted from being polytechnics, the – they felt excluded, and the exclusion of course was clearly from – from the research grant proposals that I saw had a foundation in the fact that they weren't very good at writing research grant proposals. And [laughs] – or sort of more objectively that they really had little experience of actually conducting research at an international level, and so it became very important for the Science Research Council to be open about their procedures and in particular to abolish the committee system which was sort of self perpetuating oligarchy … and the college of peers is a sort of compromise, that it's sufficiently broadly based that people will personally know one of the peers anyway. And it means that no clique can really keep a stranglehold on the research funds.

When did you actually first serve on an SRC committee, when about?

Oh I think probably when I was still in Belfast, but certainly soon after I arrived at Oxford, I remember being sent out of the room while they were making a decision on the continuation of my large rolling grant as it – as it was called, would it roll again.

And I was outside for a very long time and in the end they didn't grant it, it was too ambitious. I was very typecast I think for at least a day, and decided that next time I would put in for two grant proposals and both of those were successful [both laugh].

I was about to ask actually, are there any advantages, you know, sitting on the SRC for your own academic career?

Well certainly it helps to be on a committee if you're going to have to make a case for your own research, yes. I don't know, it probably helps – no what – what does one say? People will tend to be rather more polite to their rivals and colleagues that they know are going to sit in judgement on their grants. But that's sort of very big, very big point.

How do these committees actually work from your point of view as someone who's been on one?

The research grant selection committees? They get a – the present procedure, which is very similar to what it used to be is that the administrators get the research grant and they send it out to referees, probably about four or five ideally and then when they've collected enough referees reports they … they set up a meeting at which they invite members of this peer group to adjudicate. And then the peer group usually appoints one of their members or two to study the proposal and present it to the committee as a whole. They then put the – the academics then put the committee – the proposal into an order and later on they financiers and administrators decide how many of that list can be funded.

What sort of criteria are you looking at?

The official criteria of the research councils gets more and more short term and industrially oriented, but in – in practice the committees tend to be quite considerate of longer term research and more pure research at – the forms that the researchers have to fill in are – definitely give a possibly over – undue amount of space to the scientists assessment of industrial application and a referees assessment of industrial application. But I think they are withdrawing from previous extreme positions [both

laugh], most recently when I've had to fill out forms it seemed much easier to go along with, whereas before you really had to squeeze something out about application and industrial relevance and so on, which I don't – never had to do inside Microsoft which is really a great liberation. And I've come to the conclusion that – oh it was some time ago that a scientist should never make an estimate of the applicability of his own research.

Why?

Was pointed out to me very early on when I moved to Oxford, I went to a lecture by Sir Richard Doll, the discovery of the link between smoking and cancer, the lecture was about redefinition of the acceptable population levels of radiation in the light of new evidence from Nagasaki and Hiroshima, there were more people succumbing to cancers in later year, twenty years after than was expected. And at the end one – a member of the audience asked, 'What advice would you give to the government, what recommendations would you make based on the research that you've done?' and he said, 'I refuse to answer that question.' He said, 'If I give any advice based on my own research, then I lose the most – my most delicate and precious judgement, which is about the science – the scientific results of the research and my research then become oriented towards making my prediction come true, whereas it should always be the other way around.' He said, 'I'm willing to advise on the applicability of other people's research and I'm willing to advise on research that I did twenty years ago [laughs], but not on what I've just done, and least of all obviously what I'm going to do,' and I thought that – I was shattered, I thought, but this is what I've been doing all my life, I've been promising these things. And indeed it's true and I'm very ashamed, I had to continue to promise industrial relevance, throughout my academic career, and only on joining industry am I allowed to forget this [laughs].

[13:25]

Are there any particular claims of industrial relevance that you'd highlight in that light?

Well I think the basic thing is the avoidance of error in computer software, so we used to try to make people's flesh creep with stories of what could go wrong if the software contains an error, and none of it came true, software is using quite standard techniques, testing techniques which are nothing – well nothing, turns out they do owe something [laughs] to my research. They were quite adequate to achieve very high levels of liability of critical components, it – we always predicted that when concurrent computing came along this would change, that the possibilities of error in concurrent computing were so much greater than ordinary sequential computing that it would be essential to use formal methods to reduce the risk of error. And that also kept not happening [laughs], largely because the computers themselves got faster, so much faster, so much quicker than, you know, we were basing our predictions on, so that people didn't have to use multiple processors very much. Now it's beginning to change [laughs], people are quite exercised by – to exploit the concurrencies as a means of increasing the performance of their programmes, because the hardware designers have told us that we won't be getting raw speeds for the individual processors. But a number of years ago Intel announced that they would be making more than one processor on the same chip, and but that the clock speeds, the actual speed at which each processor obeys instructions would remain constant or even go down slightly. So in order to get the acceleration, continuing acceleration of speeds that we've come to expect, the software is going to have to exploit concurrency and now we're I think beginning to see techniques that will enable sophisticated tools to improve, usually not the correctness, sort of not – always not quite what one goes for directly, but performance, and improving performance depends on understanding more about the programme than a normal compiler, sequential compiler would have to do. And – and of applying reasoning techniques to the behaviour of the programme, using technology of computerised proof. And I think that's beginning to happen.

[16:50]

I guess this brings us onto a subject we haven't talked about much so far in your time at Oxford, your own actual research, what are the highlights of it in this period?

Well I suppose I could let … the highlights occurred mostly in the first [laughs] four or five years before, well before the undergraduate course started [laughs]. The work on programme specifications, which goes under the acronym of Zed, was developed in my laboratory by Jean Raymond Abrial, that's A-b-r-i-a-l, quite early on and with the whole other colleagues who we later recruited as staff in the laboratory. The idea of proving correctness of programmes really depends on having an independent notion of what correctness means, what it is that you're trying to achieve. Because if the shortest explanation of what you're trying to achieve by a programme is the text – expressed in the text of the programme itself, then there's nothing to prove. So you've really got to get your – get an idea of what – what you're trying to avoid clearly formulated in terms of some mathematical model of the reality in which your computer is embedded. So you've got to – if you want to say something like, the aircraft must not collide, you've more or less got to formalise euclidean geometry, four dimensional including time in order to define what a collision or a near miss really means. And without that one can't begin to – begin to apply verification proving methods to the problem. Well we – as scientists we tended to go for an even higher ideal that this specification should be written either before or during the development of the programme itself. So you developed the specification as the first stage of your programme – project, and then you performed a number of design steps and at each design step you proved that design step was correct and so in the end the last design step, or rather advanced is to write the actual text of the programme itself which maybe distressing large. But because you've designed it in this top down fashion, taking small steps at a time and verifying each step before moving on, the whole programme is going to be correct as we said by construction. So we were pursuing this ideal of correctness by construction more or less throughout my career. But it means that you've got to have languages other than the programming language itself, which are more suitable for specification and design, although the programming language is the eventual target of your design process, you want simpler and more expressive languages which don't talk about how – how the objectives are to be achieved, but talk directly about the aims and the criteria, rather than how the computer is going to achieve them. As I say Zed is the language based on set theory, mathematical set theory, based on the foundations of mathematics which I thought was a good candidate because it has already been proved, already been established that these branches of pure mathematics were capable of defining and expressing the

notions in all other branches of mathematics. So even though we were describing the real world we were constructing a mathematical model and using very general, very general foundationary branch of mathematics to do so.

[22:00]

I'm interested in how realistic a goal, sort of perfect software is, is it something you think can be realistically achieved or is it something you're aiming for as a way of just getting better gradually?

I – I think as an academic I was quite unrealistic and thought it was an achievable goal as it were in a single step. Very difficult to see how it could be achieved gradually so it was a sort of all or nothing thing which involved started out on a project in a completely different way from what everybody is currently doing and pursuing it in a way in which – well one of the attributes of it is that you don't write a single line of code until the whole design is complete, well that's a council of perfection anyway [laughs]. So ordinary management procedures which sort of like to count the number of lines of code you've written as a measure of progress would be inapplicable, so you couldn't manage it could you? We did a joint project with IBM connected with their customer information control system, which was their most profitable piece of software at the time, and was being developed in IBM at Hursley, near to Winchester, and the – what … happened was that it – like all software these days it evolved and it grew by accretion of new facilities and so on. And they found it in – as the whole thing was just held together by pieces of string it was getting more and more difficult to add new features, and this is what the customers always want and this is basically what you sell, sell the new features, not what you've got already. So they need every now and again to do a restructuring, or re-factoring it's called is the fashionable word these days, to get a cleaner infrastructure, cleaner interfaces between the various components. And very ambitiously they decided to fund a project that would actually specify large sections of the code of this – no a section of the code of this system, and try this process of top down development. And they chose the most difficult section, the section concerned with resource allocation to perform the exercise on, and they formalised and published a mathematical prescription or specification of what all the items of the software would do and then they used that to develop the code. And from

being the least reliable component in the software system, this module became the most reliable. They kept a lot of statistics as they went along and they reckon that the use of formal methods had saved them something like nine per cent of the cost of the project, or nine per cent of the cost of that project really paid over for the research, over and over again. So this was great. At the same time – so they put it in for a – entered the competition for a Queen's award for technological advancement in industry and they got it, in collaboration with us. So not only did we have [laughs] – not only were we the most theoretical department in the country, but we had two Queen's awards for industrial collaboration, a wonderful period [both laugh].

[26:25]

I think we should probably call it a day in a moment but I have just one final question I'd like to tack onto the end of that if I may; and I'm just wondering in the course of that work with IBM what sort of interactions did you actually have with them?

Oh this was very intense, the people who were working on it used to down to Hursley two days a week and they used to sit behind – sit at the person's desk and watch what he was doing, and they used to sit in on design meetings, and they used to take design meetings, which were really important part of the standard software development process in IBM, and the person who was doing the design would usually write a report and say how he was going to do it. And the people who were at the meeting should read the report before the meeting, but probably didn't, but our chaps did. And they came up with questions, based on the written report and this was the first breakthrough that the – that the industrialists realise that these people were bright and that they had a technology that would enable them to isolate issues which if they had not been isolated early could have led to untold problems later on. So it built up trust gradually, just simply by being there. And this is what led up to the, you know, Queen's award, project.

On the subject of awards as well and this is my last question today, I was just wondering, did you win a Turing award as well over your time at Oxford?

Yes, that was 1980 – oh when was it, 1980, yes? Dana Scott who was the professor of logic and was still there at Oxford at the time also won a Turing award and so we were – had two Turing awards [both laugh].

What did you win it for?

Contributions to programming languages, just the early work that I'd done I suppose mainly in Belfast. But also the work on communicating processes I think had come to people's attention. That's my most quoted paper even now, nearly half the – my reference system, my publications are for that article [laughs].

What did you feel about winning it, sometimes referred to as the Nobel Prize of computing?

Well it was great, well [laughs] yes, it's … I don't feel in – I mean … that it's pleasant and – but it is useful, certainly it was useful that people do clearly see that there is something to me perhaps, and so it is easier to get people's attention. And it – I was told it was influential in getting the fellowship of the Royal Society. Okay?

[End of Track 13]

Track 14

The main degree that was the – essentially the beginning of computer science teaching at – at Oxford was the undergraduate degree. Initially in computation and mathematics, close sort of between a third and a half in each of those two subjects, so we had to get – we got to know our mathematical colleagues well. The important thing was that it got college tutors into the colleges, so the colleges could see that we weren't all geeks and that we were interesting people to talk to which was quite important in the college. And that laid the foundation then for every passing special initiative announced by the government we would do something new of course, can't do the same thing again. So we set up a joint degree of engineering, and we set up quite a number of masters degrees, so in the end I probably have the distinctive distinction of having originated about eleven different degrees at Oxford. But it's not an ideal [laughs] legacy to leave to ones successors, each degree requires administration and planning and examinations and although we – one tries to box and cox [ph] as much as possible, it's still a lot of work. And I think now the engineering degree has fallen by the wayside.

Why the great variety of different types of –

Well really it is initially in order to get hold of passing announced special grants for new staff. It's still – it was still quite a small department by Oxford standards because a properly established subject has two tutors in each subject in every college, so you're talking about 100 as the 100 undergraduate teaching fellows in a subject like physics or history, philosophy, Latin and Greek and so on [laughs]. And that's – it was important to get – to get the people on the ground and to get good people too, both socially and intellectually, to spearhead the infiltration of computing science into the university.

Did you actually see it as, you know, the infiltration of computing at the time or was that a –

Oh very much so, the initial barrier to entry is very high because no college can admit students in the subject, it's the colleges that do admissions for undergraduates, until

they have a tutor in the subject, a tutor to actually teach the students and to fight for the subject. So we started off by splitting every job two ways, everybody who's recruited as a lecturer had a four hour a week tutorial fellowship at one college and a two hour a week lectureship at another college. Professors don't do undergraduate teaching so in our – in the first two years in which we managed to get posts we had six undergraduate posts, spanning nearly twelve colleges. And in each college they had to fight – stand up for the subject and make sure they got two students a year to fill their quotas. And then a lot of cross teaching and employment of research staff to do teaching, it was all sort of make do and mend.

It seems strange that, you know, forty years after the invention of the computer almost you're still having problems at one of the largest universities in the country actually introducing the subject and –

Yes, to introduce it as an academic subject is I think the real problem. The Oxford system is different from a normal university, in that the tutorials that the teaching as it's called, is done by essentially professorial status dons on a one or two individual or two person, or increasingly four person or six person now, basis. And the lecturers were – who are paid for lecturing by the university just do the lectures, so you have seven tutors, and each of them are lecturing in their own specialist subject but the teaching on the tutorial classes and the question answering is done by the individual tutors, so this is why more or less people – the people who are recruited have to have a very homogeneous view about the nature of the subject and which things are worth teaching and so on. So we evolve that view together and it sort of made a very coherent but from the point of view – general point of view a little bit overformal, a little bit over the top, overformal [laughs] style of degree. Where the integration with mathematics was initially and continues to be quite crucial, this is not just describing things the way they are but describing things the way they have to be because the mathematical properties of them have to be such and creating that link with mathematics was very much a go in the initial development of the degree, and nearly every lecturer wrote a textbook on the subject because there wasn't one already available. And I was editor of a series of technical monographs in computing for Prentice Hall and so I published the textbooks [laughs], a little bit introverted don't you think? But it was I think the series had a good reputation.

[07:10]

Compared to, you know, the other computing departments in Britain, what do you think Oxford offered under you that they didn't?

Well it was a specifically mathematical approach which we knew wouldn't – wouldn't be directly welcomed by employers or have any real practical advantage to begin with, but again that's characteristic of the Oxford degree, it – and a feature of the teaching content and style that I described is you can't afford to be changing things too often so you had to be pretty confident that what you were teaching was fundamental and not likely to change with fashion. And quite – or with technology really and fashion and technology in our subject changed very rapidly [laughs]. The people who attend our graduate courses, many of them – well nowadays even the majority of them will be – will have industrial experience before, and they might well find the formalism and the mathematical content a little certainly unfamiliar and maybe unwelcome. But at the end of the course the typical comment is, 'You changed the way we think about programming,' and I think is taken as sufficient praise.

Changed in what way do you think?

It's just they I think have a conceptual framework and a degree of confidence that enables them to think through what they're doing more effectively and not feel that everything that they do is just an experiment in coding, but if they have – when they learn to recognise when they have achieved sufficient understanding, which could be formalised as a mathematical model of what the programme is intended to do, then they have the confidence to go ahead and design it and even build a team to implement it. This is – I mean in the early days we had courses which were commissioned by IBM, and a lot of IBM employees came on the courses, and we put them onto little specification exercises, and they worked in a small team to thrash out a specification of what the product should do, and they discussed it and we sort of thought, this is going to be terribly [inaud], and it's sort of – but they – and maybe very slow, and so we asked them, 'Is it – did you find it very laborious and slow you

down a lot?' They said, 'No on the contrary, we got there must faster because we had this common mathematical framework which we could appeal to, and normally we would just be drawing pictures on the whiteboard, none of us understanding what the other person's pictures meant, and it would take us weeks to get where we got to in a three day practical exercise.'

[11:00]

I remember in a former – in an earlier session you described sort of earlier on in your career, you know, hitting on the idea of doing something on formal methods and looking upon it as a very long term allusive goal, how far along that way do you think you actually advanced in your time at Oxford?

I think we laid two very important foundations which are still recognised, although other people have come in to do similar things. One of the Zed specification language which is still … as a specification of the computer system, shall we say, more abstract and more powerful than more practical languages are [laughs] 'cause we designed it and taught it as a language for thinking in rather than for automation. And the CSP process concurrent model for concurrent processing, which was very influential in the design of the Transputer and the architecture of the machine was based on – based on CSP by David May and it was the basis for the Occam language which was the – well perhaps shamefully the only language provided for programming [laughs] the device in.

What –

And those, you know, people still pick up on those things and say they'd read it and they'd been inspired by it and some of them have even adopted the general approach.

[12:55]

A quick couple of clarification questions, what was the Transputer sorry?

The Transputer was a successful British microprocessor. It was set up with

government support in 1980 ish, [background voice] and David May who was an academic at Warwick at the time was recruited as the technical manager and he designed the thing and they also employed very good designers and implementers and factory workers no doubt, to actually make it. And it made quite a stir in the time because it was such an outstanding, it was I think the very first complete processor on a chip, single chip contained floating point, instruction unit and commu – network communication. And this really put it way ahead of the field in that area. The reason they adopted the communicating process architecture was that it was based on the communication rather than shared memory, and they had a vision which to some extent came to pass that you would be able to design your algorithms and write your systems and your programmes using multiple processors but without sharing memory, just communicating along channels, and then you could run the entire programme on a single machine, simulating the communication inside the same machine. Or if you needed it by two machines or four machines or seven machines, and distribute the various components of the system on different machines and get a seven-fold speed up that way. And eventually maybe 1,000 machines [laughs]. That 1,000 machine idea is just becoming to come to fruition now, yes.

Just so I've got the relationship between the two in my head straight as well, what was the relationship between CSP and the Transputer, did CSP lead to the Transputer or was it a sort of ongoing development side by side?

CSP was the inspiration in – I mean the … founder of the company gave the impression anyway that reading my article on CSP told him it could be done and he set up the company to do it. Then in the design of the language and its implementation I had moved to Oxford by that time and was already working with Bill Roscoe to refine the theory behind the language, and which led to a publication of a more theoretically oriented book, textbook by me in 1985 actually, came out. Meanwhile they were using CSP, they'd implemented the algebra of the language in an automatic checking tool and that was being used by – in a joint project between the university and INMOS, the manufacturer of the Transputer, to verify the floating point unit of their next – next development Transputer, and check that there weren't any errors. Which they did successfully and as a result they reduced their testing regime, they say, to save a year in the delivery date of the first components. That was

a very fantastic achievement if it's true but it was a good achievement anyway and the – we put in a joint submission and got a Queen's award for technological achievement, jointly between the university department and INMOS. Some years later INMOS failed to do this check and suffered a famous floating point bug which cost them quite a lot in – in compensation and replacement hardware.

[17:50]

One other quick clarification question again, said – to people who may not know, what's the difference between a specification language and any other programming language?

We said – our view was a specification language was much more like mathematics and it did not have to be implemented, which actually was a very unpopular stance in those days, people felt you could write a specification language and then write a compiler and actually execute the code, and there were very good reasons for believing that that is impossible without severely restricting the expressive power of your specification language. And that I and we refused to do because we wanted to make sure that it was as easy as possible to specify what you were doing, we didn't want to put restrictions that would mean that people would have to use coding tricks in order to say what they meant. It is still I think the correct view of what a specification language should be doing. Of course the more practical engineers can implement subsets of it and implement aids to transforming a specification into its implementation step by step, checking each step as it goes and that's still a very lively topic for research and not yet quite right for application [laughs] in industry.

[19:30]

And what do you find generally that, you know, people on the more sort of engineering side of computing actually make of your approaches?

Engineering, the software engineers, well some people have heard of me and some haven't [laughs] and people who have sometimes at a party – at a reception, some

event or other will come up to me and say, 'I read your article on this and it really changed the way I think,' 'Thank you, that's nice,' [both laugh].

You mentioned last time as well as we were talking about your Turing award, that it was handy when you came to be nominated as an FRS, I was just wondering when that was?

The Turing award was 1980 and the FRS was 1982. So about – that was about as quick as it could be really [laughs].

What does an FRS actually do?

The – the main – most serious duty is to elect other FRSs, at least that was [laughs] Richard Veighman's [ph] comment when he resigned from the National Academy of Science, the corresponding body in the US, on the grounds that maybe it wasn't quite what he wanted to – or was expecting to do [laughs]. And I took that very seriously because at the time – at the time that I was elected there were very few computing FRS and those that there were, shall we say, were not very active in recruiting. That is to say there was Tom Kilburn who didn't recruit anybody and Maurice Wilkes who recruited people but only people from Cambridge. And somehow or other we had to get around that [laughs] so I nominated a number of people and then after a few years they were not being elected so I agitated [ph] a bit with the president and – and now we're in a relatively good shape. Like all subjects of course we struggle to get as many elected as possible [laughs], but it's very difficult to begin with, it's a bit like the college situation at Oxford, if you don't have fellows in the subject then they don't know who they can refer to for references for new fellows. They don't know, I mean they can go abroad but they don't know who abroad and then of course there is a tendency, I'm afraid it's been noted even outside computer science, that computer scientists tend not to say nice things about each other. It's sad but true, and I've done it myself so I know [both laugh].

And for what sort of reasons?

I think we've been competing so long, we did in fact get quite generous allowances of funds from the government, at least in the research grant areas, and – but they also announced a lot of special initiatives in which they told you what buzzwords you had to use. And so you had to meet a deadline, use the buzzwords, perhaps collect a team of – because interdisciplinary or joint university, you know, there was – because they don't really believe it's a subject the politicians put such additional constraints on all the grants that they will give. So they – they want to be sure that what we're doing is not the same old thing but sometimes entirely new which is due to their initiative. So you've got a situation in which the majority of research grants aren't really scientific at all, they're making promises that are pretty way out of relevance [laughs]. I've done it myself, and by deadline so it's a competition, it's a cut throat competition, you're really in it so the other fellows' methods and so on are to be denigrated wherever possible, you've got to claim at least that your own methods are adequate for all purposes and superior in every respect to all your rivals. And that's the same situation is happening with publications in conferences which is our main source of publication these days. Every paper has to say in what way it's better than all its rivals and they don't say nice things about their rivals, absolutely. I always used to tell my students and co authors and so on, 'No no, you've got to say really nice things about your rivals and then let your readers judge whether you have done better, do not make claims,' but nowadays you've got to claim that your research grant has impact before you've even started it, it is the most grotesquely dreadful thing to do to a scientist [both laugh]. So there, don't know whether that counts as my life as not, fortunately I'm out of it, don't have to do it anymore.

[25:30]

Do you think computer science has had a respectability problem?

Yes, I think so. And pecking order, in universities everybody knows the sciences, it's the physics, you know, the top and for many years Latin and Greek were the top and so you don't want to suggest in any way that you're usurping [ph] any existing … I used to try to get joint masters projects with other science departments sort of internship, what we used internships in Microsoft for, get people who know computer science to go and find a problem and perhaps do an interesting coding experiment for

another – another scientist. Again you're a little bit timorous about these students who really only had a formal methods background and sending them out hack code in whatever language the scientist wanted it hacked, but it worked, and the scientists sort of saw what he was doing that was different. And I think shortly afterwards one came across the phenomenon that the science departments would employ a computer scientist to rewrite their working software, to give it some structure so that it could be used as a basis for future doctoral projects that would continue to evolve it. And that was the sort of thing that we felt computer science was about, planning and structure and organisation, in addition architecture, software architecture it was called. In addition to writing the code.

Do you think looking over the course of your whole career, the position of computer science in relation to the other subjects you've mentioned has actually changed?

Oh yes, definitely, it's much more recognised that the scientist, the programmer who is contributing to the overall experimental thrust of the department is an integral member of the team. And that I've even been told off for wondering whether this person was actually contributing any science and scientists saying, 'Well of course,' [laughs] so I've changed my views on that [laughs].

[28:20]

To return to the Royal Society business, on a practical level, other than electing other fellows, what does that actually entail?

There are a number of committees, there are – the organisation and discussion meetings I did quite a lot of, I think I did three altogether which is more than my ration, including the very year after my election. And they're usually about two days meetings and you could invite anybody from around the world and they'd give a talk and there's a little discussion and then they go on the next one. These can be quite specialised or they can be interdisciplinary and I organised, as I say, I think three, with – with co organisers, usually two or three organisers. And I think they were fairly successful but not many fellows came [both laugh].

Are there any other duties connected with being a member?

Well they have to elect prize winners to nominate and elect prize winners, they publish two or three journals in physics and biology, and fellows sometimes contribute to them, I haven't yet done so. There's a journal of the History of Science which they publish which is – I usually find an interesting article in. They are of – I suppose more inclined to be put on committees, government committees, enquiry and reports and so on. But these aren't duties but they are obviously activities. The officials obviously, the president and the foreign secretary and the treasurer obviously have more onerous duties during their period in office, which is about five years, it's quite untrivial [ph]. They invite distinguished lect – they elect lecturers to give distinguished lectures, there are specific named lectures like the Royal – Royal Lecture – no, Croonian Lecture and, oh I've forgotten now, which are quite highly praised – prized, sorry, by the fellows. On the whole computer scientists haven't yet won many of these sort of extra top-up awards.

What does being an FRS actually mean to you, if anything [laughs]?

Well I think it's really a … seemed rather a milestone in the subject – rather than an acceptance of the subject rather than anything very personal. I've given up thinking that I actually deserve any of these things [laughs], it's way too time consuming. But … I – yes I think I have been quite lucky in that the subjects that I more or less started my research on and the style in which I do the research is – has been on an upswing pretty well continuously since I started. And even now [both laugh].

[32:25]

Of course we've talked about quite a few different topics over the course of your academic career but I was interested in when did you decide to leave Oxford?

The post was advertised some time after Christopher Strachey died, he was the senior – senior representative of computer science in the department of two people, himself and one other. And when he died the – the university had to decide whether they would continue his post at the readership level, which is what he had a personal

readership, personal readership would expire when he was no longer there, or would they upgrade it to a professorship which they eventually decided to do. And [laughs] I thought, well [laughs] sort of, yes, this was – this was something that would enable me to do things that I couldn't really do, play a bit more on the United Kingdom scene, establish stronger contacts with industry, and do something for Oxford, I mean start again from scratch. So I felt it was natural for me to apply and everybody was expecting me to apply [laughs] as they all – they quite often congratulated me on getting it [laughs], long before the university had decided. Well the election procedures at that time, and to some extent even now are quite – can be quite drawn out because the electoral committee, you know, contains a lot of busy people from representatives of all sorts of stakeholder interests, who have to meet maybe more than once. And they look at the applications and they take references, and they have an external member and then they decide to appoint somebody completely different. So they offer the post to somebody completely different and he tends to make conditions for accepting it, and I suspect this is what happened to my – anyway it took two years and I was saying to myself as I do in the circumstances, 'I don't know whether I want this anymore,' [both laugh] wasn't the last time I said that. But when – when it came I didn't have much – well I – they invited me for interview, and I asked whether they had any plans for the growth of the department and they said, 'No, that's up to you, and we have no commitment,' 'cause there was talk of having an additional – quite often when a professor comes in they do promise an additional post or an existing post which the professor would be the chairman of the selection committee effectively. At least nominate the subject area and sit on the committee. But they didn't promise that and normally they would promise – it was 70,000 pounds at that time of equipment money and they didn't promise that either, but nevertheless I thought I would take pity on them and join [both laugh]. It was a good time in the children's education to move I think.

[36:30]

How many children do you have?

I have three and they all went to middle school in Oxford, which was not as good as the schools were in Belfast, and certainly not as academic, so they tended to complain

that they weren't given enough work and, you know, they wouldn't set any extra work to their clever students which is unusual I think, not the current philosophy but in those days or at least at this school, school is more about social engineering than actual education. So we took the youngest one out and sent him to the Malvern College School where he fitted in very well. The eldest one went to a secondary – well really what was a secondary modern school, it was a bumped up failed Eleven-plus school and he was one of the very first people to get entry to Oxford from that school. So he did – it suited him, we knew – sort of knew it would. And also the middle one … as I say the schools weren't as good as they were in Belfast [both laugh].

Did you have any particular direction you wanted your children to go in?

No, no, we were very standoffish as I think is the modern fashion [laughs]. We … Tom didn't do very well in – at university, he took engineering and got a 2:2, an essentially a third class degree. Joanna went to Edinburgh and studied philosophy which she didn't like very much and then it wasn't the basis of her career, shall we say, so she hasn't really had a regular career at all but she's had a very very – done wonderful things [laughs]. And … the youngest one died unfortunately while we – shortly after we went to Oxford, he had leukaemia and a two year period of intensive treatment which he didn't come through, so we make do with our grandchildren now, who are wonderful [laughs].

And what's your third child's name?

Sorry?

What was your –

Matthew, yes. That was a long time ago.

How many grandchildren do you have?

Just two, two girls, my son married a girl from a Sikh family who was also a programmer and she's wonderful [laughs] and their two children are sort of – have two cultures. It was a bit dramatic to begin with because the family wouldn't accept the marriage and it really wasn't – there was completely standoff for five years or so so the children only had one grandmother to begin with. But when Kindi's, that's my daughter-in-law's father was dying, she went to see him and met the mother and they made it up. I think with the father's blessing. And since then it's been wonderful, we've – I mean she was at – at their house yesterday for the birthday of the youngest grandchild, and her family are all good aunties and uncles, one of the uncles was there with a cousin, so really nice having a – a sort of family addition in that way.

[41:00]

If you could give me an idea of what's family life like in Oxford, as a professor there?

Well [laughs] I don't know that it's – being at Oxford makes very much difference, I tended to work rather hard and bring things home to do at the weekends [laughs]. The – quite a bit of the social life of the university revolved around college, I was a member of Wolfson College, undergraduate colleges it would be even more intensive that you would get to know these colleagues in other subjects very well, and again one of the nice things about Oxford is the sort of natural interdisciplinary, not forced simply because we're all in the same college and dine together and teach together and teach the same students and operate the same policies and so on. In Wolfson Graduate Colleges it's less intense but nevertheless we had some – we made good friends with the president for example which – and his wife and knew the other dons there. So what else, oh yes well it's very nice being in Oxford because even more than Cambridge, all the famous people in the world come to Oxford to give a lecture, so we heard Kofi Annan and Gorbachev speak in the Sheldonian which was very good, forgotten what they said now [ph] [laughs], it was exciting to hear them. And the music's very good, and the theatre and the opera and of course in Oxford the countryside is very nice, the Chilterns and the hills around. And here the – it is very nice but a little bit monotonous because there aren't any eminent hills [laughs], most of it is fenland.

[43:35]

I think we should take a break in a moment but I've got I guess one or two sort of closing questions about your time in Oxford really and you talked about, you know, this very small department at the start with you and two others and what's it like by the end?

Well I thought we'd sort of come to a natural end of our growth with about ten or twelve permanent lecturers. But my successors have proved me wrong [laughs], the growth curve is continuing upwards and I visited last week and Bill Roscoe, the person who did the original work on CSP and was one of my first doctoral students, has been head of department for his – I think he's in his sixth or seventh year now, he's got a ten year stint and he's diversifying it, he's bringing in really distinguished professors from around the world as professors, this was something I couldn't do, I couldn't really create posts as professors because there was too much undergraduate teaching to do. So that was an innovation I think largely resulting from the change in the structure of the administration of the university. And they have another FRS here, Georg Gottlob, so that's – and Bill Roscoe has been elected a fellow of the Royal Academy of Engineering which was very nice.

Looking again over the course of, you know, your longer career I was thinking in one of our earlier sessions you were talking about, you know, sort of gender balance at Elliott's, you know, lots of female programmers at the time [ph].

Yes.

I was just wondering how do you think the situation actually has compared in academia over your time there?

It's still pretty bad, the ratios are not very good and the same is true of the students. It's like engineering, very few – very few female applicants, although we try our best. I mean I was – I tend not to notice if you see what I mean [laughs]. We have quite a few female colleagues in – at Microsoft but it's still probably only ten per cent.

Why do you think that is?

Hmm … I don't know, I think it's a matter of tradition, it's a matter of culture, what else can one say [both laugh]. There are all sorts of small things that family bearing and less of a – less ambition perhaps, more – more social graces than – than … but these are just, you know, sort of informal impressions I guess [both laugh] of differences. The female managers that I know are – have been very good, I don't think I've ever reported to a female manager but they're clearly up there with the best and when on the ball and I think on the whole they – they tend to regard people as the problem, rather than just the computer, and which is of course exactly what they are [laughs]. The manager spends most of his time consoling his staff, well at least that's my impression, they all suffer from lack of self esteem and so, you know, if you're happy to boost their morale that's a very nice aspect of the job.

When do you eventually decide to retire from Oxford and why?

Well the primary motivation was push, the standard retirement age is – was sixty-five, I had a personal hangover of the – 'cause I was a – when I was appointed it was sixty-seven so I could do two more years, but I realised that actually what I was earning in those two years wasn't contributing to my pension anymore, pension was fixed at sixty-five, and I got a very favourable offer from Microsoft. And I – I spent a term in Microsoft, sabbatical term in the laboratory talking to people and really finding out – really was convinced, and still am, that the ethos of the Microsoft research laboratory is completely different from that which the research councils impose on the universities, that they appointed good people and let them get on with it. And being good included the wish that your work should have some relevance, and a welcoming of the opportunity of Microsoft to maximise that relevance, so if you produce an idea in Microsoft that is incorporated in Microsoft software there are a billion people out there who may be using it tomorrow. Well, you know, within two to five years. Now I don't think I've ever done that but I talk to people who do [both laugh].

[49:40]

How did the offer actually arrive to work at Microsoft?

Roger Needham who was the professor of computing at Cambridge was appointed as managing director to set up the computing research division laboratory in Cambridge, and he wrote me a letter and said, 'Would you like to join us?' He wrote it actually two years before – beforehand and I should have accepted then because my last two years – last – last five years of a professorship at Oxford is actually a bit of a dead duck. There were still plenty of initiatives around the place but if I applied for them they would not progress them on the grounds that they wanted to leave the option open to my successor so it was – I got one refusal that way and I should have taken the hint. Also the Science Research Council refused one of my grants applications, the one that actually supported my ten year research colleague, Chinese man, with the following comment transmitting to me, 'This is an excellent research grant, directed towards the needs of industry, do not award, do not resubmit,' and I should have taken that hint too and essentially they said anything I submitted would no longer be accepted. They wouldn't tell me in what way I had failed they just said there were better ones, and I should have taken that hint and I never applied for another. I did some joint ones that somebody else applied for and in which case I would have joined two years earlier and I would have been rich rich [laughs] because as soon as I joined the shares started going up [both laugh] and most people who were at Microsoft have got rich by – by the share options. I'm rich enough actually, I'm paid a very good –

Shall we take a short break?

Yes, can you switch it off –

[End of Track 14]

Track 15

When did you actually start at Microsoft?

I started in October 1999, that was beginning of the academic year and day after I left, Oxford University.

Can you remember what your first day was like being there?

Let's see, we were working in the centre of town at that time and I did – I had actually worked there previous December, November and October November December on the trial run for the employment. So I expect I went in, sat down at my desk, I've forgotten [laughs] but nothing interesting as far as I know happened on the first day. Except I was – I was welcomed, welcomed for example by Simon Payton Jones, who's still with us, and he invited me to be a co author on one of the papers that he was writing. And because he was interested in nondeterminism which I had a particular message to give, which was consistent with the one that he was taking, so I was able to I think assist on the wording and the general description of the approach and was listed as a co author and I thought, that's wonderful [laughs]. It hasn't happened very often since I'm afraid. I have to – I did once – I am quoted as a joint author of a patent, software patent, as a result of discussions with people in Microsoft at Redmond, so that was another occasion. But on the whole most of my joint – I do a lot of joint authorship now, is with people in academic interns, or colleagues, research colleagues in universities.

How does the environment working at Microsoft compare to working in a university like Oxford?

Well it might be considered to be all [laughs] – all advantages, I have no examining duties, no faculty meetings, no syllabus discussions, and above all I don't have to make any research grant proposals, so [laughs] that's really to be envied.

So what do you do?

I do a lot of thinking, quite often overnight and wake in the middle of the night, and writing drafts which I've always done, trying to make out some convincing story about some aspect of verification. That's – and I go to Redmond, not as frequently as I originally planned, to talk to people who are actually writing the software and the people doing research which is more directly connected with software construction inside Microsoft than outside . So I do get very – I mean discussions with people, questions are very useful and very interesting. But most of my time seems to be fairly, er, self driven. I do my – my deliverables as it were tend to be key note addresses, so I do have deadlines but I usually decide to give a sabe [ph] or a variation of an address that I've given before, so – and it's not always compulsory to actually give a written version at all. So if I have slides already prepared, which I still like, I will give the next temporary, even for a keynote address, and do very well 'cause I've given it before and so I know what the issues are and what people would be interested in, what the jokes are and so on [laughs].

[05:00]

What was the working environment like there?

That we all have separate offices except the interns and some visitors, who tend to be in their – it's quite a spacious open plan environment. I have a – a normal sized office, I was moved out of a larger size corner office to make room for my boss which did not cause any resentment and I'm in a slightly larger room than normal with – but it has no window, no external window, looks out over the foyer. And it's a bit in a corner, but I don't have – I think my office in the new building when they move to the new building close to the station next year, I will – expect it to be even smaller.

What do you think Microsoft get out of you?

Well I don't really know [laughs], it's – they say they like having me. They – every now and again, well just recently at the – at the – at a research lunch, I mean a morale lunch, they gave out prizes to various people, humorously directed at, well, whatever it is, wearing the smartest shoes or whatever and they gave me the award for having the most awards, and that is certainly true. That if you add the awards and prizes it's

– they said more than half of the whole research laboratory were attributed to me [both laugh], well I am older, let's put it that way.

[07:15]

Are there any of those awards and prizes that mean more to you than others?

Not – not particularly, the Kyoto Award was a very lucrative, very generous award and led to a joint trip with my wife to Japan which was very memorable. I met the Emperor and his wife, the Empress of Japan amongst other people and … went on a short tour around in particular to Kogajajima [ph] which was an active volcano, longstanding, erupts on 200 days a year, mostly by emitting a small plume of smoke but it can be more than that. And Kyoto is a lovely place. So that meant a lot. The – well the Turing Award was very influential and [laughs] certainly very welcome, although at that time I think it was – the actual amount of the money just bought me half an Apple computer [laughs].

Is that what you spent it on?

Yeah, yeah, thought I should do some actual programming and I did a little, haven't since [both laugh]. I taught my youngest son to programme and we wrote a little chess playing programme.

In basic or?

Erm, I think it was in Pascal, I think it was Pascal, yes that's right, it wasn't – it was an Apple computer, wasn't a Microsoft computer. So that was very nice. My most recent award has been given by the ACM again, a specialist group in – in – specialist group in programming languages and that was very nice because that's my area of research and so the awarding group were my direct peers and colleagues and rivals and also the list of previous recipients was people that I followed, respect very much, so that's sort of a nice thing. And then I went over there and gave a short address and an interview, in which another colleague from England actually asked questions,

rather similar to what we're doing now and so I was able to tell quite a few stories, and they went down very well with something like 500 people there.

[10:25]

I was interested in the comment you made a second ago which was people I follow and admire and I was wondering, you know, what sort of people do you follow and admire?

John McCarthy, Edsger Dijkstra, Robin Milner. That's enough to be going on with [laughs]. I – actually the – when I was giving an acceptance speech for the Kyoto Award I looked up the list of previous recipients of the award, and actually managed to bring – when – they only give it every four years in information technology, but of the people I had actually read books by Karl Popper, Van Orman Quine, Don Knuth, John McCarthy, Maurice Wilkes [laughs] and I was able to bring them all into the – into the description, which was basically a sort of autobiographical, was supposed to be autobiographical but I was able to – I hope that they appreciated the fact that their previous choices had been very influential scientists. Oh and Noam Chomsky, you know, so practically every one of the previous recipients of this award had had an influence on me. I read an article by Noam Chomsky in the Lenin Library in 1960, didn't understand it [laughs].

What was the Kyoto prize actually for?

Information technology, the particular citation I could look it up but I've forgotten.

[12:40]

… Just wondering if we talk a little more about your time at Microsoft as well.

Yes certainly.

Interested in Microsoft, it's one of those companies that has that reputation for unreliable software and do you have – you're I suppose coming from the completely

opposite point of view which is trying to make software as reliable as possible, what do you think they make of you?

Oh well many of them have heard of me and they know that this is my interest. When I first arrived I thought I would go around visiting the actual developers, the people who produced the programmes and ask them particularly about assertions, do they use assertions and what do they use them for? And that was very nice, I mean the people that – that actually write the software are very intelligent thinking people, it isn't, you know, they don't disregard researchers, but as soon as you talk to them you realise how little direct benefit they would get by applying research. Anyway quite a number of them were using assertions, I actually circulated by email a rather defunct circulation list called Development Managers and asked people to contact me if they had ever used assertion and then I went over there and sort of interviewed them and found out some fascinating uses of assertions. They were mostly used to – as – called test oracles, because the main testing is done at night, and if a programme goes wrong during test, they want to detect where the error occurs as closely as possible, and an assertion is a statement that they can put into their programme that checks for the symptom of an error and you put the statement as close as possible to the place where the error might have occurred, or sprinkle them around as sufficiently frequently that if an error occurs which is identifiable at a particular place, it is actually identified at that place. And then the next morning they'll get a report as to where the error occurred and they look at the assertion which had failed at that time and determined the cause of the error and the number of people who were using that facility and had built it into their standard development cycle, their development methodology, their development tools, that's what everybody did, they had a package of these assertions which they used for different purposes. And some of them were totally totally unexpected. One person had devised a way of using the standard compiler to verify the assertion at compile time which is of course what the objective is, that you actually check the correctness before running the programme at all, he managed by an ingenious coding trick to get the compiler to make that check. It was a very simple property but the compiler was capable of doing it. And another one which was new to me was not an assertion but an assumption, you called it a simplifying assumption, when you're writing a programme you don't want to consider all the ways in which that programme can go wrong, so if during test you trigger one of the ways in which it

can go wrong then you don't want to know about it, don't want even to be reported to you. So the standard example is when you allocate a new location of store, you call a routine which will give you a previously unused location of store and eventually that will run out of storage and you have to put immediately afterwards a test, whether that was a real piece of storage or not. But while you're testing, developing the programming, developing the main path in your programme, you don't want to be pulled up and told, 'No no, that might have triggered an out of memory error,' so you say, assume, assume it doesn't happen. And those assumptions are as important as assertions and I'm now – they're very much considered as duals of each other in my current thinking about verification.

[18:00]

I'm sure I've asked you to define it previously but just double-check we've definitely got it on tape, could you just briefly summarise the importance of an assertion?

An assertion is a condition that is tested, you want to test that a given variable has a value in a given range, perhaps before using it to – as a subscript to an array which might have a smaller range. And so you write an assertion, the variable is in the range and then during test the assertion is actually evaluated as the computer reaches this point in the programme and if the test fails the execution stops and the programmer gets a report of what went wrong. And that's … in – in a production version eventually when the programme is developed and ready to deliver to the customer, these assertions are automatically removed so the customer doesn't have to pay the extra – well the small overhead for testing the assertions. Although I must say that every – a lot of people said, 'Actually we're leaving them in much more than we used to,' because the problem of an undiagnosed error is far more severe than the time taken to – computers are getting faster anyway so they increasingly leave these assertions in to be testing every time the customer uses the programme.

[19:45]

Do you think that working for Microsoft has affected your mindset in other ways, other than assumptions?

I think actually talking to people who have real projects to do inputs a degree of realism to balance the idealism [laughs] which is perfectly appropriate for research scientists at universities. You begin to see actually how little benefit these – that their problems are all elsewhere. And particularly maintaining very large bodies of code that whereas my research was oriented towards programmes that were correct by construction, which were developed in a form that – in fact that isn't the problem at all, the problem is that you have this programme and you just don't know what it does, you don't know how it works, but you've got to make a change to it that will make it work differently and my research was pretty irrelevant for that. On the other hand writing assertions helps in that because when you come across that assertion again, you realise more about what that programme is supposed to do and what that programme must continue to do after you have changed it. And one of the people that I spoke to said an absolutely marvellous thing, he said, 'I think it's hard work thinking of assertions but I think it is time well spent if I can spend a whole day thinking of an assertion that will prevent the next programmer who changes this programme from making a mistake, that it would have taken him a week to detect the error.' Another person said, 'It's hard work making these assertions and when we have a delivery date we can't always do it,' [laughs], and that sort of engineer has got to – a decision an engineer very frequently has to make.

[22:00]

I'm trying to get an idea of what it's actually like working at Microsoft on a day to day basis, could you perhaps talk me through some of the daily activities you do in the context that you're doing them?

Spend an enormous amount of time just servicing my email, keeping up with academic colleagues and other colleagues. I still write references, I don't get a holiday from that [laughs]. So I suppose I get 100, more than 100 emails a day, probably reply to about twenty of them but that takes up quite a bit of time. Then there is the next keynote to prepare, which could involve wrestling with PowerPoint, or the next draft to write, or reading something which interests me, written by one of my colleagues very often. Talking to visitors, looking after an intern which means

trying to decide – interact sufficiently to decide what the chap can do, and … on the whole time passes very [laughs] very pleasantly.

How much freedom do you have to pursue your work as you see fit?

Well I have never had the slightest touch of the whip. Every year I report on what I have done and make a guess of what I'm going to do, which is not very difficult because invitations to keynote addresses come in quite a time in advance, so what I'm going to do next year. And spend twenty minutes talking to my boss, about the only time I get to talk to him actually [laughs] and on the basis of this he decides my bonus and my share allocation, poor fellow, has to do it for everybody [laughs].

Do you enjoy working at Microsoft?

Oh I hope you can see that [laughs].

Why?

Certainly been a very pleasant experience.

So what's the main part of it you enjoy?

Well I think the research is obviously – and the ability to talk to these very clever and very experienced people about what's interesting and what's relevant and what's valuable. That's a great privilege, I'm sure my erstwhile colleagues would agree [both laugh].

I was going to ask you actually, what sort of people do you find yourself working with at Microsoft?

In Microsoft, not as much as I would – I originally thought I would. Most of my research colleagues are actually in universities, so I talk to other professors, and other researchers in universities. And this is because both I and everybody else are setting their own agenda essentially and my agenda is different, my background and culture

of research is different from most of the people in Microsoft, they're mostly recruited shall we say in the Cambridge tradition and the questions that they consider interesting and the techniques which they consider relevant, completely different from what we were doing in Oxford. And one of the reasons I came here was to find out a little bit more about – see if I could really understand Robin Milner's work. And my goal was to not only understand it but like it, and ah, I don't know that I quite achieved that, you know [both laugh].

[26:30]

I'm interested in the idea of there being a Cambridge approach.

Yes, well this is I think … I mean local attributions of research culture can be made more widely, the Cambridge approach is very much inspired by the Edinburgh approach and the Edinburgh had a very good team of people looking after their laboratory for the foundations of computer science. Gordon Plotkin and Robin Milner and Rod Burstall, and both Gordon and Robin were elected fellows of the Royal Society. And so they educated people who'd – came here, and the senior professors here, Mike Gordon, Larry Paulson and others were all educated in the Edinburgh tradition.

How would you see that Cambridge/Edinburgh tradition as being different you're your own?

In rather recondite ways I should say, seemed terribly important at the time [both laugh], but I was interested in correctness, I always somehow managed to choose a diametrically opposed approach to any topic, in programming and languages and modelling, to Robin Milner. I was interested in the sort of normative approach where you are trying to work out a rational way of designing programmes and Robin was explicitly chose to be descriptive. I was interested in verifying programmes as constructing proofs of their correctness, again he was interested in how other programmes actually executed, so I used a particular form of semantics which use the proof method as the method of defining a programming language, and he used what's called an operational semantics which is describing step by step how the programme

is executed. And that really really separated us. I have just – just – I mean in the last few months, discovered [laughs] that the basic primitive judgement of his operational semantics and the basic judgement of my logic was called a Hoare Triple and I call his ones the Milner Triple has exactly the same definition and the only difference is that the arguments of the triple are rotated. And I write PQR, he writes RPQ, and every one of his laws is a law of my logic and vice-versa. Wow! That's a lifetime's ambition, unifying theories, you cannot get theories more unified than that, and I just gave a lecture about this at Oxford.

Who do P, Q and R stand for again?

Well they're just variables, they stand for programmes, the variables of the algebra. They stand for different things actually, in his they stand for programmes except that a P has to be an atomic programme, executed in a single step. In mine Q is the programme and can be large, and the P and the R are restricting to being descriptions of the programme state at the beginning and the end of the procedures. But if we generalise and treat them all as variables over the same space, which I have some justification for doing which I won't go into then the laws are the same. One for one [both laugh].

[31:10]

Do you ever think about retiring?

Yes, but not with – I never planned [laughs] – I have no plans. I'm thinking of maybe reducing the working week, and working at home a little bit more, but we'll see how it goes.

What do you think you'd highlight as being your career highlights as it were?

Well [laughs] I just told you of course. I mean it's been a long time coming, I've – I published my first paper on algebra in 1987, explicitly, and I've written papers on algebra in 2000, oh mid '80s in the year 2000 and I've written a whole book on unifying theories of programming, published in 1998 [ph] and I didn't use algebra

[laughs]. So not only do I repudiate my own Hoare logic, these triples really should have been expressed in terms of algebra, rather than in terms of triples but the whole of the book is not the way I would do it, but I don't think I'll have time to rewrite the book.

Looking over the course of your career as a whole, do you think you've made any mistakes?

Oh yes, I once – in fact last year I gave a talk in Redmond on my mistakes. I gave one at a – at a conference in London a couple of years ago called *My Billion Dollar Mistake* and that was to do with an error, a very common error in programmes and I had worked out a way of checking that it didn't occur at compile time, but it was a little bit too cumbersome, it required too much writing in the programme, made things more difficult. And so I left it out of my proposal for object oriented programming and now whenever people use this facility there is a possibility that the use of this particular object doesn't go anywhere and you get a random result. And that's just the kind of thing that I was trying to avoid in all my ideas and I left it in and it must have cost a billion dollars. The number of times people have made that mistake.

What's the mistake called?

Null reference, null pointo reference [ph], you use something that doesn't point anywhere on the assumption that it does point somewhere and you go and do something at that place and you might be overwriting your programme yourself, in entirely unintended ways. I knew it was a bad idea but I – I now regard it as a mistake and people are beginning to find or beginning to accept the extra writing that is now necessarily in order to ensure that a compiler will check against that error. There's a special class of programming language type which is the non null reference and the compiler is expected to check that it's not null.

[35:00]

To bring this interview I suppose even fuller up to date, and we are pretty much at the present day, are there any issues in science and technology currently that interest you in particular, outside your own particular research interest?

Well I'm interested in the health of science as a whole and protecting it again [laughs] more or less permanent, repetitive series of attacks on the scientific culture, in the – in the interests of either commercial or political or some other fashion or whatever. Which one tends to feel that other subjects haven't been subjected to at the formative stages of their development, I think that's the important thing. Physics seems to be capable of looking after itself, and they're allowed to find out why the sky is blue, but computing, because it really hadn't found its – its foundation and its focus, seemed to be one in which the politicians could impose other objectives which are, you know, a bit, er, well they're always inclined to do this, I mean attacking the universities for not recruiting enough people from the … less privileged families in society, and doesn't seem to be relevant to education, you choose the people who can benefit most from it, you're not there to find a balance, across the – across disciplinary work. Well if it arises naturally yes, but don't pursue it as an objective, at least not until you've established your own subject [laughs] as an identity of its own. So – but on the whole I'm exercising an elderly citizen's privilege of withdrawing from worrying about these things [both laugh], they're – there's nothing I can do about it and it won't be affecting me personally so one does gradually withdraw. But concentrating my interest on what I've just been talking about, I think some real breakthroughs in my own personal research goals, I also have – well I have two further research goals which I've just discussed with my manager. One of them is to write a small book on what I provisionally entitled *Great Ideas in Computing* which is basically about great ideas and how they manifest themselves in computing. And so the book would go back to the description of the great ideas mainly, for example the idea of logic and an attribution of description, a sort of popular science description of what logic is about, going back to Aristotle and then bringing it up to date, idea of what logic is doing for computer science now. Similarly a treatment of Euclid's elements, it's – was – I suddenly realised in looking at them that in fact Euclid was the first designer of programming language and the first person to prove the correctness of programmes. Nearly – a very high proportion of his propositions are actually constructions, where you write a programme to draw some lines in a figure, and it's written using a little

graphical programming language which is still used today and then a proof that the resulting construction satisfies the requirement. And this is a lovely illustration of what a programme proof is about, without actually teaching you a programming language. I've tried this out with works people like it [ph] [laughs]. And then there's the issue of free will and determinism. Programmes in the past have always been deterministic, and now they're essentially nondeterministic, they give different results and they're run different times, even if you give them the same input data which you have to do. How does this reconcile, how does this compare with nondeterminism, and in fact this is a – a topic that has been addressed by Aristotle, St Thomas Aquinas, William of Ockham, and in the present day by the designers of – of modal logic systems for proving correctness of programmes. So a lovely little great idea that started a long time ago and is now in computer science. So when I get time I'll be getting down to writing a short book about this [laughs], and then I would like to talk to other people in Microsoft about putting into practice some of the unifying discoveries that I've made, using them as a – as a basis or rather as an architecture, or to assist in the design of an architecture of tools that will help write new programmes and help to prove programmes correct. I'm not going to implement those tools myself but I know now sufficient number of people who do write tools and they're all putting forward new ideas, and some of them seem to be very good, and quite consistent with what I'm saying and I'd like to talk to them more and get them perhaps to collaborative a bit more on producing the next generation of tools which will be more flexible and more powerful than the ones that have gone before.

I guess that really does bring us up very much not just to the present day but into the future as well.

Yes indeed, these are both topics that I've discussed with my boss as my objectives for the next year [laughs] or two years – well two years let's say is fairly well the limit my planning horizon [both laugh].

[42:25]

I guess my last questions really are about this interview and how you've felt about taking part in our project.

In your project, oh right, well it's been great fun, it's certainly been even more pleasant than I was expecting it to be [laughs]. And I suppose your overall objective is to bring science into the culture of the country and talk to us on the same sort of basis as you've talked to artists and politicians.

Not personally [ph] –

Not politicians, no [both laugh].

I think there are one or two there, yeah.

Sculptors, dramatists, novelists, and I hope we can … justify your confidence in our humanity shall we say [both laugh].

Thank you very much, is there anything you'd like to add before I hit stop for the final time [both laugh].

No, I think I've thanked you enough directly [laughs].

Thank you [laughs].

[End of Track 15]

