Oral History of Malcolm Douglas (Doug) McIlroy

Part 1 of 2

Interviewed by:
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Brock: Doug, thanks again for sitting for this interview with me. I really appreciate it. And I was wondering if you could tell me a little bit about your family of origin, and when and where you were born, and what your kind of earliest life context was like.

McIlroy: Well, I was born in Fishkill, New York. It was quite a surprise later on to discover that this little village-- I wasn't born there. That's-- but that's my first home. I was born in Newburgh. But Fishkill I lived in from the age of about one to five. And it was quite a surprise to find later in life, and actually to visit, the giant IBM factory there making 360 [IBM System/360] parts.

Brock: And, so, that was-- did IBM have a presence yet in the area?

McIlroy: Poughkeepsie.

Brock: Yeah.

McIlroy: But certainly not Fishkill.

Brock: Right. And what were your parents doing there?

McIlroy: And-- my father was an engineer and, finally, district director of Central Hudson Gas and Electric Company. He was by training an engineer at Cornell. And, at 1937, he moved to MIT to-- and that would be 14 years out of college--

Brock: Wow, okay.

McIlroy: --to pursue a doctor's degree and wanted to go into teaching. So, then I lived in suburban Boston at several locations for 10 years. And it took that 10 years for my father to get his degree, because it was interrupted by the war, during which he was associate director of the MIT Radar School.

Brock: Oh. Interesting. And that was actually-- as distinct from-- what did they call it? The Radiation Laboratory?

McIlroy: The Radiation Lab--

Brock: Yeah.

McIlroy: --was on the campus.

Brock: Right.

McIlroy: The Radar School was on Atlantic Avenue--

Brock: Okay.

McIlroy: --right down by the Harbor in Boston, roughly, I guess, where the Harbor Hotel is now.

Brock: And that was to actually train people in the use of this developing equipment.

McIlroy: Yes.

Brock: Interesting. And then, did he-- just to continue kind of on his story-- did he stay at MIT after the war?

McIlroy: No, he then went to Cornell, where he spent the rest of his life. He was in the EE department. He got appointed assistant dean of engineering, never served, for health reasons--

Brock: Oh. Oh, dear.

McIlroy: --and died quite young.

Brock: And he had been in electrical engineering at Cornell as an undergraduate--

McIlroy: Yes. Yes.

Brock: --which has a very strong tradition of electrical engineering. Okay.

McIlroy: So, I was brought up in the engineering environment and saw World War II, had no idea what my father was working on. In fact, I remember once taking a walk with him and we came up to the top of a hill and here was this huge bedspring apparatus on top of the hill. My father looked at it and, "I think we'd better turn around."

McIlroy: And it wasn't till very near the end of the war when the secret of radar was publicly announced. I knew where he worked and this meant that we have a few artifacts from-- at that time, Atlantic Avenue was ship chandleries--

Brock: Right.

McIlroy: --a trade that's vanished from the face of the Earth now. And I still own a nice block and tackle that he bought at the time.

McIlroy: And a bilge pump for our boats and our Adirondack camp, which incidentally my father designed for his father the year-- in 1924, the year after my father graduated. Another influence from my father is my love for maps.

Brock: Oh, really. Can you say more about that?

McIlroy: He mostly collected maps. My particular interest is mutated towards map projections--

Brock: Yes.

McIlroy: --which has resulted in a series of 32 Christmas cards--

Brock: I heard about your Christmas cards! I forget who was telling me about your Christmas cards.

McIlroy: Maybe Brian [Brian Kernighan]

Brock: Yeah, it could be!

Brock: It was-- someone was telling me about them. Yeah.

McIlroy: Some people looked forward to them. I don't know wh-- other people probably thought I was stuck in a rut.

Brock: And was-- so, was-- in terms of your household, was your father's engagement with engineering, was that a big part of the household? Was kind of-- was there electrical work going on in the home or--?

McIlroy: The answer to that is there wasn't too much electrical work going on in the home. Our summer camp got a generator when I was very young. I cannot remember when we didn't have one. And, so, we were the first people in the neighborhood with electricity in our summer camp. And, of course, he was-- he designed things. And I remember when I was stuck in bed with chickenpox at the age of five and, apparently, my parents told me I was kind of obstreperous about being confined--

McIlroy: --but I remember the assignment my father gave to keep me in bed one day, which was to hand me a USGS map, sketched on it a dam. And my assignment for the day was to show what regions would be inundated by this dam.

McIlroy: And, again, later on, when we built a new house on Mystic Lake, he took me out-- and I would've been eight then-- to help in the plane tables survey for siting his house at the top of a steep bank. So, that kind of engineering thing would go on.

Brock: Right. Was he-- was there a lot of building at home? Did he have a shop? Was that part of--

McIlroy: He had a minor woodshop. I have a bigger woodshop behind the garage. And I still have some tools from him, but-- and, generally, not afraid of dabbling around the house, and have done a bit of architectural design myself since.

Brock: Okay.

McIlroy: But minor things, like, this porch, which I did with CAD.

Brock: Mm-hm.

McIlroy: Or an addition to our summer camp-- a couple of additions to our summer camp. And he gave me a really-- he gave me at maybe the age of 12 a drafting table.

Brock: Okay!

McIlroy: Which I have passed on to my granddaughter.

Brock: So, he was very encouraging in that line.

McIlroy: Yes, he was.

Brock: Yes. And was your-- did you have siblings or were you--

McIlroy: I have a sister who lives now in Boulder. And my mother was actually-- had a master's degree in physics.

Brock: Which would be very unusual for the time.

McIlroy: Very unusual.

Brock: Because you--

McIlroy: And she-- you know, she was at the University of Rochester and some of the classes she was forced to audit, because, "Oh, no, women can't take this class! But you can sit in on it, if you want." And that kind of thing persisted. My wife, I actually met at Bell Labs. She started at Duke, in nursing school. And after a year decided she didn't like jabbing athletes in the rump with a syringe--

McIlroy: --and changed to math major. And she got all kinds of discouragement.

Brock: Mm. And she--

McIlroy: Similarly with Lorinda Cherry--

Brock: Who I wanted to ask you about.

McIlroy: Yeah. In our department. She, too, switched into math in college and ran into all kinds of discouragement.

Brock: Mm.

McIlroy: And, of course, when she joined the Labs, at that time if you had an engineering degree you were a "Member of Technical Staff." If you had a bachelors in mathematics, then they were typically-- the engineers were typically men. The math majors were typically women.

Brock: Mm-hm.

McIlroy: You were an "Associate Member of Technical Staff" at most--

Brock: Right.

McIlroy: --or a "Technical Assistant." And it wasn't until about, oh, I'd say 1968 that finally the Labs realized that they were mistreating these women. And Lorinda suffered some of that, too.

Brock: Did your experience-- well, your experience of your mother's experience--

McIlroy: Yeah.

Brock: --did that kind of sensitize you to that issue?

McIlroy: I think it did.

Brock: And, certainly, with your--

McIlroy: And also when I--

Brock: --wife.

McIlroy: When I joined the Labs, Bernie Holbrook-- I don't know whether you've heard his name.

Brock: I have heard the name.

McIlroy: He was a department head-- I think he was a department head, anyway, in charge of the computer. And he took it upon himself-- and this was underway when I got there-- to dismiss the myth that women-- the Labs had already realized they were mistreating women, but they came up with a new reason: Women have a short life expectancy at the Labs, because they get married and disappear.

Brock: Mm-hm.

McIlroy: And Holbrook tore into that and gathered statistics and he found the life expectancy of women was no different than men, because men had another thing they would do: When you came to the Labs they would give you essentially a master's degree and, eventually, actually a master's degree, at their expense.

Brock: Mm.

McIlroy: And a lot of people played them for this.

Brock: Oh, came and left after getting it.

McIlroy: Yeah, after three years they were gone.

McIlroy: So, Holbrook dispelled that myth, but it still took a while before finally women were hired as Members of staff.

Brock: And had your mother-- just to go back to her, had she done her master's degree at Rochester?

McIlroy: Yes. But she never practiced until my father died. His PhD was to invent the critical component of an analog computer for analyzing pipeline networks.

Brock: Huh. And it was--

McIlroy: The critical component was that a-- there's the usual analogy: head of water pressure is analogous to voltage and current is current.

Brock: Right!

McIlroy: But a pipe is not a linear resistor. It's a non-linear resistor.

Brock: Right.

McIlroy: Theoretically, current goes-- is the square of the voltage; but, in practice, because of roughness and all kinds of other things, this isn't quite right. And, typically, they use the 1.85 power from the Hazen-Williams Law. And he devised a decent non-linear resistor. Actually, I have a bunch of them upstairs-- actually, it's a very carefully crafted tungsten filament plus its leads and exactly the way heat dissipates it, it gives it--

Brock: That factor.

McIlroy: This non-- makes it a very good approximation. So, he-- as soon as he finished his degree, he went on to Cornell. He had one of the-- he had a small one of these analyzers in his lab and ran a small consulting business. Most of them were big machines that went out to major gas distribution companies and water distribution.

Brock: Right.

McIlroy: But his small-- she took over his small consulting business when he died.

Brock: Oh, sure.

McIlroy: And she stepped right in.

Brock: And she had-- because she had the machine for doing these analyses. Interesting.

McIlroy: She had also been to Cornell in the summer of 1927, taking ornithology--

Brock: Oh.

McIlroy: --which became a family avocation. And my father joined in. So, I was brought up as a bird watcher and kept it more or less until my hearing began to decay.

Brock: Oh.

McIlroy: My mother's hearing decayed, but in a very strange way. Usually, what you lose is the high pitches. She lost the low ones. So, she couldn't hear people, but she could hear birds.

Brock: Hear birds.

McIlroy: And she-- when we go to Cornell, she dove in as an amateur member of the Cornell Lab of Ornithology and eventually ended up being-- the Cornell Lab of Ornithology is probably the leading ornithology department in the country.

Brock: Yeah, I mean--

McIlroy: And they were-- both studied birds in the lab and in the field. And they produce a magazine. One time she was put on the cover as Ithaca's first lady of birding!

Brock: Oh, right!

McIlroy: And we now have a sanctuary not too far from Cornell with her name on it, which is nice.

Brock: That's wonderful. And, so, at what age did you make that move to-- or did your parents make that-- how old were you when your parents went to Cornell after MIT?

McIlroy: That would've been 10th grade, age-- I would have been-- I became 15 shortly after.

Brock: And, so, that was-- yeah, right in the middle of-- well, in terms of other-- in terms of your household I often ask people what were kind of the main themes of their household. Birding certainly seems one, but--

McIlroy: And, more generally, outdoors.

Brock: Okay.

McIlroy: Mother was interested in both birds and plants. My sister took a master's in botany and has practiced out in Boulder, again, mostly as an amateur, but sometimes as an employee of the Boulder Open Space, checking up on distribution of plants, the survival of rare species and all that sort of thing.

Brock: Right. Was--

McIlroy: And Barbara, my wife--

Brock: Yes.

McIlroy: --mostly, I think, as a result of meeting my mother, has gotten much into plants--

McIlroy: --and now has organized the town for invasive species control. And that has led to also organizing deer control.

Brock: Oh, my gosh, yeah.

Brock: Yeah, the ultimate invasive species, I guess!

McIlroy: Yeah.

Brock: Were there--

McIlroy: And I-- in town, while she's doing that, I've been a chairman of the trails committee for about 15 years. I'm still on it, but I've passed on the chairmanship.

Brock: So, with the outdoors, with birding, I would imagine that hiking was a big part of life.

McIlroy: Oh, yes. Mm-hm.

Brock: Yeah, yeah. And then spending the summers at your family camp in the Adirondacks. I mean, it sounds like you had--

McIlroy: It was a good--

Brock: --mainly outdoors summers. Yeah, yeah. That sounds-- was-- well, with both your father's pursuit of his education and your mother, was education and reading and learning that sort of a big theme--

McIlroy: Oh, very, very central part.

Brock: Yeah. Yeah. Was there anything in particular that the family or you were reading when you were a youth that stands out for you?

McIlroy: Let's see-- there are a couple of books. One was one that my father had as a kid, and I forget its title, but it was a big, fat book mostly about mechanical things and how to build tunnels and so on and so on.[1] And another one was a book-- and that was-- Pessels[2] was the name of one of the authors, but it was a nature book and also a thick book that covered, birds and bees and earthquakes and gosh knows.

[1] *The Book of Wonders*.
[2] Eleanor King and Wellmer Pessles, *Working with Nature*, 1939.

McIlroy: It's interesting that children's books-- there are almost no fat books for children anymore.

Brock: Huh.

McIlroy: There are all these-- they take one story, instead of giving you-- another one of my favorite books, and my grandchildren like it, too, was Carl Sandburg's "Rootabaga Stories."

Brock: Mm! I don't know it. I should look at it.

McIlroy: And it's a whole bunch of stories about characters who went off on a train trip to nowhere--

Brock: Mm!

McIlroy: --with a yellow leather ticket with a blue spanch across it. And now we go see all these nowhere places: the Village of Flongboo -- I'm sorry, Le Flongboo lived in the village. And Flambeau lost his tail in a wind. And then we had the manager of the winds who lived in Medicine Hat, which is a real place. Anyway, that's another thick book, a collection of his stories. So, I read a lot of thick books.

Brock: Okay!

Brock: And, so, you were--

McIlroy: And I read a lot of-- and I enjoyed atlases.

Brock: Oh, yeah, because they were-- and your father had many in the home.

McIlroy: Yeah. And I-- he had some.

Brock: Yeah.

McIlroy: I ended up collecting them more seriously than he did.

Brock: Mm-hm. And, so, was it more-- was the move to Cambridge-- did that coincide with you starting to go to school? Or to the Cambridge area?

McIlroy: Well, I moved in--

Brock: When you were five, did you say?

McIlroy: --moved to Cambridge-- yes.

Brock: Yeah.

McIlroy: I started kindergarten in Watertown, Mass. Yes.

Brock: Okay. And you went through the--

McIlroy: So, I went up to 10th grade in various school systems there.

Brock: Okay. And what was your school experience like? Was it easy for you?

McIlroy: Yes, yes.

Brock: Yeah, yeah.

McIlroy: I always had fun in school, particularly with mathematical things. Not always to my teachers' pleasure. I do recall in third grade I was put in charge of making a map of-- a little committee to make a map of South America for display in the room. And I started this map by going to a book and carefully measuring out the coordinates of latitude and longitude intersections, rather than just--

Brock: Right: drawing it.

McIlroy: --kind of sketching the outline.

Brock: Yeah.

McIlroy: And our group was the last to finish.

McIlroy: And the teacher said, "I didn't want you to do that!"

McIlroy: Or another time in-- I think it was fifth grade, maybe sixth, where there was a question on the-- there was an assignment that said, "The height of Mount Whitney is 12,000-and-some-hundred feet. And the depth of Death Valley is 250 feet. What's the difference in their altitudes?" And I added them up and my teacher said I was wrong, because difference is subtraction.

Brock: Oh!

McIlroy: So, I went up to the front of the class and I said, "Look, here it is. Here's Death Valley and here's Mount Whitney and here's sea level." And she agreed that I'd done it right, but--

Brock: And was that something-- to give you the confidence to do that, was it just something that in mathematics that you felt particularly--

McIlroy: Yeah.

Brock: --comfortable in that.

McIlroy: I did.

Brock: And I suppose that it is inherent to the subject, that you can be definitive about something.

McIlroy: Yes.

Brock: Or, at least in certain areas you can be definitive about something. So, was it that-- it's interesting: In talking to people who have worked in mathematics, or have a great facility of mathematics, it seems that there's almost like two camps. One is a kind of very, almost geometrical kind of, visual sort of--

McIlroy: Mm-hm.

Brock: --alignment and the other is kind of algebraic--

McIlroy: Yes.

Brock: --symbolic sort of camp.

McIlroy: Yes.

Brock: You have probably known a lot more people with a great aptitude for mathematics than I, but, if that at all gets at something, which camp did you find yourself in?

McIlroy: I would have been the geometric.

Brock: Okay.

McIlroy: I had incredible admiration for Linda Kaufman, who was in computer science, to whom everything-- at Bell Labs-- and she could see the algebra in everything.

Brock: Hm.

McIlroy: And I had to struggle to keep up with her.

Brock: And did that kind of orientation for you, did that-- were you also interested in puzzles of different kinds? Was that-- I mean--

McIlroy: To some extent, yeah. Mm-hm.

Brock: Sometimes I've heard that. Okay. How would you--

McIlroy: And enumerations.

Brock: Hm.

McIlroy: So, one of the-- once Dick Hamming [Richard Hamming] who's name you certainly know--

Brock: Yes, yes.

McIlroy: --brought up at [sic] lunch table, he said, "Could you construct crossword puzzles with a computer?" And I said, "Well, I think you can, but m--" and that led me to try one simple kind: word squares.

Brock: Okay.

McIlroy: And I wrote a program that generated word squares. And we had-- between Lee McMahon and me, we had collected various dictionaries on tape and that kind of thing.

Brock: Right.

McIlroy: So, my first foray was to get all the seven-letter word squares that you could make out of Webster's Collegiate Dictionary. There were about 50 of them. And this was actually something of a tour de force, because it took two and a half months on a PDP-11 just in the background. Now-- and also every time the computer came down, I had to restart it. So, it would go for several hours sometimes without—but, anyway, that's how long it took.

Brock: Wow.

McIlroy: The same program now takes a few minutes.

Brock: Yeah.

McIlroy: And the other thing on the PDP-11 was if there are something like 47,000 seven-letter words in the dictionary--

Brock: Right, right.

McIlroy: --how do you fit them in the tiny memory of PDP-11?

Brock: I have not a clue.

McIlroy: So, made an interesting trie data structure that managed to *just* squeeze them in. Partly trie and partly strings. Not too long after I'd done that, the British Computer Journal carried an article about constructing word squares and that article provided as a benchmark a small vocabulary of 250 words to make four-letter word squares. And he thought this was about all he could do on his computer.

Brock: <laughs>

McIlroy: And I had done way, way, way beyond that, you know.

Brock: And you published that, I think I've seen that--

McIlroy: In 'Word Ways.'

Brock: Yeah.

McIlroy: Not in any--

Brock: Yeah. Well, we'll get to this later, but it does seem that not just this word play or word puzzles, but there seems to be-- well, within the story of Unix at Bell Labs, but I imagine before that, this real interest in using the computer for composing texts, texts that are programs, texts that are English, everyday language and also formatted documents. That seemed to be a real-- just such a strong element. I know it was a strong element--

McIlroy: In which many people participated, yes.

Brock: Many people. But it seemed that it was so prominent I have an inkling that maybe this is something that was prominent somehow in interactive, timesharing computing more broadly but certainly in the Bell Labs' context, it was very prominent. So, I wondered if that connects at all to your personal interest in this kind of word play, word puzzles, language--

McIlroy: Yes, well, I-- particularly, I would say Lee McMahon and I brought this into Unix.

Brock: Okay.

McIlroy: Now, Bob Morris and Ken Thompson and Dennis Ritchie all also did things like, at least, making formatting programs. And Ken did things like code-breaking, as did Bob Morris.

Brock: Right.

McIlroy: Where was I going?

Brock: Does--

McIlroy: But the interplay of language with merely string processing certainly had always intrigued me and I ended up doing that Speak program, for example.

Brock: Right.

McIlroy: There had been text-to-speech work done in the acoustics department. They had their-- they were set on something else. They were set on-- their goal was to make synthetic speech that was instantly understandable by anybody.

Brock: Mm-hm.

McIlroy: When the Votrax came out of the Federal Screw Works, of all places, Joe Ossanna grabbed one! And Lee McMahon took over the job of feeding it-- making up phoneme streams for him. You may have seen this story, but a couple days after the device was installed, and people had laboriously written down the phonemes to send to the device which also had a telephone interface, came with it-- Lee was in his office and doing it. And he sent-- and he entered the phonemes without ever having heard them. It said, "It sounds better over the telephone." And we were listening-- and we had the loud speakers in the labs saying everything that anybody put on the device.

Brock: Okay.

McIlroy: And we all heard it. And we all immediately thought of, "Come here, Mr. Watson. I need you!"

Brock: Right!

McIlroy: Because we all understood it.

Brock: Wow.

McIlroy: But the goal of synthetic speech, there are t-- one is to make it intelligible to anybody at the drop of a hat. Another one is just to create it and create it very systematically. And if you have to learn to understand it, it's just like getting to know a foreign-- a non-native speaker: The first time you talk to him, you may have difficulty, but after a while you understand him without any difficulty.

Brock: You get used to its voice. Yeah.

McIlroy: Yeah. And that's what happened with the voice synthesizer in our lab. But it was still laborious to create these phoneme sequences. So, one night, about a week after the device came in, it occurred to me, most of English is phonetic; why don't we at least take care of that part?

McIlroy: And I wrote a program that-- and I learned a lot of phonetics along the way. It was interesting. You know, one knows it, but you know you've never been--

Brock: Yeah.

McIlroy: You've never been-- actually consciously written down what the rules are.

Brock: Right.

McIlroy: So, that was really fun doing that.

Brock: And, so, that--

McIlroy: And that immediately took over the device. Nobody ever wrote a hand-tailored phoneme stream after that. And the device was put on to all kinds of uses, like announcing whose phone calls are coming in or what the day's ephemeris was. That was another interest of the Unix lab. Joe Ossanna, Ken Thompson, Bob Morris were probably the central ones there.

Brock: And it was to announce the-- which of the day?

McIlroy: The daily ephemeris.

Brock: I'm-- I will confess that I don't know what an ephemeris is. I'm sorry to be so ignorant!

McIlroy: Well, a very important book—the book is the nautical ephemera-- the American Ephemeris and Nautical Almanac, which has been published in the U.S. since around 1800. The Naval Observatory publishes it now.

Brock: Right.

McIlroy: "Ephemeris" means a table of where the stars are.

Brock: Okay, okay!

McIlroy: Or a table of celestial events.

Brock: Right, right. Which would be, of course, critical for navigation of the day.

McIlroy: <laughs> Yes.

Brock: Okay, okay. Thank you.

McIlroy: So, the ephemeris of the day, which Bob Morris made this program that-- well, let's go back one step further: Joe Ossanna, before he joined computer science, had been in an engineering department involved with the Telstar satellite.

Brock: Okay, okay.

McIlroy: And he wrote the program that pointed the ground station-- the antenna at it. So, he knew about the celestial mechanics that let you predict where satellites are going to be. And he brought that program to Unix. And then Bob Morris wrote a more general one that did all the planets and all the stars. And then Ken Thompson took that one for the planets and, using that, you can determine when sunrise and sunset are and when the eclipses are coming and all that sort of stuff. And that was what the daily announcement was: "Transit of Mercury at 11:43." You know.

Brock: Important to know every-- well, were people also doing astronomy? You know, doing observations to go along with this knowledge?

McIlroy: Well, then came Rob Pike who was an amateur astronomer of-- and had a pile of telescopes, made some, and in high school published a paper on-- with a simulated picture of the Earth at night. One of these light pollution things, which we've all seen now.

Brock: Right.

McIlroy: But he was predicting from past pollution what it was going to be like in the future and astronomers are really concerned about this.

Brock: Yeah.

McIlroy: One of the events where they brought together all these things from the department, you've all-- you certainly know about the department air force--

Brock: Well, I know that many people took to flying.

McIlroy: Yeah.

Brock: Is that right?

McIlroy: Yeah.

Brock: Yeah, yeah.

McIlroy: So, one day, I discovered that there was going to be an annual eclipse at our summer camp in May. The astronomer Rob Pike brought his telescopes and the department air force carried people up there, and we had a wonderful party on the local inn's lawn to look-- to observe this eclipse. And the innkeeper came out and the post mistress abandoned her post, came over-- it was a great day!

Brock: Is that something that you participated in, this aviation recreation that many people did?

McIlroy: I went occasionally on the adventures. When I first went to Bell Labs, I roomed with a couple of people who liked to fly. And they roped me in on a joint ownership of an airplane. And I learned to fly it, but I never advanced beyond the learner's permit, never got my pilot's license. So, I did that for about three years. And I gave it up, because I realized I so often found a little pile of junk off the end of little runways where I'd land, which were memorials to people who didn't fly very well. And I wasn't doing it often enough to-- but people like Ken Thompson, Sape Mullender, Fred Grampp, and Dave Presotto all had their-- all had real flying licenses and kept them up.

Brock: Well, let me take you back to-- I wanted to hear more about your-- kind of your educational experience and high school experience and how that just shaped your thinking about what you might do, and how your interests progressed. I guess you had to make a change in the middle of high school in the shift from Massachusetts to Ithaca.

How would you describe as you were kind of coming towards the ends of high school, what you were thinking about, what you wanted to do, and what you were interested in?

McIlroy: Yeah. The switch to Ithaca fortuitously went very, very smoothly. It happened in March. And in ninth grade part of the history course in Winchester, where I'd been, was ancient history. So, I had had this ancient history course. And one of the units in the ancient history course was mythology. And I landed in Ithaca in an English class on the day they were having the unit examination on a mythology unit. And the teacher said, "You don't have to take this." And I said, "I'll take it." And I got the highest grade in the class. And, so, that-- at least from the faculty standpoint, I was established in the school right away.

Brock: Yeah!

McIlroy: Didn't have to earn my way in. I took all the advanced math classes that I could. In those days, there was a separate trigonometry class that lots of people took, solid geometry class. One thing they didn't-- oh, and advanced algebra. They never hit calculus in high school the way they were then. Nowadays they do calculus and they don't do solid geometry, and they don't have separate trade courses either, I don't think.

Brock: No.

McIlroy: I knew I wanted to go into-- and I took the science classes except for biology, and my mother went to bat for me so I could take six courses one term when I wanted to do French and German. No, no, French and Latin. When it came time to apply for colleges, I looked at a whole lot of catalogs, and I was-- exactly how I decided that I would probably go into physics I don't know. But the catalog from Cornell had this new curriculum called engineering physics. I think I was in the third class in that, to enter that, and engineering at that time at Cornell was five years. They thought they were setting a-- they thought they were the vanguard of a movement.

Brock: Yeah.

McIlroy: But as they lost students who could get MIT degrees in four years, Cornell had to cut back. But the engineering physics curriculum had all the good physics and math courses, and it had time for liberal arts, and this just looked so good that I—of course, I was going to get free tuition if I went there, but the real, the real determining, was I wanted to apply to that. It happened that we had a backdoor neighbor whom I didn't know very well except from playing croquet with him, who was one of the founders of the EP [engineering physics] curriculum. So I went to talk to him and he warned me, he said, "You know, this is really hard. This is really hard thing to get into." But it just looked so good that I applied to it. I can't remember where else or if else I applied, but I did get in, and that was just a terrific thing to be involved with. There were only 27 freshmen. We all knew each other. The faculty in physics, you know, there were these big lecture classes with recitation sections, and they would pick the engineering physics-- the faculty would do one, and that would be the engineering physicists, so we got, we really got, a good connection to the department, and from that you could go any direction-- at the time, one of the motivations was the advent of nuclear power. But only one member of the class went into that. He ended up being the Assistant Secretary of Energy. Others went in all directions. Couple went to math. I was one of those. They went to physics. They went to chemistry.

Brock: Mm-hm. A really solid foundation.

McIlroy: Yeah.

Brock: By the time you got to Cornell as an undergraduate, I guess your father had already designed this component for an analog computing system.

McIlroy: Mm-hm.

Brock: Were computers in your-- had you had any experiences of them by the--

McIlroy: The answer's you couldn't have. <laughs> But there were-- about 1946 is when electronic computers started to appear, and in 1948 or '49, there was this book by, oh, who's the professor in North Carolina? Called "Giant Brains, or Machines That Think."

Brock: Oh, right. Right. Right.

McIlroy: Oh, my goodness.

Brock: Is it-- that's not Berkeley, is it?

McIlroy: Ed Berkeley? It may be.

Brock: Yeah. I'm not-- yeah.

McIlroy: Okay. And I got hold of that--

Brock: Oh, you did?

McIlroy: --and was fascinated.

Brock: Okay.

McIlroy: When I got the-- and I thought that was going to be neat thing to do, but there weren't-- very few places had computers, and there weren't any at Cornell, but I was looking forward to possibly being in that business, I took numerical analysis, which was all computers were good for in those days, but... Numerical analysis and accounting.

Brock: Yeah, right.

McIlroy: And Bob Walker, who taught that course, made sure that the computer-- that the CPC, IBM CPC, which I-- just arrived at Cornell, would get used by us. So I got to use the first machine, even though it was not really a computer. It was...

Brock: Right. A kind of a programmable calculator? Yeah.

McIlroy: Yes, with a-- with instructions coming in on punch cards. If you wanted to go through a loop, you stood in front of the hopper.

Brock: <laughs> Right.

McIlroy: Picked the cards that came out and put them on top of the stack.

Brock: Yeah.

McIlroy: It had a conditional transfer. The cards had a left side and a right side, and you could either take the left stream or the right stream. That's the limit of the go-to.

Brock: Right, and--

McIlroy: But... So when it came time to go to grad school, I went to MIT because they had the biggest computer that was available. <laughs>

Brock: Okay. That's what I was wondering, and so that experience doing numerical analysis on the CPC, I mean, it obviously didn't put you off of computing. You know, what was--

McIlroy: No, no, it fascinated me, and--

Brock: Okay.

McIlroy: --for my senior thesis, what I did was try to do my father's job digitally.

Brock: Oh, wow.

Brock: Did you have any success?

McIlroy: The answer is "No."

Brock: <laughs>

McIlroy: Yes, I got something running. Clearly the computers-- a computer of that power was nowhere near up to the ability of the analog, and it wasn't until the mid '70s that people started buying the digital one rather than the-- so there were a bunch of-- it was a nice income stream for my mother.

Brock: Good. <laughs> Yeah.

McIlroy: The royalties, and it lasted a while.

Brock: And did--

McIlroy: And the analog computer did have one wonderful visual advantage. Because tungsten filaments were the elements. The bright shining ones are the ones where there're real trouble.

Brock: Oh, interesting.

McIlroy: Those are the ones with high head loss.

McIlroy: And lot of current. The ones that are being stressed.

Brock: Right. Oh.

McIlroy: So when you start you know exactly where to look for the troubles.

Brock: That's fascinating. Huh. Yeah. I guess that is the great advantage of computing by analogy, is it's there, you know.

McIlroy: Yeah, mm-hm. <laughs> Yeah.

Brock: Well, did, I mean, computing has become so predominant that at place-- now all the undergrad computer science is the biggest undergraduate major at all of these schools.

McIlroy: Yes.

Brock: And, I was wondering if you could just talk about the difference between your experience as an undergraduate with the CPC and today, because I think it might be hard for people, people just going to bring their intuition of the present to it. It must've been a real fringe activity in a way or a very, at the very cutting edge of activity.

McIlroy: Yeah.

Brock: How did it--

McIlroy: Well--

Brock: How did it seem?

McIlroy: First thing is, there was great fraternity.

Brock: <laughs>

McIlroy: Everybody in the world who did computing knew each other. <laughs>

Brock: Right. Right. Yeah.

McIlroy: It was-- and another is there was very few people had an intuition of where it was going to go. You've certainly heard the stories about the predictions of how many 704s the IBM might sell.

Brock: Right. Just a handful or something.

McIlroy: The big estimates were 50 would saturate the world's needs, and they sold 3,000. About the only thing you needed computers for was numerical-- besides accounting, and that, in the technical world, we didn't pay much attention to that-- was numerical analysis, and I got disillusioned by numerical analysis when I didn't-- I can't say I read-- looked at the paper by von Neumann and Goldstine about matrix inversion. They calculated how many-- they said that you probably needed to do 40-digit calculations to be, to do, invert, 10-by-10 matrices. Everybody was inverting 10-by-10 matrices at that time, and they're doing it far less than 40. If the-- a brilliant guy like John von Neumann can't do a better job of estimating the--

McIlroy: Of analyzing these algorithms, what hope was there for somebody like me? <laughs>

Brock: You mean, so you're...

Brock: So--

McIlroy: It was much-- numerical analysis was much too hard, and it wasn't until late '70s[3] when Wilkinson [J. H. Wilkinson] in England invented backward error analysis, rather than the forward error analysis that von Neumann was doing, that people began to under-- actually treat numerical analysis as an analytic subject.

Brock: Interesting. Huh. It was that radical of a development.

McIlroy: Oh, stunning, and of course, he got the Turing Award. I had the great fun of being on the awards committee that year, and that-- we gave one to, we gave that one to Wilkinson. We gave one to McCarthy [John McCarthy].

Brock: Hm. Well, and, I mean, I think if-- well, I think I have a clue about how I would try to, probably not very well, explain numerical analysis to somebody who hadn't a clue about what it was, but I would be interested to hear how you would explain it.

McIlroy: Well, if a person knows about integration, and they know that integration comes as, is defined as a limit, the-- you can estimate the area under a curve by taking a few points along the curve and summing those up. But if you take more points you get a better and better answer, and numerical analysis is just doing this.

Brock: <laughs> Yeah. For all kinds of situations.

[3] His book was published in the late 1950s. [Correction by Doug McIlroy.]

McIlroy: For all kinds of problems. Yes.

Brock: Yeah. That wa-- you know, it's kind of a way to do when-- it's methods to get at an answer--

McIlroy: Approximation answer.

Brock: -- when doing it directly is not tractable for whatever reason.

McIlroy: Mm-hm.

Brock: And the computer was good for numerical analysis because it could essentially try more points along the curve, if you will.

McIlroy: Yes. Once you could add up a thousand points instead of 10, you could get much better answers, and good enough for all practical purposes. <laughs>

Brock: Right. And so, you're fascinated by thi--

McIlroy: But--

Brock: Okay. I'm sorry, go ahead.

McIlroy: But just that you could do more calculation is not the essence of modern numerical analysis. It was in those days. But tricks, new approaches that will reduce the total number of calculations you need to do, is the heart of numerical analysis, and these, when they reduce O of n fourth [$O(n^4)$] to O of n squared [$O(n^2)$], it just is dramatic, and Norm Schryer, who was our resident numerical analysis for a long time at Bell Labs, numerical analyst, loved to give a talk about comparing the speed-up in computers, which everybody understood, to the O of n [O(n)] improvements in numerical analysis, which are not so well-known.

Brock: Right.

McIlroy: And the two have been comparable over time.

Brock: Right, I can imagine.

McIlroy: A factor of a million here and factor of a million there, makes a--

Brock: Now you're talking.

McIlroy: Yeah, it's...

Brock: Well, so, I mean, you had become interested enough that you wanted to pursue, continuing to stay with digital computing, I guess.

McIlroy: So-- yeah. So I didn't do my thesis on that, partly because of this disillusion, but I did know that I was going to go back to computing after I finished.

Brock: Okay. <laughs>

McIlroy: So I did my thesis in elasticity theory.

Brock: Okay.

McIlroy: And my-- when I finished, my professor asked me what I was going to do, and I told him I was going to go to Bell Labs and play with the computers, he was greatly disappointed. He-- I guess I had never revealed to him that computing was my--

McIlroy: Was what I had my heart set on.

Brock: And that was at MIT that you did elasticity theory.

McIlroy: That was at MIT, yes. Yes.

Brock: Interesting.

McIlroy: <laughs>

Brock: But had you-- but your attraction, you said, your attraction to MIT was its computing.

McIlroy: Yeah. So the whole time I was, I mean, the whole time I was there I arranged to do things in the computer lab. Worked there in the summer and...

Brock: And was that working with-- so you were at MIT then starting in 1950--

McIlroy: 1949. 19-- yeah, 1949, yeah.

Brock: '49?

McIlroy: Oh, I'm sorry, that's Cornell.

Brock: Yeah.

McIlroy: 1954. Yeah. <laughs>

Brock: 1954. Okay.

McIlroy: Yeah. <laughs>

Brock: So at that time, had the digital computer that you were using, was that-- '54, was that the Whirlwind?

McIlroy: That was Whirlwind II.

Brock: Whirlwind II, okay.

McIlroy: And when I got there it had 1K of 16-bit memory. Within the year it was upgraded to 2.

Brock: <laughs> Okay. Right. Well, by--

McIlroy: And that was gigantic. The CPC had 24 words of memory.

Brock: Right, <laughs> right, and this was now-- and Whirlwind II, it was called the digital computing laboratory or something like that?

McIlroy: It was the Whirlwind lab, as far as I know. It was before Project MAC and-- which may have had a title like the digital computing lab. I'm not sure.

Brock: Yeah. Well, how did you-- could you talk then a little bit about so which-- in applied mathematics you were doing this elasticity theory.

McIlroy: Yeah.

Brock: And could you talk about how you-- just a little bit about that, the computing scene around Whirlwind and how you fit into that and just that experience?

McIlroy: Yeah. Well, let's see, Whirlwind was in a separate building, small building, three stories high, with rotating equipment taking AC input and producing a lot of DC output.

Brock: <laughs> Yikes.

McIlroy: Yeah, in the basement. Oh, electronic power supplies on the first floor, and the control room and the computer proper on the second floor. You had a feeling when you were in that building that you were in a nice fraternity. Everybody, everybody there was involved with and intrigued by the computer. The control room looked like out of a typical movie. <laughs> Lots of flashing lights and indirect, subdued overhead lighting. Most of the output you got from the computer was graphical, or came off a graphic device, because it could-- even if it was text it was delivered to you in microfilm. Because this was much faster than going to the typewriters.

Brock: Interesting. I didn't realize that.

McIlroy: It also had graphic input, because it was a prototype for the Sage missile defense-- or, I'm sorry-- early warning system.

Brock: Right.

McIlroy: And some people got to use the graphical input, but, you know, there-- but that was mostly at night, because there you took over the whole machine as a personal computer, and that was expensive. So I never, I never got to do that kind of thing. People like Doug Ross, who essentially invented numerically controll were involved in that, numerically controlled machine tools.

Brock: Right.

McIlroy: And I, in fact, I did not know Doug Ross until later on, and I don't think I actually, while I was a student there, knew anybody who was privileged to use the graphic input.

Brock: Hm. And at this time, again, just to kind of, to frame that, you know, it was the people interested in and working with the Whirlwind computer, in this time period, the mid-'50s, were they-- was there a sense that this was, like, the center of the action or this was a new activity that was just one of many activities going on? I'm just-- guess I'm trying to hunt around for did it seem like--

McIlroy: People came in from all branches of the school to use it. It wasn't-- by the time I got to Bell Labs, it really was a hub. If you were in computing, you got, you had your fingers in touch with the entire laboratory. Every Friday afternoon we sat down to accept or reject time applications. It was free to the department, but it cost us $600 an hour[4], so...

Brock: Wow, yeah.

McIlroy: So... Out of general funds. So you didn't want to be used in a silly way, and sometimes because there were mathematicians sitting in on this, they'd, "I know how to do that problem," and-- or you might, "This is an interesting thing. Maybe I'll look into it a little more, and so we got these applications from all over for all kinds of things, and we could join in to their activities." Whirlwind didn't quite have that culture around it yet. In fact, way up on top of Whirlwind, because it came out of computing, there was another-- there was a guy who had a room full of punch card equipment and Whirlwind was thought, was somehow organizationally inferior to that. In fact, one summer job I did, I programmed the simulation of a torpedo, a torpedo that was allowed to make a few mid-course corrections, and we did a Monte Carlo to get to a-- a simulation to see what its probability of finally hitting a target was, and I'm told that this ran, actually once I had the program running, gave it over to the people who really-- who had the problem, I'm told that it ran 120 hours on Whirlwind, which is a lot of, was a fair amount of computing. Anyway, I didn't produce my program quite as fast as was desired, and I was called in and said, "If you don't finish quickly, I'm going to have my girls do it on the punch card equipment." That's how little-- <laughs>

Brock: Wow.

[4] "The department" is the department to which any particular user belonged. "Us" is the computer center, which was part of the math department. As most computer runs took only a few hundredths of an hour, this budgeting arrangement avoided a lot of cost-accounting busywork. [Clarification by Doug McIlroy.]

McIlroy: That's... And that was at MIT, <laughs> and in the rest of the world, that situation is of supposedly high management over computers, where the high management had never used one, persisted, and it had, it had strange effects.

Brock: And did you-- did I read somewhere that you also did summer work one year at Bell Labs while you were...?

McIlroy: I-- two years, actually.

Brock: Oh, two years.

McIlroy: Yes.

Brock: How did that connection come about?

McIlroy: Just because I knew Bell Labs was a great place, and Bell Labs recruiters appear and you just walk in and say, "Could I have a summer job?" "Summer job?" and, "Yeah, you can."

Brock: And what was that?

McIlroy: So one of them was in West Street, on-- in what is now the Westbeth Artists colony. <laughs>

Brock: Where my wife lived when she was--

McIlroy: Oh, really? Yeah. <laughs>

Brock: --just a little girl for a couple years, yeah.

McIlroy: No kidding-- <laughs>

Brock: So familiar with West Street both from personal history and Bell Labs history. <laughs> Yeah.

McIlroy: Interesting, interesting, yeah.

Brock: Yeah, yeah.

McIlroy: And it's also the end of the High Line now.

Brock: It is. <laughs>

McIlroy: The railroad actually goes through the, used to go through the building.

Brock: Oh, I didn't realize that.

McIlroy: On the second story, yeah, and there, I was up in the penthouse on the 13th floor overlooking the river, and I was on a job to see how good fax was, and it was-- clearly kind of thing could—a high school student could've done, and I didn't do it any better than a high school student would have. We had a connection that went to Chicago and back and sent faxes to ourselves, and looked at how good they were. At the end of that summer though, for some reason somebody said, "You ought to go meet Bill Keister."

Brock: I've heard Bill Keister's name before.

McIlroy: Keister, Ritchie and Washburn wrote the first book about <laughs> digital technology.[5] "You ought to go see Bill Keister," and I went to see him, and he told me about Shannon's master's thesis. I had taken-- I had taken a course, the only math course I ever took in the Philosophy Department at Cornell, on logic, and all Keister had do was say, you know, "Boolean algebra is related to digital circuits," and <laughs> "Ah, yeah."

McIlroy: So I remember the-- I remember that little interview very well. <laughs>

Brock: And Bill Keister was sort of, I think, very good friends with Alastair Ritchie.

McIlroy: Yes.

Brock: Isn't that it? Because--

McIlroy: That's... Yes.

Brock: --that's where I had heard his name was I interviewed Dennis Ritchie's siblings.

McIlroy: His brother took Bill Keister to market.

Brock: Oh, with puzzles, right?

McIlroy: All the puzzles, yes.

Brock: Yeah, yeah, yeah. Yeah, yeah.

McIlroy: <laughs>

Brock: So that-- and so that's-- yeah, okay, and is he-- he's in New Jersey still, Bill, or...?

McIlroy: Well, he must be long dead by now, but yeah.

Brock: Oh, oh, oh, yeah. Yeah. That's true.

[5] The book was the first formal treatment of the subject. [Clarification by Doug McIlroy.]

McIlroy: <laughs>

Brock: Yeah. So he-- so you-- and was Bill Keister at this time, was he in West Street?

McIlroy: Yes, mm-hm.

Brock: Okay. And so how did that, I mean, beyond all the light bulbs going on with Shannon's master's thesis, did that change your thinking or your course?

McIlroy: Well, yeah, it meant that I became alert to work like Huffman [David Huffman] and that sort of stuff, and opened my eyes to look in a new direction.

Brock: And what was your-- that was your first summer experience with Bell-- and then you--

McIlroy: Which was first? I think that was probably the second one. The first one was-- man, which way up was it? I don't know. The other one was at Whippany, and there I was given the job of writing test specs for a radar system, and somebody gave me a sample of a test spec, which was a very bad sample, I'm sorry. Instead of writing a test spec, what the guy did was write a, was invent, a testing device, and he wrote this-- <laughs> and he drew up this device which then gave test signals, rather than merely saying, "Please provide these signals and see what the results are," and I started to imitate that, and that was trying to devise some digital analog equipment. I did a-- whatever I produced for them they could never have used.

Brock: Oh.

McIlroy: <laughs>

Brock: Hm. But your-- despite that, your experience with them was...?

McIlroy: But I became aware, whenever they had a hard problem at Whippany, they did things-- part of the analog devices were the circuits that actually simulated geometry, and they had-- they held the Math Department in awe and they would take these things to the Math Department, and so I became aware of what was going on there.

Brock: Okay. And then when your--

McIlroy: When in-- okay, go ahead.

Brock: Oh, no, no, please. I was just going to say and then as your-- as you could see your thesis in elasticity theory kind of reaching its end and you're thinking about what to do, is that when you, reached out to the Mathematics Department or how did... <laughs>

McIlroy: Well, interestingly enough, sometime during my last year there, Brock McMillan [Brockway McMillan] and Walter MacWilliams dropped into my office and said, "You've worked at Bell Labs before. Are you interested in interviewing?" So they actually-- and yes, I was.

McIlroy: So I interviewed at Bell Labs, and I forget how I got in touch with IBM Research. I interviewed there too. I had worked one summer with GE in Ithaca, but I did not interview there. I think IBM and Bell Labs may be the only two places I talked to, and I saw interesting things at IBM. But I knew Bell Labs, so I went there.

Brock: And that was '58 that you--

McIlroy: That would've been probably-- yeah, that was '58.

Brock: '58, yeah, and so did they-- I'm not sure-- actually, I don't know quite how it happened.

McIlroy: So--

Brock: Were you hired into the Mathematics Department in partic--

McIlroy: Specif--

Brock: Specifically? Okay.

McIlroy: That's where the computer was, and I learned later on this wonderful story that the director of Mathematics said at-- when they were-- in the post-interview discussion that the department held, "It's all very well for you to hire somebody specifically to work with a computer, but what's he going to be doing in five years?" There was this notion of-- which Aiken [Howard Aiken] is famous for at Harvard, that once you got all the mathematical functions programmed up there was nothing more to do.

Brock: Hm.

McIlroy: Dick Hamming had a different idea.

Brock: He had a more expansive view.

McIlroy: Wow, did he ever. He-- people would say, "Oh, that's just Dick being his usual hyperbolic self," when he predicted in 19-- about the time I arrived, that in 10 years, 50 percent of Bell Labs' budget would be involved with computing. The only thing he got-- everybody thought that, "It can't be like that." It was a little less than 10 years.

Brock: Really, it--

McIlroy: Yeah.

Brock: And the Labs had an enormous budget.

McIlroy: It did.

Brock: <laughs> So that's, I mean, that is a very dramatic rise and a very dramatic, I would think, change for the Labs overall.

McIlroy: Well, of course, when we say that it should be involved in computing. There already were projects like electronic switching, which were well underway. So that that became very big, and the rest of switching just vanished. <laughs> So...

Brock: Right. So it includes something like the--

McIlroy: Yeah, mm-hm. <laughs>

Brock: --ESS?

McIlroy: Yes, exactly. <laughs>

Brock: Okay. Yeah, which is a computer.

McIlroy: Yeah. <laughs>

Brock: Yeah. Yeah. So I could see that, yeah. But still, it's an extraordinary-- well, I mean, it seems like it must've been extraordinary transformation in terms of, the rise of digital technology within the Bell System in general.

McIlroy: Oh, mm-hm.

Brock: And yeah, and just computing for the laboratory itself, as a scientific tool, as an engineering tool, and as a domain of inquiry in and of itself. Well, maybe you could describe, I could ask you to describe, the Mathematics Department as you came into it. You know, just about how big it was and the sort of facilities and the computer, the computing capability it had when you came in.

McIlroy: Yeah, well, Building 3, where the Math Department was, had the Math Department actually ringed around the computer.

Brock: Oh. <laughs>

McIlroy: There were—the computer was in the middle and there were four corridors around it where the offices were on the-- facing outwards. So the department might've been 30 people?

Brock: Okay.

McIlroy: It was-- there were the old-timers, who were particularly expert in integrating around contours for filter design. There were Shannonites. Shannon left, went to MIT, just a few weeks before I left MIT. I never met the man until unfortunately he was senile. But there were people interested in combinatoric problems. A really hot

thing just when I arrived was the traveling salesman and minimum-spanning-tree problems. Why the traveling salesman problem? Both of these had to do with billing. In different constituencies, if you billed for private network, I mean, you can set up the wires however you want, but what is an objective measure of billing, for billing? Well, one was the minimum spanning tree, whether you happened to put your wires in that way or not. Going beyond that, it was the minimum of all possible spanning trees, and some clever-- even if you had more points in it.

Brock: Right.

McIlroy: If you could introduce points, you could reduce your bill, and we actually had customers who--

Brock: <laughs> Were clever enough? <laughs>

McIlroy: Who created empty offices to reduce their bill.

McIlroy: So that was the Steiner problem, and there were other jurisdictions where the traveling salesman problem was the bill, and if we couldn't--

Brock: That's fascinating.

McIlroy: If we couldn't-- and it was embarrassing to offer to send out a bill and have your customers say, "You billed us too much, because I got a better traveling salesman solution."

Brock: <laughs> Okay.

McIlroy: So there were collection people who were fascinated, and I found this fascinating too, but I made no--

Brock: And you worked on spanning-tree algorithms--

McIlroy: I did a spanning-tree enumerating program, yeah, yeah. I didn't work on the optimization problem.

Brock: Okay.

McIlroy: <laughs>

Brock: But this was part of that--

McIlroy: Yeah, mm-hm. Mm-hm.

Brock: --that context. Wow, that is fascinating. You know, because both of those had become such kind of paradigmatic--

McIlroy: Yes, yeah, mm-hm.

Brock: --problems in computing that-- and the relationship to billing, I think, I have never heard that before.

McIlroy: Yeah. <laughs>

Brock: That is absolutely fascinating.

McIlroy: So two of the-- the two-best-known spanning-tree algorithms would be Prim's and Kruskal's. Prim [Robert Prim] was already there and Kruskal [Joseph Kruskal] joined shortly after I did, obviously, because <laughs> of that connection. And for the shortest, then the shortest route problem and we had Ed Moore who published at the same time as Dijkstra [Edsger Dijkstra] produced the shortest route program. Well, Dijkstra's the one that's known in computer science, but and well deservedly, too. You should read Ed Moore's program. Read Ed Moore's description. He describes it by example. It's clear what the algorithm is and Dijkstra describes it even non-deterministically rather than <laughs> just very-- It's a very modern paper written in the 1970s.

Brock: Right.

McIlroy: 1960s, pardon me.[6] <laughs>

Brock: And--

McIlroy: And then there were the people who did partial differential equations which came up in radio transmission and coaxial, analysis of how coaxial cable worked.

Brock: Right.

McIlroy: And then there were the people around the computer who sort of did all kinds of things.

Brock: And how many people were there around the computer in that latter group do you think?

McIlroy: Well, okay, there were of Members of Technical Staff--

Brock: Yeah.

McIlroy: There were five, I believe. I'll adjust that to six. And then there were as they were called then the computresses.

Brock: The computresses, yeah. <laugh>

McIlroy: Yes, that was a term of longstanding at Bell Labs once upon a time, the computresses had run-- had run the calculators.

[6] Actually it was the late 1950s. [Correction by Doug McIlroy.]

Brock: Mm-hmm.

McIlroy: And by and large they became the first programmers and for some time engineers looked down on programming. Yeah. "Oh, that's for the computresses to do." So they'd be-- But as soon as engineers discovered that programming is fun and interesting, then the computresses' expertise was forgotten and it was never really recognized because when they had it, it was deemed unimportant.

Brock: Right. Mmm. Were they physically separate? Were they part of the Math Department?

McIlroy: They were part of the Math Department.

Brock: Okay. They were.

McIlroy: And but they typically were quartered two to an office instead of one to an office like everybody else.

Brock: Mm-hmm. Mm-hmm. And were they-- Were they more associated where, I mean, I would imagine there were still a lot of, well, were they just integrated into Building 3 with everybody else?

McIlroy: Yes. Mm-hmm.

Brock: Okay. And the computer or the computing, the computers that the Math Department had by '58, what was that--?

McIlroy: It was just one.

Brock: Just one.

McIlroy: That was for the whole Bell Labs. Other ones would send their work in remotely.

Brock: And this was an IBM.

McIlroy: And it was an IBM 704.

Brock: 704, okay. And so that--

McIlroy: Yeah, upgraded in 1960 as 7090 and then the 7094, mm-hmm.

Brock: And by the--

McIlroy: And by then, identical machines had appeared in Holmdel and Whippany and Indian Hill.

Brock: Right.

McIlroy: And we began to lose our really beautiful contacts with the rest of the Labs.

Brock: Oh.

McIlroy: We had contacts with the computer centers but we didn't have contact with people in the field.

Brock: Right. And had the-- By the time that you-- Well, yeah, by the time that you arrived there had already been this tradition of Bell Labs developing its own operating system for the computer, is that correct?

McIlroy: Well, yes, but it was absolutely necessary because IBM didn't.

Brock: Okay. And there was--

McIlroy: And everybody had to do it. We were particularly astonished at MIT when we, while I was there, we got the 704. And there had been an operating system for the Whirlwind and the 704 came absolutely bare hardware.

Brock: Wow.

McIlroy: The Fortran program, Fortran was a standalone program. You put punch cards in and it gave you punch cards out.

Brock: Right.

McIlroy: And now you could-- <laughs> Now you could feed those punch cards in to run them later on. And the diagnostics in the Fortran program--

Brock: Of course.

McIlroy: You know about the stop book?

Brock: No, I don't.

McIlroy: When they find a-- When it decides to stop compiling it would halt, execute a halt instruction. Operators would read from the lights where it stopped. You would then give that back to the programmer and then there was a big fanfold stop book where you could look up what the meaning of that--

Brock: Of that. <laughs>

McIlroy: Of that code was. What Bell Labs and I'm sure a lot of other outfits did at the same-- Interestingly enough, I do not remember how MIT made its own operating system, but I don't remember anything about it, although I did use it once for my-- in connection with my thesis. But at Bell Labs one of the critical things was how do you subordinate Fortran to an operating system when Fortran thought it had the whole computer, like, to itself.

Brock: Right. Right. <laughs>

McIlroy: Well, one thing you had to do was go find all the stops and replace them with a return to the operating system telling what the number was. We still had the stop book.

Brock: Right. <laughs>

McIlroy: But the other thing was there's no room for the operating system when Fortran is in there.

Brock: Oh, right.

McIlroy: And so they swapped the operating system out and bootstrapped Fortran in and when Fortran stopped it had to bootstrap the operating system back in.

Brock: Oh, okay. <laughs>

McIlroy: Dolores Leagus did that. She was a-- The two most amazing programmers I've known are Ken Thompson and Dolores Leagus.

Brock: How do you spell Dolores's last name?

McIlroy: L-E-A-G-U-S.

Brock: Thank you.

Brock: Could you say more about what impressed you with the two of them? What made you--?

McIlroy: Ken, Ken just had an absolutely beautiful conception of a program. If you read-- If you read his programming, he doesn't put in many comments, but you don't need them. It just reads like a novel. Un, just unbelievable.

Brock: So it's the clarity and--

McIlroy: Yes.

Brock: Yeah, okay. Clarity.

McIlroy: Just and of course that clarity just shines through in the original design of Unix. Once you see Unix, you know how it works inside. And when my wife got her Macintosh I was baffled by this machine.

McIlroy: Supposedly easy to use. It's easy to use as long as you use it for what Steve Jobs thought you'd want it to do.

Brock: Right. <laughs>

McIlroy: But they had the “Hello World” program is in their manual. And it was a page long.

Brock: <laughs>

McIlroy: And it in turn had, in Ritchie, it's three lines.

Brock: Right.

McIlroy: So but just to be specific about how the swapping was done. We're on a machine with little secondary memory. No secondary memory, in fact, except tapes.

Brock: Right.

McIlroy: You swap it out. They didn't want to dedicate a tape to that, to swapping out the operating system. And they came up with the clever idea of swapping it onto the output tape.

Brock: Oh, my God.

McIlroy: At the end of the output tape.

Brock: <laughs>

McIlroy: And then re-- <laughs>

Brock: And rewinding.

McIlroy: And then backing over it.

Brock: And was it-- It was that a signature, that sort of solution, was that something that Dolores Leagus came up with or?

McIlroy: All that happened shortly before I got there.

Brock: Okay.

McIlroy: So I can't attribute names. But the people involved were George Mealy, Gwen Hansen, Ron Drummond, Dolores Leagus.

Brock: And could you talk about why you thought you were so impressed by her as a programmer?

McIlroy: Oh, yeah. I really-- Bob Morris and I wrote out of desperation the PL/I program, the PL/I compiler that was used for Multics; until they got a real one, we wrote a temporary one.

Brock: Okay.

McIlroy: We wrote it because the contractor that we had hired to make one just didn't come through. And we brought in Dolores for one sticky part of it and she wrote 2,000 cards of programming, put them in the machine and it ran.

Brock: <laughs>

McIlroy: Never-- She-- However, both Bob and I, you crept up on it, like, adding a little bit and a little bit and a little bit. And she just could conceive a program as a whole and get it right.

Brock: So it's just the, like, the capacity of her imagination to hold that whole structure.

McIlroy: Yeah. Mm-hmm.

Brock: Yeah.

McIlroy: And also, to look at the code and see that and this was going to work.

Brock: Right. <laughs> Yeah.

McIlroy: I mean, a lot of us say we-- I know that when I take a large hunk of code that I've written that I just hold my breath when I put it in the machine.

Brock: <laughs>

McIlroy: And I know it's going to tell me something's wrong.

Brock: Yeah. And to expect, yeah, to have that expectation that it's not going to work on the first try versus yeah.

McIlroy: Yeah. <laughs>

Brock: Well, well maybe we could talk a little bit about when you came into the Labs, you know, with the idea that you would be working closely with the computer, but also, what was your-- So how did ,when you first got to the Labs, figure out what in particular you were going to focus on or--?

McIlroy: Well, I sort of fell into a good project and I was immediately put in the-- on to the Friday afternoon meetings, which was a very good orientation. And I think the-- And I dabbled for a while in integer linear programming. I had an idea and it seemed to work very nicely. And then I, Gomory [Ralph Gomory] had another idea and I sent him mine. And he sent me back a counter example to mine.

Brock: Okay.

McIlroy: But fortunately I didn't go into-- I didn't go into print with this mistaken idea. And then one day George Mealy came in and said, "You know, we need a macro assembler." Macros were something that were known about and GE had one. And he came into the Friday meeting to say this. He didn't want to do it himself.

Brock: <laughs>

McIlroy: But he came in to propose it. And Doug Eastwood in the office next to me and I said, "Hey, that's a neat idea. We'll do it." And that got me established.

Brock: Okay. And that became, you really dove deep into this whole world of macros and macro instructions and language and macros as a language extension, if I'm understanding it right.

McIlroy: Yes.

Brock: And I also saw that you had a patent on the use of macros that I--

McIlroy: Yeah, that--

Brock: Was looking at but it was, it-- I'm not sure that I fully grasped it.

McIlroy: Okay. The patent had really nothing to do with macros.

Brock: Oh. Maybe I missed-- Though then I really misunderstood it. <laughs>

McIlroy: The patent would-- <laughs> Yeah. Although it was cast, one implementation of it was cast in terms of macros.

Brock: Okay.

McIlroy: But the patent was on string manipulation.

Brock: Okay.

McIlroy: The machines were not byte-addressed. They weren't addressed.

Brock: Right.

McIlroy: And but you had to get out pieces of words for characters. And all I did was say if you use bit addresses rather than byte-- rather than word addresses--

Brock: Then you solve that.

McIlroy: Yeah. And I wrote little macros that did the bit addressing. Yeah.

Brock: I see. Okay.

McIlroy: And at the time *Benson and Tabbot* was the Supreme Court decision ruled--

Brock: Oh, against--

McIlroy: Benson and Tabbot happened to be a Bell Labs patent on BCD to binary conversion, a particular program that did that. And the patent office that-- I'm sorry the Supreme Court knocked that down on the-- in a decision by Justice Douglas. It was stupid. <laughs>

Brock: Huh.

McIlroy: What he said that this was a patent on a mathematical process, and it would preclude anybody else doing binary to BCD conversion.

Brock: Oh.

McIlroy: Because-- No, it wasn't a-- It was a particular implementation of something that people had been doing for years. <laughs>

Brock: Right.

McIlroy: And that was widely seen as saying that software is unpatentable.

Brock: Interesting.

McIlroy: Our patent-- our Patent Department didn't like this outcome. They thought there was sometimes software should be patentable. And they could understand my idea and they took this and they met-- <laughs>

Brock: Okay.

McIlroy: And they invented a steam engine that would do the-- that would do my algorithm. And then they said, "And by the way, it could be implemented in a computer this way."

Brock: <laughs> And they used it--

McIlroy: And they got it through.

Brock: Okay. Because I did notice that it took-- Okay. So that period while they were pursuing your patent was the period, this kind of period where software was not patentable.

McIlroy: Yes.

Brock: Oh, that's so interesting. So they used yours as kind of a test case for--

McIlroy: Yeah. There probably were others at the same time but that's a purpose that it served.

Brock: Huh. I had not realized that it was a Bell Labs patent that, was involved in the kind of "software cannot be patented" regime.

McIlroy: Yes.

Brock: That's very interesting. And, well, could you talk a little bit more about--

McIlroy: There's a nice story about this--

Brock: Oh.

McIlroy: About my patent. I'm sorry.

Brock: Please.

McIlroy: A side story. It isn't actually about the patent. It turns out that Digital Equipment Corporation had come up with the idea independently.

Brock: Okay. <laughs>

McIlroy: And they used it in the PDP-10. And didn't-- There were cross licensing meetings and Digital Equipment was playing hardball with Bell Labs and saying, "You don't have any patents of interest to us." And Bell Labs, our patent attorney went to the meeting and among the things he carried was my patent And said, "You're in for it." He didn't actually get to talk about I,t but their hardware was infringing my patent.

Brock: <laughs>

McIlroy: Whether who invented it first, that doesn't matter in the patents-- as patents were then.

Brock: Right.

McIlroy: But it turned out that the case turned on another subject. They had an expert witness and he went with another piece of information from us which was that we had discovered that he was selling Unix code filched out of our ops, filched out of our programs as his. Claimed he'd written them. He'd written clones of them, but he had--

Brock: Just a string-- <laughs>

McIlroy: But he had actually just taken our code and compiled it and was selling it. And we had dumped his code and looked at it and compared it and yeah, it clearly came from our source as object code. And our patent attorney played, I don't know how he managed to do it, but sort of at the end of one day of discussions he somehow got this guy to look at a piece of assembly language and a piece of source code and he-- and, "Did this assembly language come from that source code?" He looked at it. "Oh, obviously."

Brock: <laughs>

McIlroy: "Would it interest you if I told you this assembly language is yours and this source is ours?"

Brock: Ooh.

McIlroy: Their expert witness never appeared again.

Brock: I'm sure.

McIlroy: And apparently--

Brock: Yeah.

McIlroy: So he didn't need-- He didn't need to use his portfolio. <laughs> He just shot down-- He just shot down their arguments.

Brock: And then the cross licensing happened?

McIlroy: It did.[7]

Brock: Yes.

Brock: Oh, my gosh. Yeah. That's-- There's quite a bit of hubris in serving as an expert witness knowing that you've kind of--

McIlroy: Yeah.

Brock: Done that. But I did want to-- I did want to ask you a little bit more about just that work on macros and the macro assembler and how that-- how that shaped your-- did that change the way that you thought about programming?

McIlroy: It certainly got me interested in programming languages.

[7] I should say "I believe it did." I don't recall specifically being told the final outcome of the negotiation. I do know that our attorney returned from that multiday session in a very happy mood. [Clarification by Doug McIlroy.]

Brock: Okay.

McIlroy: Because I, the first really big application of macros that I did was to make a Lisp compiler, which was only a bunch of macros. And so the assembler became a Lisp compiler.

Brock: Oh, wow.

McIlroy: And maybe 50 or 60 levels deep in macro calls it would finally issue some assembly language and that's what led me to write the paper. But to do that I had turned the assembler into-- made it Turing complete by putting in some conditionals.

Brock: Okay.

McIlroy: Although Christopher Strachey eventually showed you didn't even need conditionals for a macro system to be Turing complete. And after that lots of people like Waite [William Waite] and others really parlayed macros into a big deal. And they caught on at Indian Hill and I'm afraid that there they actually set progress back for a while. Or they made progress but they they stuck with it too long. Their switching programs were all written on a big macro assembler.

Brock: Oh, the programs for the ESS.

McIlroy: For the ESS.

Brock: Right.

McIlroy: And they had a language, the macro language.

Brock: Okay.

McIlroy: But it was constrained by the fact that it was a macro language and they couldn't-- And it meant, it also meant that it took a long time to compile because the macro language works in text.

Brock: Right.

McIlroy: And finally <laughs> produces text at the end.

McIlroy: And I had-- I had an Executive Director at Indian Hill once tell me why they were the best-- They exploited computers more than anybody else at Bell Labs because they used more computer time.

Brock: <laughs>

McIlroy: But I knew why they used more computer time, just because they were using macros.

Brock: Right.

McIlroy: <laughs>

Brock: Well, this is-- This gets to something that I wanted to ask you about. You know, so them keeping with this macro language, it was-- It's about the unusual or maybe I'm wrong but it strikes me as the unusual demands for reliability for everything happening in the Bell System. I remember one time I did an interview with Julius Blank who had been at Western Electric and then was involved with Fairchild Semiconductor. But he was talking about, we were talking about vacuum tube reliability and he said he was involved in making these vacuum tubes that were absolutely reliable for 20 years because they were going to put them on the submarine cable and it was just a question of how you engineered the vacuum tubes so they would be reliable for 20 years. And I was struck by that when I was reading I think some notes on a lecture that you gave about history of computing at Bell Labs. And you were talking about I think it was the ESS or some other system that was designed not have a failure for at least 40 years or something like that.

McIlroy: Yeah.

Brock: And these maybe it was the ESS system, but that these systems would be designed with that kind of reliability not to have a failure and mean time between failure of five decades or whatever. <laughs>

McIlroy: Yes.

Brock: And I just thought, well, maybe for the military, but is there any-- I couldn't think of any place else that was designing for that kind of level of reliability.

McIlroy: No. And least of all the computer manufacturers.

Brock: <laughs>

McIlroy: The notion-- But the first computers were delivered with the notion that you would have an hour downtime every day for the customer engineers to--And when you upgraded you would take the computers offline, install the new software and put them back online.

Brock: Right.

McIlroy: And all of these things were absolute "no no" in the Bell System. And I still think that reliable computing is shortchanged in our-- in computer science in general. There's a little bit about program verification.

Brock: Yes.

McIlroy: Which is related to reliable computing but is not the answer. Is not a silver bullet. Reliable computing has a lot to do with monitoring on the side, error recovery, error detection, redundancy. And by and large this is not discussed.

Brock: Was it-- But did you think that let's just say if I could shorthand that is that culture of reliability in the Bell System, did that, do you think that relates to some of the kind of the software work that was going on, for example, with, like, this macro language for the ESS, that it, part of why it's maybe, they kept with it is because they were working on engineering, that kind of reliability into the system?

McIlroy: Well, that does make-- that does make you think long and hard about changing your methodology, I agree.

Brock: Yeah. <laughs>

McIlroy: But it should not keep you from thinking about a change in methodology.

Brock: True.

McIlroy: For example, one-- They used to watch-- The Bell System was always hung up on indexes, how often this-- How well you performed this particular task, if-- that was a measurable thing for that particular task.

Brock: Okay.

McIlroy: In software they came up with errors per thousand lines of code. As a measure of how well they were doing. But our-- We had one project that Ken Thompson, Joe Condon, Bob Morris were involved in where they decided they were going to make a little switching system, just so that we'd-- They thought they had an idea that might be cleaner and smaller than ESS. And it was smaller but it was not engineered for the ages the way ESS was. But because they made it smaller, say a quarter of the size, and I suppose they had only half the number of errors in their system as the other one did. The folks at ESS would have said, "Your code isn't as good as ours because yours got-- You got twice the error rate."

Brock: <laughs> Oh, I see. Yeah. Right.

McIlroy: <laughs> Even-- Even though you don't have as many errors.

Brock: Right.

McIlroy: And I did think that that would-- That there were certain things that got ingrained in the ESS project like that that I think held them back. But yes, when you're-- if you do adopt a new technology you've got to see that it's going to be at least as reliable as the old.

Brock: Right.

McIlroy: But one key to reliability is simplicity.

Brock: Right. <laughs>

McIlroy: Unfortunately, because things do fail due to quantum errors or being rained on or who knows what, you have to build in lots of checks and redundancies.

Brock: Mm-hmm. Well--

McIlroy: And that was not much of a subject in our Computer Science Department.

Brock: Right.

McIlroy: Or in the Math Department, except one paper published by Shannon and Moore.

Brock: Huh.

McIlroy: "Reliable Circuits from Crummy Components." "Crummy" was in the title.

Brock: <laughs> I'll have to look that up.

McIlroy: Yeah. I don't have the wording quite right, but "Crummy" was there.

Brock: Right.

McIlroy: And you've probably heard of the little toy that they made which was a box you push a switch on the front of the box and a sleeved arm with a cuff link comes-- The box opens up, the arm comes out, pushes the switch down and goes back in the box.

Brock: Right.

McIlroy: Really cute. But the interesting thing about that box was the electronics were made of crummy components or use these methods.

Brock: Oh.

McIlroy: So they were all triply redundant.

Brock: Oh.

McIlroy: And you could take anything out of that circuit and it would keep on working.

Brock: Oh, isn't that interesting. So that's it was, I mean, I've heard of this, you know, the box that turns itself off.

McIlroy: Yeah, mm-hmm.

Brock: But I hadn't realized it was the demonstration for--

McIlroy: Yes. <laughs>

Brock: For this reliable circuitry. <laughs> What were the connections between sort of the computer people in the Mathematics Department and computer people in other locations like back at MIT or elsewhere? Was there-- because the community of computer people was small. Could you just talk about that, how you-- how the Bell Labs Mathematics Department was connected to these other groups?

McIlroy: Various parts of the Department would be connected to different groups. In Computing our connections were primarily I would say, but by the time there got to be 704s, no longer was it true that you knew everybody in the world.

Brock: Okay. Right.

McIlroy: We all had connections with the places we'd come from. But I think the users group was really the important, really the nexus of connections.

Brock: IBM Share.

McIlroy: IBM Share. So that our system was-- became the BESYS under Share.

Brock: Right.

McIlroy: And I don't know how many places used it. Not a whole lot, but it spread here and there. And then the rest were, would be personal connections I think that--

Brock: Right.

McIlroy: The most amazing computer science talk I ever went to was when I got a letter from McCarthy in 1959 saying, "I'm giving a talk in such and such in the afternoon in Building 2 and-- And I thought you might be interested." He didn't say what it was.

McIlroy: But I went. I did drive up and go hear this talk and he was introducing Lisp.

Brock: Oh.

McIlroy: And in an hour he went from car, cdr, and cons to symbolic differentiation and it was all perfectly clear. That's what finally led me to go make a Lisp compiler within macros.

Brock: And that was just an astounding tour de force or I mean it must have been--?

McIlroy: Just a revelation in so many ways. One was its simplicity. Another was introduction to recursion.

Brock: Hmm.

McIlroy: I remember sitting around in probably around 1957 in a bull session in MIT in the Barta Building and somebody said, "What would happen if a subroutine called itself?" My first question is what's it mean to call yourself? <laughs> And I went home that night and I said, well, here's how you could do it. And the stack just invents itself, but as soon as you want it-- as soon as you need it. But I don't know what you'd use it for. And yet all of us had seen formulas like the recursion for the Bessel functions or the just linear differential-- difference equations and so on.

Brock: Right.

McIlroy: We'd all seen it and we never made the-- never made the connection to computing. And McCarthy just took that and nailed it in just a beautiful demonstration and it's just so the eyes opened. <laughs>

Brock: Yeah. Oh.

McIlroy: So that, but so the connection with McCarthy is, well, that kind of thing makes a big difference.

Brock: Sure. Yes. And well, I wanted to talk about that in '65 I think it was, you became the head of the Computing Techniques Research Department.

McIlroy: Yes.

Brock: And I know that around this time was the kind of separation of Computer Science from the Mathematics Department.

McIlroy: We had been split off a couple of years before that.

Brock: Okay. Could you-- I wasn't quite sure where like the landscape was by the time that you became the head of that Computing Techniques Research Department, how the computing work had kind of evolved into the different groups, if, yeah.

McIlroy: Yes. What-- first of all, it became the Computer Center and operating the Computer Center became a bigger deal than the Math Department wanted to be involved in, so that that got split out. And those of us who had been primarily attached to the computer in the Math Department went with it.

Brock: Got it.

McIlroy: So we became part of the Computing Center. But there was more and more operational responsibility in the Computing Center, so we started having-- there were huge racks of magnetic tapes to take care of and index. And we started hiring and by then, 1964, I guess, is when computers, the first computer science department was founded in a university.

Brock: Okay.

McIlroy: And we started hiring graduates from Computer Science departments, people like Jeff Ullman and Al Aho. And there wasn't much of a home for them in a-- well, in where operations were the center, were the-- And so then Computer Science got split out of the Computing Center.

Brock: Got it. Okay.

McIlroy: And now so we have two parallel directors reporting to the Vice President of Research: Computer Science and Mathematics.

Brock: Okay.

McIlroy: And Computing Techniques Research was just they were a bunch of garbage names for the--

Brock: <laughs>

McIlroy: You had this Computer Science Department with 25 people and you split it up into three bunches.

Brock: Okay.

McIlroy: And, and my bunch had a few software people and a few theoreticians, but they would, they were not the numerical analysts.

Brock: That was the key to-- I mean, what was the logic behind the three groups?

McIlroy: One group played with hardware a little more. Elliot Pinson had been brought in from Visual and Acoustics Research and he'd been involved in making special purpose hardware for graphics and that kind of thing. That was one group. Another was the numerical analysis people. And the third were whoever was left over.

Brock: <laughs>

McIlroy: And that was theoreticians and folks who were primarily languages and software.

Brock: Okay.

McIlroy: And they got-- and it was a happy marriage, 'cause things like YACC were born, because they're-- because of their additions[8], and the language people got together.

Brock: Right.

McIlroy: And of course, the theoreticians were terribly interested in some language issues like parsing and--

[8] I certainly meant something about their complementary competencies—a deliberate result of hiring. Sam Morgan always asked about what orthogonal capability candidates would bring. [Clarification by Doug McIlroy.]

Brock: Right, and could you talk about how you became invited to head up that department, and what you thought?

McIlroy: A sad accident. I mean, a sad occurrence. John Kelly died on the streets of Manhattan outside of Bell Labs, and they needed a department head. He had been the department head, and he died at the age of 41, or something like that.

Brock: Oh, my gosh.

McIlroy: Excessive smoker.

Brock: And so you were invited to replace him.

McIlroy: Mm-hm.

Brock: But did you--

McIlroy: But by then I was-- I think I was-- The other, George Baldwin had become a department head in the computing center, so he would-- He preceded me, but I by then would have been probably the senior person around computing it.

Brock: Yeah, and did you--

McIlroy: Oh, Dick Hemming didn't want to be department head. He was always called a department head, but he always carefully arranged that nobody reported to him.

Brock: <laughs> Right, I had heard about that.

McIlroy: He had enough cachet to pull that off.

Brock: How did you feel about-- I mean, how big of a change was becoming a head of a department in the Labs in terms of the management responsibility or the organizational responsibilities? You know, did that mean it was--

McIlroy: Well, the great thing about our particular director, Sam Morgan, was he kept budgeting to himself.

Brock: How?

McIlroy: Department heads didn't have-- didn't worry about the budget, so I've never done one, and in a department with such experts, your principle job is to keep them happy and to make sure that what they're doing is known up the line, and what-- You make sure, and by-- and insulate them from pressures from above.

Brock: Right.

McIlroy: They're doing their best jobs when they're doing something that they wanted to work on, and there's enough-- In Bell Labs was a-- had wide enough interests that whatever you wanted to work on was probably alright.

Brock: Yeah, right.

McIlroy: I've only known of one person that went off the rails, working on the four-color theorem for too many years, and nothing else.

Brock: Right, and so establishing-- Well, that's very interesting, and especially the idea that you're really exposing the work to the organization at large is one of the main functions, and it's--

McIlroy: Yes, and that included also, since I'd been around longer than most of my people, I had further-- wider connections in the Lab, and would-- "Ah, somebody wants to know about-- Why don't you go out and talk to him?"

Brock: Mm, and it sounds like it didn't really mean that it would-- Well, certainly there was a lot of care and effort in kind of exposing people's work and protecting them, and allowing them to kind of--

McIlroy: Not an onerous task, though.

Brock: Not-- Yeah, so it wasn't a huge--

McIlroy: It doesn't take you away from the lab bench, as they say.

Brock: That's what I was trying to get around to, the question I was fumbling to get to. Thank you for helping me get there. So--

McIlroy: So I was able to participate in the Unix room like everybody else.

Brock: Right.

McIlroy: Except that, with regard to my expertise on Unix, I was definitely a junior member.

Brock: <laughs> Well, I wanted to talk about, if we could, just the whole start of Bell Labs' involvement with the Multics effort, and your group in particular, and how that figured in.

McIlroy: Okay, that happened during-- That happened before I was a department head.

Brock: Oh, okay.

McIlroy: That started in 1964, and that really was a top-down kind of thing. David [Edward David], who was our executive director-- Oh, yeah, I said those directors reported to the vice president. That's not true. There was one more level of management, both an executive director, and David had computer science and math under him, and visual and acoustic research.

Brock: Okay.

McIlroy: The fan out was not so great at Bell Labs. They had a fairly deep hierarchy, with maybe a fan out of three or four at each level, but it was a hierarchy that you didn't have to go through channels to go see the vice president.

Brock: Okay.

McIlroy: Anyway, Ed David knew the folks at MIT, and he and Licklider [J. C. R. Licklider] in talks that I know nothing about, thought that this would be a good idea, and I would not say that we at the lower levels were initially particularly excited about getting into Multics, but we did it, and it had some interesting aspects, so Bob Morris-- I happened to have been on the PL/1 committee of SHARE, and I brought PL/1 to Multics. They were looking-- It had-- They wanted-- It had enough features that they could do their-- that it could satisfy their system programming needs. Algol didn't quite make it, and a local candidate at MIT was Doug Ross's language is called—The name escapes me at the moment, but it unfortunately, it was the thing that was in his mind more than on paper. You couldn't say, "Here's what it is," <laughs> although it certainly would have sufficed. So that--Joe Ossanna got interested in it from-- particularly from the text and input/output aspects. He specified the I/O for Multics and he specified the Teletype Model 37 to be a great supporter of Multics. I'm not quite sure how Ritchie and Thompson got drawn in, but they started writing software and started-- and as time went on in the back room, began to see Multics as too complicated, and talking about-- Well, you know all this story by now.

Brock: Well, I mean, it would be great-- There's no harm in going over it, you know. Yeah, there was a concern that as Multics was developing, it was not going to support the number of users. I know that there were concerns along the way about it.

McIlroy: We probably were running-- actually tried to run Multics in our lab as a usable machine before they did at MIT. At MIT, the Multics machine was the lab bench that developed stuff over here and then measured it over there, but they didn't try using it, and three or four people could keep it busy when they were, with their official simulations, were saying Multics was a 20-user system, and the reason for that was curious. Primarily, it was the difference between half-duplex, and duplex operation. CTSS had been half-duplex, which meant you couldn't enter the next job while the current one was running.

Brock: Okay, right.

McIlroy: You could type ahead in Multics, so if it was being slow, you would be way ahead. You would have several lines of input for it to go onto, and CTSS had a fast compiler, had MAD. Multics was running our very slow PL/1 compiler, and they just said, compilation takes so much time in their simulations, but in real world, that wasn't true.

Brock: Right, so for--

McIlroy: So we were not very happy with the way Multics was performing, but I think the unhappiness with Ken and Dennis had started earlier, that they just didn't like the way this Multics system programmer's manual was growing to a five-foot shelf, and started thinking about a simpler organization of a system.

Brock: So that would be-- And this is getting back to these ideals of clarity, or of utmost clarity that, if it's requiring that much of a shelf of instruction, it's not-- It's not approaching self-evidence.

McIlroy: Yes, and also they did not have the objective of making a utility. They had the objective of making a system that would be fun for them to use.

Brock: <laughs> Right, and I think I saw somewhere, I can't remember where, that there were dozens of people at Bell Labs involved with Multics, is that true?

McIlroy: No, no I'm sure it was more like a handful.

Brock: Okay, and was that mostly happening within your department?

McIlroy: Certainly all within computer science, so it-- and about half of them in my department and half of them here and there.

Brock: Okay, and so the decision to-- So it was four years of effort or something like that before Bell Labs--

McIlroy: We got in in '64 and out in '69.

Brock: Okay, well, I was interested in how, while the Multics effort is going on you become involved with this whole discussion and these NATO meetings around software engineering, and you're-- and you start coming up and expressing these ideas about mass-produced software components.

McIlroy: You've really studied up for this interview!

Brock: Well, I try to do my best. I will not say that I-- I try, at least, to get the gist of what's going on. I get lost in the details sometimes, and like, in your patent, I can get confused by seeing macros and missing the point, but I do my best, but I did think it was interesting. So I was wondering if Multics was supposed to be this like, public utility for computing. I was trying to draw the line between, does that make the idea of, if you have a public utility for computing, does the need for having all of these software components become greater? I was just wondering if there's a relationship.

McIlroy: I certainly did not, myself, perceive a relationship.

Brock: Okay. Well, then could you talk a little bit about maybe just about how you got drawn into this kind of evolving conversation about software engineering, and the perception of a software crisis?

McIlroy: We will have to go back and credit Ed David with that. He founded Multics, and somehow, he too had been in on the very initial thoughts about this NATO conference, but sent me as a representative to be an organizer of the conference, and the only time I've ever made a one-day transatlantic flight round trip. Now, and I'm trying to reconstruct how it is. Had I thought about the software components thing before I participated at that organizing meeting? I clearly went with that in mind as a topic to bring up, but I really don't recall having thought about it

much before, but I did bring it up in the organizing meeting, and some people saw this. There were people who wanted NATO to found an institute, and that was in background, and I really wasn't in on that very much, and when I brought this up, apparently a lightbulb went off, and somebody said, well, this is a possible focus of this hypothetical institute, and they arranged that I give an invited lecture, one of only two at the whole affair. It was mostly just discussion.

Brock: Oh, wow.

McIlroy: And so I had to go off, and work hard to put together this piece, and it's the only piece I've ever written, I think that-- of a sort of technical content where it was pie in the sky, rather than something that I had completed, and it's the only-- and it's far and away the most referenced thing that I ever wrote. So that's how it came about, the accident of Ed not wanting to go to Brussels and sending me in his place.

Brock: <laughs> Well, could we-- I mean, the idea at the time, the idea that NATO would be having a conference on software engineering was just -- The idea that the growing realization that software was such a tough and enduring-- Well, was such a central issue as the application of computing was spreading, and that in some ways, I guess, that software was getting no easier to make.

McIlroy: And also this realization that software was not organized. Engineering was, and software did not really play a role in the design of computers. Software was something that you left. That was what those people that you wondered about, what they were going to do in five years, were going to fill in the blanks in your computer.

Brock: Right.

McIlroy: There was something else I was thinking of. It's lost.

Brock: And it seemed-- Well, the other possible connection, I saw-- So your idea was for this idea of software components was really to have just a more systematic landscape of this.

McIlroy: Oh, yes, okay. Yeah, and there was one thing that I had been observing, which was this method, this sysgen that IBM had for when you brought up your software for the 360. I'll have one of these, and one of this, and one of this, and one of that, and if you're tailoring things, tailoring by-- Essentially, what they said was, we've got this immense operating system. You could have as many parts of it as you want, but by and large, they didn't offer much tailoring of the parts, and this didn't seem quite like ordinary engineering catalogs, you know. You've got all kinds of different vacuum tubes that have-- serve the same purpose, but with different degrees of reliability and different power levels, and I parlayed that into a talk.

Brock: <laughs> But it was-- I mean, there was one-- There are a number of good lines in the piece, but there's one I think about where you're talking about-- You say something like, the tragic waste of how, at the time that software is being produced, you know, duplication, and--

McIlroy: Duplication, and also amateurism, because if everybody's making his own, you don't get the very best that-- I-- Have you run into Noel Lovisa? Do you know him?

Brock: No, I don't.

McIlroy: He's in Australia, and he's had sort-- In some ways, it's the first original idea about how to modernize the software components notion, which is simply generating a version of a subroutine with certain properties for separate-- and it was also, it talked about rather small things rather than big things, rather than the things that-- Lovisa has this idea that-- of how, transactionally, to put-- to use pieces, the expertise of this person and that person, to build big ones out of small ones, really integrated, rather than taking them off the shelf. Look for his white paper.

Brock: I will.[9]

McIlroy: Let's see, what's the name of his company? Hm, that escapes me. Anyway, he gives me more credit than is due for-- in his white paper, and it's an entrancing idea of how to put this software together. It's so radically different. I can't guess whether it will work or not, but he's trying to do it.

Brock: Oh, I'll have to look for it. Well, I was curious. So, you present this kind of picture about software components which in part was about wide availability of these subroutines with a lot of variation, but identifiable as suiting different needs, and I was just thinking about, wondering if like, the world that you are describing there, in software components, has in a way, come to pass, but in a very kind of anarchic fashion. You know, I think about people-- People talk about writing programs today is a lot of cut and pasting from routines that you find on GitHub or wherever, and I was just thinking, well, this does sound-- It echoes the software components idea, that people are just pulling these things off the shelf, certainly, but it seems different in a way, because it doesn't have any of like, the rigor or, I think, the safety that you had talked about in your paper, that, where you could trust to take this as a black box, and a component and put it into your system. I was just curious to hear your thoughts about that.

McIlroy: Yeah, I think that there's something to that. The variation is not systematic, and I find myself going for-- I love Haskell these days, and I find myself going and looking at the huge Haskell repository for pieces, and it turns out that the pieces are not so easy to pull out of their environment and put into yours, that I end up still re-writing, rather than stealing stuff that would be nice to just be able to take off the shelf, 'cause often people know how to use the language, in particular in this one. People know how to use this very sophisticated language in ways that I don't at all, but they--When they've done what I want to do, they've buried it so deeply, that I can't get it out.

Brock: Right.

McIlroy: Yeah, there's something about this point that's worth thinking about it, but I don't have-- I have nothing definitive to say now.

Brock: Well, fair enough. It was a pop quiz, so yeah. Well, to go back to then, to that NATO conference, and, what did that-- Did that experience of organizing that conference make an impression on you, or how did that--

McIlroy: Attending the conference did.

[9] Noel Lovisa and Julie Lovisa, "CODE VALLEY – A PEER-TO-PEER SOFTWARE ENGINEERING SYSTEM," 2015, 9. https://codevalley.com/whitepaper.pdf

Brock: Yeah, could you talk about that?

McIlroy: For several reasons. One was that the organizing committee-- It was a by-invitation conference, and the organizing committee had put together an invitation, so I-- There were people in Europe that I didn't know about that got invited that I very much valued meeting, and there were people that I invited that were totally new to the Europeans, so it was a really good meeting place, much better than any other meeting that I can remember going to, but that's a personal benefit, and it actually seems to have affected the world, too, that whoever gave it the-- Whoever came up with the name of the meeting, just hit on a very felicitous word.

Brock: Yeah.

McIlroy: I know that word-- that one can find it used sporadically before, but it never caught on, and it-- This just introduced a responsible notion that you're-- of responsible, reasoned discipline in creating software was worthwhile cultivating. Yeah, people had been doing it before, perhaps, but this gelled an idea, and everybody grasped onto it, some of them for dubious reasons, but generally much to the benefit of the industry.

Brock: Were there people there from the Apollo program effort?

McIlroy: I do not remember that. There were people-- There were people from some other big efforts, but not Apollo.

Brock: Hm, 'cause I know in talking to a few of the people who were involved with that, Dan Lickly and Margaret Hamilton, they mention that in the context of their effort for the Apollo Guidance Computer, they were talking about these same sort of ideas of software engineering, or many of the same concerns: a rigorous approach, and also--

McIlroy: And in fact, Apollo had been going a long time by then.

Brock: Yeah.

McIlroy: It was almost ready to land!

Brock: So I was just curious if that was part of the mix, and I know, maybe not under the name, "software engineering," but I think Barry Boehm and some other people were from that kind of military or government computing sort of side, were into this rigorous kind of discipline, if you will.

McIlroy: And these people were represented at the conference.

Brock: Okay.

McIlroy: Somehow, Barry Boehm must have been invited. I don't think he was there, but I'm-- If anybody was invited, he would have been.

Brock: Yeah. Well, you-- So was that after you returned from the NATO conference-- Did the Bell Labs getting out of Multics, did that happen after, or--

McIlroy: That happened after.

Brock: After.

McIlroy: And no relationship.

Brock: No relationship, sure, but I just was wondering about the sequence, and could you talk a little bit about, for your group and the people who had been working on Multics, was that-- Did that kind of-- Well, what was that like?

McIlroy: Okay, it was-- It certainly was a considerable disappointment to people like Peter Neumann and Joe Ossanna who had invested a lot in Multics. I think it was probably something of a relief to Dennis and Ken. I can't say that definitively, and all along the way, to people like Bob Morris and me there had been-- I think we liked the objectives, and we had fun doing what we did, but we always thought it was kind of a command performance, which is most unusual, or had been at that time in Bell Labs research.

Brock: And so it would be almost, in a way, a return to the normal operation to have this thing stop.

McIlroy: It did certainly leave us-- leave everybody who was involved at loose ends about how we would be computing in the future.

Brock: Right, because it was also the computing center was thinking that they would have this big GE machine, and this would be how we would compute for the Labs as a whole.

McIlroy: And as a-- They were, as a result, running a GE machine, which was really uninspiring to use, and had no vision of where-- what might follow on, so we had one computer center running 360s and the other running GE, and everybody regarded it as something of a mystery how to really exploit these systems. People from the-- from Holmdel would tell me about how little decks of JCL would be passed around. "This works!" This will actually-- This will--

McIlroy: And this, to a lesser extent, but the same kind of thing happened in the GE which had-- One of the system control cards had the bizarre name of, "FUTIL." It actually meant file utility, but F-U-T-I-L. It was this kind of-- I forget whose word it was--Somebody had, not at Bell Labs, the word, "programmering" rather than programming. These little silly sayings you had to learn that had nothing to do with your problem, these systems were full of that.

Brock: I wanted to-- Well, two questions. At about this time, I guess I was curious if you, in your department or in computer science, if there had been an engagement with computer networking to this time.

McIlroy: The answer is the computer science, yes, my department, no, but we had Sandy Fraser in particular who pushed networking, and I think retired an unhappy man from Bell Labs, because AT&T-- He really thought AT&T was-- should be getting into, not just digital as a way to-- method of more reliable transmission, but the digital

messages themselves were important. We demonstrated them long since, and were using them, but way high in AT&T it was observed that digital messages were a tiny fraction of what we were transmitting, and digital communications-- Digital encoding was important, because it improved the use of bandwidth, but digital messages themselves were unimportant, and he could never get their attention, but anyway, he made a couple of interesting networks that we used within our lab, and the first one was definitely local. The second one was planned with an eye to scaling, but interest in scaling, it could-- none whatsoever, and when Arpanet wanted to grow into an internet, Sprint was interested, AT&T had no interest whatsoever.

Brock: Hm. It just seems so-- somehow, so ironic. I don't-- I mean, but the rationale that you explain, if it's a-- I guess it's that kind of a thing about the incumbent product or something like that, the voice transmissions or whatever you want to call it is so dominant that even though this small thing that is still gigantic, it's just that the-- just doesn't-- can't attract the focus.

McIlroy: That is so true. But certainly, AT&T lost its mojo on that one completely.

Brock: The other thing I wanted to ask you about was the kind of-- the culture of your department, in part because I want to ask about the culture of, once we get to there being a Unix room, the culture of the Unix room, but I just wanted to I guess see if there was a-- if that was a continuation of kind of how your group had been working, or was that an evolution of how--

McIlroy: It certainly-- The fact that we had a Unix room was actually a complete change. Everybody had his own office before. Yes, there was a computer room, but it was an input/output desk.

Brock: Right. <laughs>

McIlroy: It wasn't a place where you went to work. So that-- It was not a foregone conclusion that when we put a computer in the attic that people would start working around it, because right from the start we had remote access.

Brock: Yeah, that--

McIlroy: Why did we come out of our offices? I don't know. In the case of Ken and Dennis, they worked so closely together that I understand it, but why did Lee McMahon and I, for example, also come to join into that room? I don't know.

Brock: It's interesting.

McIlroy: It was useful to be there, because the-- There was always somebody who knew what was going on. Maybe if the manual had preceded the system I wouldn't have gone up there.

McIlroy: I mean, it wasn't a particularly pleasant place. It was a true attic.

Brock: Well, that's interesting. I'll just-- Maybe we can return to that.

McIlroy: The later Unix room was planned as a meeting place, but the need for that was discerned after one developed that wasn't intended as-- It was intended as a computer room.

END OF THE INTERVIEW

