Gene Amdahl Oral History

William (Bill) Aspray Interviewer

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William (Bill) Aspray: Would you prefer to be called Gene, or Dr. Amdahl, or--?

Gene Amdahl: Gene.

Aspray: Gene. Okay. Bill.

Aspray: Gene, I understand that you were born in South Dakota in 1922. Would you tell me a bit about growing up in South Dakota?

Amdahl: Well, we lived on a farm, and we were fairly close to school, a quarter of a mile across a field, or a half a mile if we followed the driveway and then the road. In the summertime, we often crossed the field on the way to school, but on the way home we'd generally go on the road because then we'd mingle with the other kids. In the wintertime, you took the road because it was too hard to go through the snow.

Aspray: And did you work on the farm yourself? Did you take apart equipment and rebuild equipment?

Amdahl: I didn't do much of that, but I observed a lot of it done. I worked on the farm, of course. I don't think I was entrusted with taking any machinery apart. But my father would repair most of the machinery, and he would build buildings. He was really very inventive. I remember in the Depression years, we had to paint the barn, and he couldn't afford the paint. So what he did was he got Portland Cement and ochre for color, and skim milk mixed up as paint, and it worked very well. So he was able to provide that kind of preservative to the wood.

Aspray: And what level of education did your parents have?

Amdahl: My father-- of course, his father was a homesteader, and he ended up getting approximately-- buying up about five or six homesteads. So he owned a lot of land, and my father was farming 120 acres of that land. My father had only been able to finally complete about three years of school because he had to work on the farm until the harvest was done in the fall. Actually, until the corn picking was done in January. And then he had to go back to work as soon as the fields had thawed enough to do the spring plowing, which would be in early March. So he would have only-- probably six to eight weeks of school that he could attend each year, and he always regretted that. He felt that an education was the most important thing. My mother, of course, was a school teacher. She had been very well educated, and he really admired that. As a matter of fact, when I went to college, I wanted to go to South Dakota State instead of Augustana. South Dakota State had engineering. Augustana was really a liberal arts school. My father didn't want me to go to South Dakota State. He told me that he didn't really think I ought to go to school to learn how to make a living; I ought to go to school to learn how to get the most out of life. And I thought about that many times since, and I think still the school I went to allowed me to get the most out of life.

Aspray: And so did you believe you got a good education at South Dakota State?

Amdahl: Yes, I did. Probably not as good as I might have gotten at some other school, but probably I did better than if I had gone to a school that was more competitive, because at first I wasn't really much of a student. My mind would jump too quickly to some other thing, and I'd think about it. So I'd kind of lose the train of thought if the lecture didn't keep me totally involved. It wasn't until I got to South Dakota State and got into physics that all of the sudden my mind was just fully consumed.

Aspray: So how was it you chose physics as your study?

Amdahl: I had to take it one summer after my first year at school, first year at South Dakota State. It was a required subject. I took it during the summer. This was just after World War II started. It started my freshman year, in the fall. That summer, I went to summer school for half the summer, and I took my first course in physics. And it was just like the whole new world had been opened up to me.

Aspray: Were you generally a good student?

Amdahl: No, not until that time. After that I was a good student.

Aspray: Were you able to finish up your undergraduate education before going off to the war?

Amdahl: No. At the next-- I was able to go the next year, and then I ended up-- I wanted to get into the service as a Seabee. Actually, I'd tried to get into the service first, but they already had drafted so many of the young people from the area that there wasn't anyone to harvest the crops. So they weren't inducting us anymore. But I felt very guilty at not being in, and so I tried to get them to let me in to join the Seabees, since I could run fairly heavy equipment. They didn't think that was worth it. So I ended up-- went back to school during the fall, after harvest, and then I was involved in teaching. They had the Army specialized training program, and there weren't enough teachers. So they engaged me to be a teacher. I taught physics laboratory.

Aspray: This was on the campus on South Dakota State?

Amdahl: Yeah. Mm-hmm. It was a very good experience, and I think from the student reaction, probably I was one of the better teachers they had. <laughs> Anyway, it was really fun. But then I saw something-- I saw an ad about the Eddy program in the Navy, where you could go to school to learn electronics and radar and radio operation, and sonar. And so I decided, "Well, I've got my electronics-- just ought to equip me to pass the test." I took the test, passed it, and then I again went back to the draft board. This time they decided, "Well, that's a worthwhile thing." So they did allow me to go in. And I would normally have-- with my eyesight at that time, I would have been in limited service. But they allowed me to go in as a regular sailor at that time. And so I ended up going first through basic training, then to a school where we learned how to use the slide rule effectively, and ordinary electrical mathematics, which I already knew. It was still a good refresher course. Then we went to school at 190 North State Street, right in the heart of Chicago. We had our school on the third floor of the Balaban and Katz Theater. And just below us on the second floor was a television studio for the new thing they were experimenting with, television. That was an interesting experience in itself. But we went to school there

for about I think close to three months, and then I went out to Treasure Island here in the Bay Area for training on the radar and sonar. And we had some very good teachers. It was quite remarkable, the capabilities of those teachers that they had managed to assemble. Anyway, at the end of that time, I had my-- we were asked to recommend what places we would like, and I knew that I was subject to getting seasick. So I decided I would first take a land job, second an aircraft carrier, third a battleship, in that they would be the least affected by stormy weather. And they decided to put me in as a teacher. So I went back to Chicago, took a teacher's training course, and taught at Herzl Junior College in Chicago, and then down to Gulfport, Mississippi, where I taught essentially radio theory.

Aspray: And you did ship overseas though at one point, right?

Amdahl: Not while I was in the Navy. As a matter of fact, my three brothers were in the Army. They all went overseas on a ship. I never went to sea on a ship. I had gone into a battleship in dry dock...

Aspray: So when the war was over, did you go immediately back to college to finish up?

Amdahl: I tried to get into the University of Minnesota. But there were so many returning veterans that were Minnesotans they wouldn't take a South Dakotan even though I was only three miles from the border. So for the fall quarter, I was living in Minnesota at Lake Minnetonka in a small cabin, and I had gotten married when I got out. So we lived there for something like four months. At the end of that time, I decided-- well, after I couldn't get in to the University of Minnesota, I decided that what I would do is go back to South Dakota, and I could get in there for the winter quarter. So what I did was I went back to my wife's farm, and there I built sections of a house. I was going to assemble it on a lot in Brooking, South Dakota, but there were no fittings available to connect to city water, and they wouldn't allow me to hook up to any water without that. I went to cities four hundred miles away. There were no fittings. They were in absolutely zero supply, all the building that was happening at that time. So, bright idea came along. I decided to go to a trailer court and find out if they would allow me to rent a space to assemble my house, and connect to their water and power. And they very kindly agreed to do it, at a very modest price. So I assembled our house there around the first of January. Everything was frozen. We had to, of course, use a pickax to put down this temporary foundation, which was wood, dig down and connect to his water and to his electricity. And then we got that done in time for the start of the winter quarter. We had the basic house assembled, but in between classes and in evening and that, my brother would help me, and we would put in the finishing touches on the interesting, including-- I'm having a little trouble thinking of the word-- insulation-- because it was very cold. And we got the house done very nicely. It was a huge place-- 22 feet wide, 14 feet 6 inches deep-- and a little entryway that was 4 by 6 feet, which helped a lot to keep it warmer in the wintertime.

Aspray: And you could commute to school from there?

Amdahl: Yeah. So it was about a mile and a half to school.

Aspray: So as you-- your undergraduate degree was in engineering physics, is that right?

Amdahl: Yes.

Aspray: And what is that?

Amdahl: It's physics, but held in the school of engineering. And I had my choice really of four different majors. I could have had mathematics, could have had chemistry, could have had electrical engineering-- I guess I could have had mechanical engineering as well-- or engineering physics. I decided I wanted to take physics, because that was what had really turned me on.

Aspray: And were there particular teachers or fellow students that you remember that were important to you?

Amdahl: The first physics course I had the summer of my freshman year, just after the freshman year, that physics teacher was the one that had got me so excited about physics. He was probably the turning point in my career. And he ended up dying from renal problems. And as soon as I had a little bit of money that I could spare, I set up a scholarship in his name. It's still there today. Reinhardt [ph?].

Aspray: Reinhardt. When you were getting finished in your senior year of college, did you think about going to work, or were you sure you wanted to go off to graduate school? What were your plans?

Amdahl: I was so consumed with physics, I was being taught a special course by the dean of engineering, Dean Crothers [ph?], on relativity. And I was just so excited-- the only student. I don't think he ever taught the class before. You couldn't really call it a class; it was really done at my request. And he interceded with the University of Wisconsin. And so I ended up at Wisconsin [Madison] with a fellowship, which made a lot of difference in being able to afford going to school. So I went to school with what I considered an adequate amount to live on. My wife worked all the time, of course.

Aspray: And in hindsight, was Wisconsin a good place for you to have gone for your training?

Amdahl: Oh yes. My major professor was Professor Robert Sacks [ph?], who was an excellent teacher. Handsome fellow with a marvelous voice. I think he should have been in the movies. But he was very helpful. And I wasn't prepared as well as a lot of the students because I didn't really have the background that many of them had had. So I was kind of struggling a bit, but I was making out well enough, and it was at that time that I was assigned a task, along with two other graduate students, to determine whether or not the proposed force between nuclear particles could describe the simplest three-body nucleus, tritium-- hydrogen-3. And we worked for 30 days using a desk calculator with eight significant digits, and a slide rule to hold two more significant digits. So we mapped the energy of that system for that 30-day period for all values of the parameters and found out there was no bound state. Close, but not quite. And I decided there had to be a better way. So I began to invent computers of my own. And I had no way of learning what was going on. At least I didn't know I had any way. So I was just doing it on my own. First thing I did was I invented a digital differential analyzer, because I thought solving differential equations was probably the thing we wanted to do. But then I began to think also the stored program

computer which I had heard about through this book called *Giant Brains*, which had no information in it other than that such a thing existed--

Aspray: Edmund Berkeley's book.

Amdahl: Yeah. But I was working also on my thesis, and the subject that I was assigned was the contributions to the magnetic moments of heavy nuclei due to spin antisymmetry and velocity-dependent forces. And I was making reasonable progress when a man by the name of Charlie Davidson-- he was also in physics-- would keep talking to me about this computer I was thinking of. So I described to him pretty much what the whole computer was, and he went over to the electrical engineering department and told them that they really ought to have me give a seminar on it over there. So I did, and the next thing I know my major professor told me he'd been approached by the head of the electrical engineering department and had requested that my thesis subject be changed to recording the plan for the computer, because they'd like to use it to train their electrical engineering graduate students in this new field. So my thesis subject was changed. I was actually given-- I'm trying to think of the actual title. It isn't quite the level of-- it was not a research-- yeah, I guess it was research associate. Big change in amount of support. And go over there and write my thesis on that subject and start the project, which I did for basically a year and a half.

Aspray: Let me interrupt the thrust of this narrative to ask you a couple of questions about your background though. So had you-- you knew about desk calculators-- had you seen any differential analyzers before, or used them before?

Amdahl: No.

Aspray: Had you known about numerical analysis techniques?

Amdahl: I knew of numerical analysis techniques, yes. But I hadn't yet heard-- I knew there were such things as analog differential analyzers, mechanical ones, and after I had started with the digital one. I actually ended up taking a course in electronic differential analyzers, which were continuous. We used to have debates; they accused me of being in discontinuous world, and I explained to them in response that-- can't quite think of the response I had. But anyway, I had a response.

Aspray: So let's go back to your narrative then. So you started to work on this machine and its design. What did you know? I mean, was it all done from your own first principles, and what were the challenges in building it?

Amdahl: Was it done from my own first principles? I studied binary arithmetic on my own by just trying to do it. I thought I had made a new invention in being able to do division as fast as multiply serially. I found out that von Neumann had patented it some-- I think it was three or four years earlier. So I missed out on that one. But I had the first-- so far as I know, I had the first overlap computer. We were doing four different things concurrently. While the machine was picking up instruction, n, it was looking up the operands for instruction, n minus 1, or performing the arithmetic for instruction, n minus 2, and while

storing away the result for instruction, n minus 3. And that allowed the serial machine to go reasonably fast. And it was all in floating point.

Aspray: All in floating point? That was something-- it's unusual.

Amdahl: Didn't have any fixed point. Didn't have any fixed point arithmetic. But we had a way of accomplishing fixed point arithmetic.

Aspray: Was it harder to design with floating point?

Amdahl: No. I had ten instructions; I only needed nine. I was in redundancy. I had a branch. I didn't need that. The conditional branch was easy to generate to make an unconditional branch whenever you wanted it.

Aspray: Was the electrical engineering side of the project hard?

Amdahl: No, that was really something that I had learned enough about in the Navy to deal with that. We had flip-flops, stuff like that, false generators, in the Navy. And then in the case of reading signals from the drum, that was something you could analyze mathematically. You'd either integrate the signal coming out, or you'd differentiate it, and you can get your pulse from that signal.

Aspray: And were the--

<crew talk>

End of Tape 1 / Beginning of Tape 2

Aspray: What about the availability of the components, the vacuum tubes and so on?

Amdahl: Well at the time I was in charge of this project at the university, I was looking around for dual triodes and the 6J6 was my favorite. And I found out that there was war surplus at the army at the airbase near Madison, Wisconsin, so I arranged to buy a whole mess of 6J6s.

Aspray: And they were reliable for the job?

Amdahl: Yeah, their lifetime was not too long. That is they would fail probably a little earlier than you would like in terms of some others that might have been available at the time. At least IBM had some that were would have a longer life. But they were reliable. They were very well suited for using for flip-flops, things like that.

Aspray: What about the memory device?

Amdahl: I thought long and hard of what to use. I was thinking magnetostriction things like that for the delay line, but then I finally concluded that the only reasonable thing that we could do at the university would be if we could get a magnetic drum, and put recirculating registers on it for the arithmetic section and for holding instruction information.

Aspray: Did you think about building it yourself at the university?

Amdahl: I thought about it a bit and decided that that was probably not a feasible thing to do. So I learned about Engineering Research Associates in St. Paul and so I contacted them and they were willing to talk about it so I went up and described what I wanted which was some 32 tracks all around the drum and something like four or five recirculating registers. And they decided that was a reasonable thing to do and so I contracted for that.

Aspray: And the university could afford this?

Amdahl: Yes.

Aspray: What were the other major technical challenges in building this computer?

Amdahl: Getting the circuits to be reliable. I was not an accomplished logic designer yet, but I did know a little bit about it. So that was a bit of a hurdle. I had to spend some time thinking about things before I could really structure it mathematically.

Aspray: Were you working on this more or less on your own or were there other people helping with this?

Amdahl: Up until the time I went to the electrical engineering department it was all my own. And then at the electrical engineering department, two people: Charlie Davidson was one and the other one was Jacob Johnson.

Aspray: Yes.

Amdahl: Jacob and I both went to IBM.

Aspray: Right, you worked together later on I understand.

Amdahl: Yeah.

Aspray: And how long did it take you to build this machine?

Amdahl: We didn't finish it by the time-- as a matter of fact we got by the time-- the first six months was spent me writing my thesis on the design of the machine which is what they wanted, and doing some of the circuit development. The next year was spent we were doing more, we got the drum, we were doing more of the circuit development and much of the design of the machine but not all of it.

Aspray: Yes, but the machine was eventually finished?

Amdahl: Oh yes, it was finished and it was actually used in the electrical engineering department, but mostly the purpose was to teach graduate students in electrical engineering about digital computers. Eventually the last man who knew how to maintain it reached retirement age and he negotiated with the university to get the machine because he'd like to use it in consulting. And the university decided that its usefulness was really largely over and there would be no way that they could keep it running so they might as well let him have it. So he knocked a wider opening to his basement, installed the machine there and consulted with it for probably about three years and then he began to get a little too senile to be consulting.

Aspray: I've heard the story that this was not only good for computing but in those cold northern winters that it was awfully good for heating the house as well.

Amdahl: That's right, great space heater. Almost all vacuum tube machines were considered as space heaters. Anyway when he died in his will he wanted it to be given to me, but before the will was probated and all of that while his father was not using the machine anymore, his son wanted to make use of that basement as a target range so he was setting up targets on the top of the console for pistol shooting. And I don't know if you're familiar with pistols but if you were right-handed you would use your pistol this way and you pull the trigger you tend to pull down and to the right. And you can if you looked where you put those targets you can see the pattern goes down and to the right so he must have been a right-handed pistol shooter. But going down it got to the console. Of course when people would ask me I'd explain that it was really irrational that people feared these intelligent machines.

Aspray: And then eventually the machine ended up where?

Amdahl: Well at Ontar Corporation. For some reason it got to Ontar Corporation without getting to me first. They held it as a secret from me until they got somebody- they knocked out that basement wall again <laughs> got the machine out, rebuilt the wall, sent the computer back here and that's the first I knew of it and then they told me the story.

Aspray: I see. Now it's a little surprising to me that a physics department would be satisfied with a dissertation on the design of a computer. Was there any concern on the part of the physics department to accept that topic?

Amdahl: Well my professor decided he couldn't evaluate it and there was nobody at the university who felt that could, so he sent it to people that he knew that were in the field of computing and asked them to determine whether or not it was of adequate quality to be a doctoral thesis and apparently got back very positive responses. As a matter of fact when I got hired into IBM in part because of that thesis, Nat Rochester who is the one I went to work for wanted to hire me because he wanted somebody who could write like that, and my major professor complimented me on the writing. I didn't write it the way people normally write technical material. I wrote it I suppose it was more along the lines of a missionary preacher or something like that trying to engage the listener in what I was talking about.

Aspray: Do you happen to know who those external reviewers were?

Amdahl: Yeah I knew one of them. That's the only one I knew.

Aspray: Okay. So you're getting finished with a doctoral degree in physics from the university and you're starting to think about what you're going to do with your career. What did you consider doing?

Amdahl: I kind of wanted to start a computer company but I couldn't figure out how I was ever going to get it financed. And then all of a sudden I was faced with an invitation from IBM to come and interview. It turned out that in Milwaukee that was the branch manager that I guess he'd be the regional manager, the branch manager from Madison had contacted him about this computer and my thesis had gotten them to at Rochester and they wanted to interview me and I got hired into IBM as the most highly paid man directly out of school in their company's history.

Aspray: And were you happy to go work for IBM?

Amdahl: Yeah, at that time it was a big name. I still had entrepreneurial genes in my body but that was an exciting place. I got there in the most exciting period because this was all new, and as a matter of fact the most exciting thing about the computer field at that time was almost anything you thought of was new.

Aspray: How did you feel about moving to the east coast?

Amdahl: I didn't really want to go to the east coast. I wanted to go to California. Back where I came from they thought being in California was having one foot in heaven. That haunted me all of my life basically until I got here. Haunting me.

Aspray: They knew they were right.

Amdahl: Yes.

Aspray: So what were your initial duties at IBM?

Amdahl: Well the first thing they wanted me to do because of my mathematical and physical background- physics background, they wanted me to work on this subject that they were just beginning to study that was Nat Rochester was beginning to study it. It was to determine whether or not we could make a computer behave like the brain. And he was using a monograph by Professor Hebb from the University in Quebec. And we modeled this computer or computer programs as close as we could to the Hebb's concept. In fact Nat Rochester had the name put out was the Conceptor.

Aspray: So did you know about some of the other work that was done on massive systems at the time like Von Neumann or Rosenblatt's or did you know about McCullough and Pitt's work?

Amdahl: Knew a little bit about McCullough and Pitt's work but only after we had gotten to the point where I had kind of decided the avenue we were following was a dead end.

Aspray: This was more or less a personal research project of Rochester's?

Amdahl: Yeah but it was funded very inexpensively. It was myself and another man, a very good mathematician, and Nat Rochester spending most of our time on it, but we also did other things at the same time. And we used machine time on the engineering model when nobody else was using it, so we'd be up there in the middle of the night running these models.

Aspray: What other kinds of projects did you work on in your first few years?

Amdahl: I worked on character reading.

Aspray: Character recognition?

Amdahl: Recognition, yes. And we got a pretty good result. We were able to read a wide variety of fonts even wire printing we were able to get about an 85 percent correct reading on pretty tacky wire printing. And we burned out of solenoid on the typewriter, the electric typewriter, and while we were waiting for the replacement solenoid, IBM decided they were going to move the project to Endicott.

Aspray: Because that had related kinds of projects?

Amdahl: Well in a way I suppose they did have some related kind of projects but it was pitched to us on the basis that they had to have some interesting projects at Endicott. It wasn't fair that all of the things be done in Poughkeepsie.

Aspray: So did you consider moving from the Poughkeepsie labs to the Endicott labs?

Amdahl: Not really. I really would not- did not want to get- I thought I was already far enough away from New York City. To get that far away which was really more than a day's drive.

Aspray: It's out in the middle of the state someplace right?

Amdahl: Yeah, actually pretty close to the western part of the state.

Aspray: So the things that you seem to be best known for during these early years at IBM are your work on the 700 series, the 701 and the 701A and the 704. Can you tell me about that?

Amdahl: Yeah, the 701 was really done before I got there and I ended up using the 701. I was asked to run a computing service there and so I had brought three or four programmers that would take problems that needed to be solved by some part of the engineering group or manufacturing. One of the problems was they wanted to do a table on springs for the manufacturing where they use springs in a lot of the mechanical designs. And I assigned a guy to do it. He worked, didn't get anywhere. I finally got him cornered and asked him to tell me what was the problem. And it turned out he couldn't- it was really a third degree polynomial that he had to solve. And he couldn't get the root. And I said "Would you show me the polynomial?" I looked at it and I said "This looks like it's got a double root." Two roots that-

Aspray: Yes, right.

Amdahl: And so I just spent about three minutes and I found what that was, found out how to get the other root.

Aspray: And then the problem was reduced to a simple problem.

Amdahl: The problem was reduced to really just writing down the numbers.

Aspray: So how did the 701A project come about? What was the purpose of it?

Amdahl: Well the 701A was a design was a plan put forth by Palmer.

Aspray: Ralph Palmer.

Amdahl: Ralph Palmer to provide greater function in the 701 and I'd looked at it a bit and suggested we could put a floating point quite easily. So he apparently he thought that was a reasonable idea and so he decided he'd give me the project to do that and I went through and tried to make as minimal a change as I could but put in floating point and indexing which was a new concept at that time derived or based on the B tube in England.

Aspray: At Manchester.

Amdahl: Yep. The 701A tried to keep as much as possible of the 701 so there would be minimal programming change and the management looking at it finally decided that it really would be better if they- if it made a cleaner design that didn't try to retain the 701 as much as they planned, so we changed it to being a 704 and cleaned up the machine and was able to add instructions that gave it more capability.

Aspray: But at a sacrifice of compatibility?

Amdahl: At a sacrifice of compatibility almost entirely. The databases couldn't even be used anymore because they- we got rid of the half-word which was in the 701. The 701A retained the half-word so you could use the databases. On the 704 we got that design pretty well completed when we were asked by the pricing people I was asked, would I be satisfied with a market potential of six machines? They said "We got requests for more 701s now that we can't build." I think there are going to be more machines than we sold of 701s when they get the 704 out there. Well they thought about that a while. They came back at 12. Again I told them it was going to be more than the 701. Then he came back with 18. I said "It's still going to be more than the 701." So they came back with 32 and I bought off on it. They sold 140. It was the most profitable machine program because it was priced on 32 and they sold 140.

Aspray: Yes. What were the technical challenges if there were any other ones on these machines?

Amdahl: There weren't any real technical challenges for me there because technology was in place. We did add magnetic core memory but we didn't really have the responsibility of designing the memory. The memory was designed by a group that was under one of the men that ended up going to the National Academy of Engineering. Actually another group above or alongside of the National Academy of Sciences or National Academy of Engineering that was responsible for providing information to the government.

Aspray: I understand that it was at this point in time that you first had experience with John Backus at IBM?

Amdahl: Yes he was doing FORTRAN and we had some discussions back and forth about how to do indexing and fit that into his FORTRAN property and one of my concepts on indexing he never did use because it would have required that he count down in his FORTRAN program instead of counting up. He didn't really cotton to that. Actually I don't think it would have made any difference except that in hardware you can have one instruction, you could determine when you hit zero which is a lot easier than determining when you hit N.

Aspray: You talked about the influence of the Manchester machines in the technological development. Were there some others? For example was there anything learned from the SAGE computer?

Amdahl: Yeah, actually I never learned anything from Manchester. I learned it via SAGE. A friend of mine Mark Asterham [ph?] worked with me in the early days when I was doing things on the Conceptor, programming that, and he was moved into SAGE project and he talked to me a little bit about their indexing and I think we talked on that subject for probably 15 or 20 minutes and I thought about it afterwards and I thought I didn't really want to do it quite that way. I wanted to do it in a some what more generalized way and that's what we put into the 704.

Aspray: And how similar were your designs on the 701A and 704 for floating point from your Wisconsin experience?

Amdahl: Well my floating point from the Wisconsin experience was a bigger word length. There we had- I had 50 bits. Here I had 36 so it was a question in my mind as to whether or not 36 was really an adequate word size for computational purposes, but I thought well it's at least marginally close and I'll put in some capabilities to do double word length if you really needed that so I put those things in and the of course I used all the thinking I had done on WISC in putting it into the 704 and I also did things in the way for instance indexing didn't cost any time on the machine. The reason it didn't cost any time was that the way it was organized for the 701 there was enough time in the time you brought in the address you were going to modify you could get the index value to be added to the address in the instruction in the instruction cycle. I carefully analyzed that and found out you should be able to do it and it did work. So it was the only zero time indexing that I know of.

Aspray: Stepping back from the details of the project what did the 704 project, 701A, 704 project mean to you, your knowledge of computing, your career?

Amdahl: It made my name. I don't know how much new knowledge it gave me except I did some interesting things there that I wanted to put into the 709 that got in to the 709 but not into the 704. One of them was the channel. The other one was table lookup capabilities which allowed you to do decimal arithmetic in a binary machine by doing binary arithmetic.

Aspray: So I understand that while you were-

<crew talk>

End of Tape 2 / Beginning of Tape 3

Aspray: So I understand that the development of the IBM 709 mainly occurred after you'd left IBM for the first time but that you were responsible for the early design on this project. Can you speak to that?

Amdahl: Yes it was a plan to do an improved 704 to provide some new facilities in terms of the functions that could be performed by the machine and also to improve the I/O capability which involved the addition of channels, so the channel was probably the biggest improvement. With that channel we were able to read a series of records and from tapes, do sorting on the addresses used by the channel instead of on

the data. We'd only look at the one part of the data and then instead of moving the data to do the sort we just moved the address to be used by the channel that was writing out. And so we were able to do sorting in the 709 less expensively, remember it's a more expensive machine, but we could do it less expensively than the model 703 which was designed to do sorting and collating for the U.S.…

Aspray: Census Bureau?

Amdahl: No, handling the monetary part for the government.

Aspray: I see. So that probably meant more sales of this machine over time?

Amdahl: Yes, I don't know how many 709s were sold but it was- it was very effective product and was followed by the 7090 and the 7094 which were the essentially that machine probably expanded a little in functions but principally using technology that was developed for Stretch.

Aspray: That's a good transition. I wanted to ask you about the Stretch project. It's a project that started just before you left the company for the first time and was still going at least in terms of product development when you returned later. Can you talk about this?

Amdahl: Yeah it was going for a year before I left. And it started with myself and John Backus how to get a machine that would go even faster and so we were investigating look-ahead capabilities, and John was a strong contributor in that and between the two of us we were able to get that going in such a way that we could keep the instruction- the execution mill pretty nearly running full time. And we made a proposal to Livermore for the procurement they were making for what they called the LARC, Livermore Automatic Research Computer. Sperry Rand was competing with us and Sperry Rand my understanding was that the proposal or the procurement was really based on the Sperry Rand proposition to them in the first place, and although we had a good response I think it was really-

Aspray: A foregone conclusion.

Amdahl: Yes, but Livermore, I mean Los Alamos became interested. We went out and presented to them and they got very excited about it.

Aspray: Were they an active partner in the design? Did the set specifications for you?

Amdahl: Not for me. They may have done something after I left but not before I left. But after we presented to Los Alamos, maybe two months later Red Dunwell came into the scene and he was interested in that, and he wanted to make the machine structure a little different where you would have an instruction initiating unit that was really a commercial processor followed by a mill that did the scientific computing. And that way you get two machines out of one project and I thought about that for quite a while and I told them that I can't see any way to do it and get the performance that we need and we just sort of had a kind of a running battle. And then one day I was invited to come and listen to a proposed

reorganization of the Poughkeepsie engineering labs and what they were going to do was put the machine projects in what they called a matrix organization where you had managers of the programs for the different machines and people with responsibilities for different functions in the machine and Dunwell was to be the manager of the program. I was to be on the head of the design team to do it, and I knew right away that I couldn't do what he wanted to do and come out with a machine that I would like so I didn't respond to, I didn't give them any kind of response to what they told me. I was there alone so they were really curious I'm sure as to what my response would be. I just went back to my office and I called Ramo Wooldridge and asked if they could use another man. They gave me an offer over the phone on the spot and I took it and left a note for the Nat Rochester, my boss. I told him that I was resigning from IBM.

Aspray: What was the response from IBM?

Amdahl: They wanted to keep me but they were they wanted still to put in that matrix organization. As far as I was concerned they could have the matrix organization that was their call, but me was not their call.

Aspray: And why did you choose Ramo Wooldridge of all places?

Amdahl: My brother was there.

Aspray: I see. They'd been doing any work on a lot of military contracting, right? And aerospace work?

Amdahl: Yes.

Aspray: And how active had they been in the computing field?

Amdahl: They were doing little computers. Matter of fact I ended up designing or doing the plans for quite a number of their proposals on computers. They were even considering maybe going into competition with IBM and I told them seeing the state of what they had that they shouldn't bother doing that. But I did the initial planning for their one computer they did make. I did planning for some airborne computers that would be built and put into fighter planes for being able to control, maximize their capabilities in a dogfight. And this required getting some very new concepts in for how to generate signs, cosines and all of that for maneuvering to make sure that you didn't have a radius and curvature more than the wings could withstand or the pilot and yet project where the enemy plane was going to be and where you should be in relationship to it in order that you maintain the upper hand.

Aspray: But I take it you weren't very satisfied at Ramo Wooldridge either.

Amdahl: No, I'd wanted a project and I was there for about four months and they had a raise. My raise was like one percent because I hadn't been there for as long as the others, but I couldn't have a project. What they called me was their Utility Outfielder and I just felt out. So I decided that I wasn't going to feed that proposal mill anymore.

Aspray: So what did you decide to do?

Amdahl: I went to a company called Aeronutronic where I had a good friend from college days. He'd been working on me for some time to come there.

Aspray: Who was that?

Amdahl: Harold Hall he was Vice President Xerox PARC as a matter of fact.

Aspray: And Aeronutronic was a newcomer.

Amdahl: Yes, it was a company that was founded with money from the Ford Motor Company and then acquired by the Ford Motor Company.

Aspray: What was their mission?

Amdahl: Their mission was aeronautics, nuclear physics, electronics, and missiles or space vehicles. And I worked in the computer part and also did quite a bit of work in the space part for tracking instrumentation for the White Sands Missile testing set up. I was able to make a linear tracking problem out of what was a very nonlinear otherwise.

<crew talk>

Aspray: So tell me about the most important projects that happened while you were at Aeronutronic.

Amdahl: Well we did an awful lot of things at Aeronutronic. As a matter of fact life was quite grueling. We used to go very frequently to Washington D.C. to talk with potential customers. I'd catch the redeye at midnight, arrive in Washington and shave and wash and change shirts in the lavatory in the airport there and then we'd go and see the various military customers. We'd do that until their close of the day, rush back to the airport, catch the plane home and get home about midnight. Next morning at eight o'clock be there writing a new proposal. And that kind of got on my nerves. I decided that life was really not the sort of thing I wanted to be in very long and that's when IBM began to get to me.

Aspray: Before we go on and talk about the IBM story, could you tell me about the project for the FAA?

Amdahl: Well for the FAA what we did was make the data entry system for all the flight plans so you could sit down at this console and present it on the screen, a form to be filled out and you could set your position that you were going to type into a cursor, and you could just type in your flight plan. And send it at the end. Your entry not only showed as displayed letters on the screen but it also had the code to send over the wire so you could it would wire this the things that you entered directly to the FAA.

Aspray: Was this put into operation?

Amdahl: Yes.

Aspray: And used for how long?

Amdahl: I don't know how long it was used but I know it was used for quite some time in their test facilities which were in New Jersey.

Aspray: So you're one of those small number of people who worked at IBM more than one time. How is it that you went back to IBM in 1960?

Amdahl: Well all during the time that I was away, IBM would or people from IBM, Bob Evans mostly would contact me and encourage me to come back and even went so far one time offering to provide support for a startup company. And we were sort of thinking of taking it except that between the three of us that were working on that company <coughs>, we ended up having a slight falling out and so we decided it wasn't going to be a wise thing. We could work together nicely but we couldn't decide who was going to be boss.

Aspray: So then Manny Piore was appointed to be Vice President for Research and Engineering I believe.

Amdahl: He was Chief Scientist.

Aspray: Chief Scientist. Okay and he played a role in your return.

Amdahl: Yes. He decided the one to work on was my wife. He was married to a woman who was part of the Romanov family. And the Romanov family had a leading restaurant in Los Angeles and so he invited my wife and I to come there for dinner and he and his wife were there and we were treated like royalty. My wife decided we got to go back to IBM <laughs> which she had wanted to do all of the time. She also didn't like the schedule I was on. She liked the security of IBM. And I decided the proposal he made sounded pretty good, that I would go back to the east coast for a minimum of five months and a maximum of seven. Then I come back to California.

Aspray: As an IBM employee.

Amdahl: As an IBM employee, uh-hum. Well it ended up I was there for four years and then I got back by negotiating with Stanford to be a visiting professor for a quarter and then informed IBM I was going to go back as an individual or as an employee of IBM, it was their choice.

Aspray: So they chose to keep you on as an employee and you got to relocate here to California.

Amdahl: That's right.

Aspray: Was there any sense of your having been disloyal to have left IBM in the first place? And therefore there were some concerns about hiring you back?

Amdahl: I don't think so because they worked all of the time I was gone to try to hire me back so and they understood why, and in retrospect they may not have ever made that organizational change.

Aspray: So it had been four or five years that you had been gone. Had the conditions within IBM changed sufficiently that it was a new different and more satisfactory place to be?

Amdahl: It was a new and different place, probably less satisfactory because it became somewhat more bureaucratic. Before when I first went there IBM was a company of entrepreneurists, almost free agents in many respects and it was much more difficult to be a free agent the second time.

Aspray: What were your assignments when you went back?

Amdahl: The first thing I was assigned to do was to be in research which was run really by Dr. Piore, and in research I was to be responsible for developing a new scientific computer, what's it called, Project X and I began that project working with John Cocke and Elaine Boehm and we ended up with the three of us doing quite a bit of work on how we would organize it. Actually showed quite a bit of promise. It was a stack machine and in the meantime they decided to make me head of one of the six departments of research in which they had essentially three projects going: a software project which was kind of amorphous, sort of a thinking group with about three or four people in it; another machine project which was really to be a commercial machine which it had a very complex instruction set so that you really almost stated things like you would state them as a human telling a clerk what to do, and but the clerk understood what he was supposed to do as long as you used the right word. And I concluded they really didn't have any way of measuring how well it could work. The other thing that they were doing which was quite a large project was supercomputers, super conductors to make a computer, and one thing was quite clear, there was no way to produce any power gain anywhere in the system. And it took quite a bit of power and you had to remove all of the heat from it and it was it would have been a very costly sort of thing. It would go fast, but you couldn't make it very complex before it would have to expand significantly in complexity in order to compensate for not having the power gain. And I decided that was not a reasonable approach for a computer and so I really insisted that it be discontinued.

Aspray: My understanding was that that was quite a disappointment for the company that there had been a great deal of hope and significant investment in this area. Is that right?

Amdahl: That's right. And I didn't realize this myself. I had a very close friend that was also a theoretical physicist from the University of Wisconsin at the time I was there and I talked to him about it and he and I were in complete agreement that it couldn't be a practical solution.

Aspray: So when you'd first gone back and you were working in research, you were located in Yorktown or Yorktown Heights, is that right?

Amdahl: Yes.

Aspray: But when you took on this new responsibility for running the division was that the time that you moved out of research?

Amdahl: No I was in research.

Aspray: You were still in research at this point.

Amdahl: Uh-huh.

Aspray: But at some point within a year or two you moved to Poughkeepsie again.

Amdahl: That's right. That's when System 360 started.

Aspray: I see.

Amdahl: But while I was there at research the company also decided they were going to move out of the New York headquarters sent them in Armonk so we had the president of the company move his offices to Armonk I mean to their research center. One nice little story from that, one of the researchers was sitting on a bench along a walkway where you'd come from the parking area to go to Mr. Watson's offices. And this researcher was wearing a shirt that was short sleeved, I'd call it a Hawaiian shirt, sandals, had a beard, shorts and a bank president was being ushered in by his regional manager. And the bank president saw the guy and said "Does Mr. Watson really allow his employees to dress like that?" And I just admire what that regional manager had to say. He said "Oh Mr. Watson likes his wild ducks provided they fly in formation." <laughs>

Aspray: Another thing that was happening at this time was the SPREAD committee was formed and they prepared a report which I guess was completed in 1961. What affect did it have in the company and what affect did it have on you?

Amdahl: Well at the time it was being done I was in research. I was called up to give one short talk. I guess I spoke for maybe 20 minutes to the SPREAD committee. I would hear a few leaks now and then

about what was being presented and I didn't really think too much about it at the time. There was another project on a computer that was being proposed in Poughkeepsie that was being worked on for some time, and they were wondering whether or not they should really put it out. You may know the name of that machine project.

Aspray: This was the 8000 series?

Amdahl: Yes, the 8000 series. And they sent some people down to present it to me at research. I listened to their presentation and I decided that it shouldn't be anything they do because it couldn't be significantly anymore than just the rate at which technology could improve. It couldn't be made any cheaper unless technology got less costly because it was too complex, most of it using a lot of memory cells to hold what information you'd like to have in registers. And so you couldn't really ever afford to put it in registers and you couldn't really get any performance if you put the last of the registers back in memory so I said it really shouldn't be a machine. So they canceled it.

Aspray: The machine had had some quite strong proponents, however.

Amdahl: Oh yes, one was my boss later. The other one worked alongside of me and then just under me.

Aspray: So you're referring in the first case to-

Amdahl: Fred Brooks and there was Gerrit Blaauw. Both very capable bright people.

End of Tape 3 / Beginning of Tape 4

Aspray: The 360 system of computers at IBM: We've talked about one challenge to that being the 8000 series. Another challenge seemed to come from John Haanstra, who was very proprietary about continuing self-determination for his small computer division at Endicott. It seems on the face of it to be a surprising choice for him to be the chair of the SPREAD committee, given that that's what eventually led to the 360 system. Do you want to talk about that?

Amdahl: I can only shed light on it from the little bits and pieces that I learned afterwards. John Haanstra, I understand, was made chairman of that committee in order that he would feel locked into executing the decision of the committee. So it was really a political maneuver with the basis for it being essentially technology considerations as well as market considerations. And he didn't like the outcome, but he signed off on it, and he tried to make an end-run later, where he wanted to do an accelerator on the 1401 successor; I think it was the 1410 or something like that. It might have not been there yet, but it was-- anyway, he was going to do an accelerator. And that turned out to be the basis for putting in emulation features in the 360. Actually the suggestion came from the people at Endicott that were in charge of defining the model 30. And they felt if they could only make it run the 1401 programs reasonably easily, they might be able to fight that accelerator. And by putting it in there, they were able to

show that they could out-perform that accelerator version that John Haanstra was trying to push, and that killed John Haanstra's run-around plan.

Aspray: I see. Historians today think of the SPREAD report as extremely influential, as though it was what changed the course of the IBM company. But I've heard recently that maybe the report was just a window dressing after decisions had been made. Can you speak to that?

Amdahl: I never actually saw the report. I didn't care what was in it, really. There was one thing that was binding from that report, and that is that we use an 8-bit byte, and that we address to the byte with the address capabilities of the machine. That <inaudible> a consequence fitting were lengths, things like that, that would make-- you almost had to make the words binary quantities of-- powers of two, that is-- of the byte. And so it gave you a 16-bit-- it gave you an 8-bit, 16-bit, 32-bit, 64-bit, and sometimes 128 as a later addition.

Aspray: Now, had you wanted to look at the SPREAD report? Would it have been available to you?

Amdahl: I don't know. I never asked to see it. The SPREAD report called for machines being upward-compatible-- a family of machines being upward-compatible-- and I was asked by Bob Evans to come, and he wanted to recruit me to work on it. I was in research at the time, responsible for Project X. He asked me to come to Jug End, where he was having his annual budget meeting, and he would find time to talk to me in between some of the budget requests. Well, I sat there and listened from the beginning as each member of the generations of each of several different machine families-- the people responsible for them requesting funds for adding, for example, a new tape drive. Each of the generations members required an engineering budget to modify those machines to attach the tape.

Aspray: So let me see if I understand what you're saying. So there's a 700-series of machines. There are three generations of them. Each of them needs its own peripherals, and therefore each needs its own engineering budget, because they're all incompatible.

Amdahl: That's right.

Aspray: And then there's another family, and then yet a third family, and so on.

Amdahl: And then also with them is software to support it. It had to be done for each member. So you had two different projects, software and hardware, for each generation of each family. And it was a nightmare. It was quite clear that that couldn't go on probably for one more generation without running out of people or money. And I listened to this all morning, and after lunch, Bob had a short break of about-- less than half an hour-- to talk to me. And I decided he had really done this to set me up. But he wanted me to head up the design of these machines. Not the 360 program, but the design of the members of the families, architecturally, and the initial data flow so we could have the right cost and performance for each member of the family, and also to do the initial work on the software. The latter one we never got going. But I told Bob that I would take this job only if it was downward-compatible as well as upward-compatible, because otherwise we'd be in that same boat but for one much larger family.

Aspray: That is to say it would be just identical situation to what it was with the different 700 machines and the different--

Amdahl: That's right. Not complicated by different families, but you would, in effect, have five different families for five products within-- since they would have been upward-compatible, the bottom one was not compatible with the top one. The top one was compatible at the bottom, but not the bottom one, though they would have been different families all the way along.

Aspray: And did Evans agree to this?

Amdahl: He did. He agreed to it. He only thought about it probably three or four minutes, and agreed to that.

Aspray: And how much of a concession was this? How much of a problem did this cause in the design for the family?

Amdahl: I don't think it caused any problem. It allowed you to make one set of functions that you wanted to build in, and along with that, only the different data flows-- actually for six machines.

Aspray: So why don't you go ahead and tell me about the actual process of doing this work on the 360.

Amdahl: Well, I went in there. I reported to Fred Brooks, who had responsibility for the project. Under him there were four functions. I had three of them, and a person from marketing had the other, which was market requirements. And under me was Gerrit Blaauw, who was really Fred Brooks' choice to be in charge of the design. And so that caused a bit of friction. And I didn't really like the Gerrit Blaauw designs because they were too complex. I wanted something simple that you could put into registers at the high end, and into memory at the low end, and so be able to keep the costs in line all the wall along. And the performances should match with the cost.

Aspray: You were telling me earlier a story about that, a little anecdote. Will you tell it on tape to us?

Amdahl: Okay. One of the guys I had on my staff at that point was one who had worked earlier on the 8000 series. When I was laying out how we wanted to set it up so it could be in registers at the high end and in memory at the low end, he said, "Well, normally in a serial machine, 40 percent of the cost is in the data flow and 60 percent in controls. When you put it in as a parallel machine at the high end, you have about 60 percent in data flow and about 40 percent in controls." But he said, "If it's a Blaauw machine, you have 60 percent in data flow and 60 percent in controls." And that was really the problem in the 8000 series.

Aspray: Now it seems very strange to have Fred Brooks in such a high level of responsibility on the 360 project, given that he was such a strong proponent for the competing 8000 series.

Amdahl: Well, he was a good manager. He just didn't have his prized designer in charge of the design. And Gerrit Blaauw was an excellent designer; he just wanted things more complicated than I thought we could afford if we were going to try and make a family of machines that were compatible.

Aspray: So tell me about how well IBM succeeded with its design intentions for the 360 series.

Amdahl: Actually, I believe that the family we had met, so far as I know, all of the expectations that the management had for it, possibly better than they expected. The project was a struggle in terms of I didn't want to continue with the 8-bit byte. I wanted to make it 24 and 48 instead of 32 and 64, on the basis that this would have given me a more rational floating point system, because in floating point, with the 32-bit word, you had to keep the exponent to just 8 bits for exponent sign, and to make that reasonable in terms of numeric range it could span, you had to adjust by 4 bits instead of by a single bit. And so it caused you to lose some of the information more rapidly than you would with binary shifting.

Aspray: Would you like to speak about some of the issues relating to the operating system in the 360?

Amdahl: Well, yeah. We had the three software people that had been in the operating system area, and they were to provide input on how we should structure the machine to have the best relationship to the operating system for adequate control and as simple as possible. We didn't get any input. We tried just-- they couldn't seem to tell us what they needed. Later, before 360 was announced publicly, I was sent around to several places that were considered as bellwether accounts, to see-- or really to get them prepared to accept this machine, get them to essentially bless it. Well, I think the first one was the Rand Corporation. And there I spoke to the three top people in the software-- well, both hardware and software. And I started describing how we'd set this thing up so that we'd design it from the standpoint of the technology available, the functions we wanted to put in to serve across the board, from commercial through scientific and so forth, and we also had included the software people to provide input on the structure for operating system control. And I noticed a strange look appear around the eyes of the top men in the group listening, and I thought I'd stepped on a rotten plank. So I just smoothly went though discussing what we did without mentioning anything more about software. And I saw him edge forward on his chair. He could hardly contain himself. Finally, after about five minutes, he couldn't-- he broke in and asked me, "What experience did you have with those software people?" And I said, "We couldn't get any input from them." He got a big smile on his face and he said, "That's what I thought." <laughs> He said, "We made a study at the Rand Corporation, and we found out that engineers and physicists by and large like to modify the environment to simplify the problem, whereas mathematicians and programmers like to have a fixed environment in which to set up their structures." And he said, "I would expect they couldn't tell you anything till you had it all done." <laughs>

Aspray: I'd also like to talk a little bit about the machines at the high end of the system, in the particular the models 91 and 95.

Amdahl: Yeah. Originally-- there are two machines that we really need to talk about there: The model 75-- it was really at-- it was slated to be at a performance level, where the technology being used for the lower part of the line had really run out of gas. So it couldn't quite meet the performance goals. I had to work with them in trying to restructure what they did. It helped, but it didn't help enough. They had a very complex structure to try to make the best decisions in terms of when the channels should be allowed to

make and interrupt, and how that would-- when the computer should have a chance to get in. And I asked-- I sat them down and I asked them if the I/O word is there, do you ever let the computer get in? "No." And I asked this about the other channels as well. Well, they had their own pecking order and channels. But between the computer, the computer always lost. I said, "That's what I thought you'd do. Why don't you get rid of the logic you have to tell you that, just only allow the computer to come in when there's no I/O." That took out a lot of hardware. It sped it up considerably. It still wasn't going to be enough. The costs were too high to try to make-- I told them they almost have to reduce the speed of multiply, because it took too much hardware. They did that, and the machine was still faster than it was before, but it couldn't get up there. The costs were in line now, but not in line with the performance-- in line with what it should be for that member of the family. So it turned out to be a fairly unsuccessful member of the line.

Now, the model 92 is a different one. That was our continuation of Project X in the 360 mold. We had a structure which allowed us to look ahead until it almost came out your ears. But one of the designers made some real inventions in how to control it so that you didn't go from registers to an arithmetic unit and back to the registers, back to the arithmetic unit, and so forth. Each arithmetic unit-- each functional unit in the arithmetic section-- had its own latch at the end of the operation. So it could function as a register, in effect. The way it ended up working, you never sent anything back to the registers till the sequence of operations was over, and in effect it made the register set appear to be much larger than the four floating point registers in the machine. It could function as-- it turned out to be equivalent to having more than 16 individually addressed ones. But this was-- we did a very successful job designing this to match to one-quarter microsecond access time core memory with backup storage of three-quarter microsecond. And this was our model 92. Well, I moved out to the West Coast to do my stint with Stanford, and while I was there, Haanstra was made president of the division that was doing 360. He went up and he listened to the technology that was being done for memories, and there was some flat film memory that could be one-eighth of a microsecond, but very expensive. But he thought in this machine, if we put in a one-eighth microsecond memory, it won't need to be so large. The three-quarter microsecond memory will supply the additional capacity. And he went back. He gave orders to kill the quarter-mic memory, put in the flat film. He went back and proclaimed that he'd doubled the speed of the machine. I got a call from Bob Evans about a couple of days later where I learned about it then. Bob asked me how much that would really speed it up, and I did some quick figuring and I said, "Somewhere between 15 and 20 percent. And the cost will make it impossible to really get your market." It turned out that was true. He only got a few machines out. Two model 95s which had the flat film memory; the rest were model 91s with only three-quarter microsecond memory, and very small marketplace. But Haanstra's experience had all been with small computers, where you essentially had no look-ahead, and the speed of the machine was related just directly to the speed of the memory.

Aspray: Was it about this time that you decided to leave IBM for the second time, or was this a little later?

Amdahl: No, that was later. I came out here to teach at Stanford for that quarter. I did some work on the time sharing, and the work was very successful, but it didn't go anywhere because there was nobody to execute it. Then, at this time, IBM decided they were going to set up the Advanced Computer Systems Laboratory here in California. And he sent out Jack Bertram and John Cocke, who were from research. John Cocke had been involved in the Project X before we went up and tried to redo it in 360. And John was an aficionado of 48 bits, which I was also. But I decided after working there for about-- they brought me into it, since I was out here anyway, and I was a fellow, so I could work in anything I wanted to. So I

decided I'd go along with them. And after about three months I decided it wasn't really going to be any better than the 360, and it was going to cost a lot to get the software, because they'd need an entirely new operating system, an entirely new programming for any of the applications. But the word size would have been nicer; I agreed with that. They also wanted to use a lot of registers. They wanted 32 registers, which they felt would give a big improvement over the 16. However, <inaudible> work on the model 92, this _____ got the effective multiplication of the number of registers in the machine by having latches at the end of the arithmetic operations. It was quite clear to me that they would gain very little with their additional registers, and it would take longer to make an access to them because you had to go-- you had to select between twice as many registers. Well, it turned out that I ended up being put in Coventry, because they didn't want me talking to anyone, because I was, from their standpoint-- I don't know what you call somebody who is undercutting.

Aspray: So why don't you explain what you mean by being in Coventry.

Amdahl: No one could talk to me.

Aspray: So how did they do this?

Amdahl: Whenever anyone would come into my office, within just minutes, they'd be called to a meeting. If I went to somebody else's office, within minutes they were called to a meeting. So I could never talk more than about two or three minutes to anybody. But one thing happened. Their top project designer, a really gifted designer, was not very manageable, and he'd gotten into some kind of trouble in Philadelphia and had been badly beaten up. He got out of the hospital, came back, and was recovering from it. But he was still unmanageable, and so they decided the best way to get rid of him was to move him over to me. Well, I figured at least I got somebody to talk to. So I began telling him what I had in mind doing, and it took probably more than a month to get him to understand what it was that I had in mind to do. And he did. He decided, "Looks like pretty fertile territory." So he began to do the logic and testing the number levels to do the controls, and we were able to show that we could do it, go faster than the 48-bit machine, and be cheaper. And that was sort of the death knell for the other computer, because we clearly had an advantage in not having to do our own operating system or application programming. So--

<crew talk>

End of Tape 4 / Beginning of Tape 5

Amdahl: So with the logic designer I inherited, he was the one who had done the timing for the 48-bit machine and designed the critical paths for it. So here he designed the critical paths for our alterative version and did the timing on that to show the improved performance and the lower cost as well. So this was really the basis for a shoot out, which we held. Management from the East coast came out; some six people I believe and we worked for about three days. The 48-bit people had two days and we had one and they had no way of really challenging our work since the work that they were using to evaluate it was done by the same person. So my inheriting that designer turned out to be a very valuable thing. Any way, we won the shoot out. Then we decided we would go and find out from pricing what would happen if we put that machine out in the field. Well they found it'd be a loser, like the Stretch had been and in the

Stretch case they had gone back in history and looked at the technology that Stretch had generated and been billed for and how it'd been used in other machines and they were able to go back and show that the Stretch finally made a minute but positive earnings, which was important from the standpoint of anti-trust position. So here we were with a loss. So we decided, well we'll put in one more machine, see how that goes. We did that, the next machine down on the line, and that came out with break even. So we put in a third machine, and that came out with normal profit. If we'd had a whole family we'd have really been in clover. But with those three machines we went to management, proposed it, and we got turned down on it and this sort of just proved to me at least that the rumors that we'd heard initially, that we were really set up to design a machine, get the technology developed and all of that, and find out that we couldn't bring it out as a product because it'd be a loss leader, which would be a risk for anti-trust, so they could cancel project, take that as a write off, and then use the technology without having the next machine project to have to pay for. So they could more easily be profitable. Anyway, they didn't want to make that a company project, so I told them the only reasonable thing they can do at this point is to close the laboratory down. They thought about that for a while and decided that they really had to <laughs>. So they did close it down. They had a lot of their technology developed so they got most of the benefit I suppose anyway. But I decided I didn't like to be used in that way by the company. And so that was the basis for me deciding I was going to leave.

Aspray: So when you thought about leaving, what options did you consider?

Amdahl: I decided I was going to try to do my own thing. And I had a young man that was in the financial part of the project talk to me and he said he thought he knew how to get us in contact with the venture capital world. Well, he did, but it turned out that period was one of the lowest points in venture capital ever. This was 1969 - 1970. One of a group of our people left the company, went into a startup. There were two other startups going, one in Berkeley, and one down in the Los Angeles area and they had initial funding but they couldn't get any more. We came out and at that low point when they couldn't get any more, and we managed to get 2 million, we were looking for 5, but we got 2 million, which was enough for us to get a good start and we talked to the other groups that had started their company and they were having great troubles, and they didn't want us to recruit their people from them, so we agreed we wouldn't recruit any of their people until they told us they'd given up hope and that if they give up hope, to let us know, and then we would make offers.

Aspray: So were these other two companies in business to do more or less what you were trying to do?

Amdahl: No. One was. Company down in the LA area was doing something called Gemini, which was to do a model 165 dual processor MP. They had only enough money to get started and they couldn't get any more. The other one was from Berkeley, they had a time sharing system and the groups that left IBM had started a time sharing company, both in non-compatible; but we knew the quality of some of the people, so we hired them when they became available.

Aspray: What was your business plan?

Amdahl: Business plan was to make a compatible machine. Just one year earlier, well in July of 1969, IBM announced internally that it was putting its old software in the public domain and was going to price the new software separately and that immediately told me that if we made a compatible machine, IBM

would, if they were not going to violate anti-trust, would have to provide the software to us, because they were not allowed, under anti-trust law to have tie in sales on separately priced products.

Aspray: Of course there was a whole series of litigations against IBM for anti-trust in this period of time.

Amdahl: They stemmed from earlier things. IBM had a very unfortunate fire that destroyed some of their records on the model; I think it was on the model 9195.

Aspray: What made you think you could make a business of this; you didn't have most of the organizational capabilities of a company like IBM. What kinds of organizational capabilities did a plug compatible manufacturer need?

Amdahl: Well, I had some ideas. I had seen what we'd done on trying to get higher levels of integration and I concluded that the whole world was doing it wrong, that when they were trying to make their circuit--chips, they were packing the things in as tightly as they could, which meant they really had a very demanding task of trying to interconnect the circuits on the chip. And just thinking about that problem, almost all of the failures had to be taking place in the active semiconductor area, not in the interconnect area. So if you spread it out just enough, then you could make your interconnections much easier, you could design a chip quickly, and so you could make a much bigger chip as well. And I planned to do that; I presented this to those 22 people we ended up hiring from the group that had left the IBM before us, and they improved on it.

One of the people there came up with the idea of making 25 on a 5x5 array of component parts, resistors and transistors, and leaving space in between paths; four paths by four paths, several wires wide so they could interconnect quite easily that way and make whatever collection of gates they wanted in each of these 25 areas. So we could make a whole variety with one basic chip up to the point of putting the personality on it, which was a great idea, and I noted right away that gee, if they do that, then we can use our printed circuit board routing to route this thing. And that worked just fine. We ended up using IBM 1103s, they're a little industrial machine. We became the world's second largest user of those machines; we used it for routing those chips. But we went to the various semiconductor companies trying to get them to do it for us and we went to Motorola. Motorola agreed to do it because they thought we'd made some breakthrough in routing. They wanted the router first, and then they'd do the chips and we knew we'd never get the chips if they got the router first, and found out what we were really doing. We went to National Semiconductor; they got about 60 people to come and listen to our presentation, as soon as we got done, they said their plate is full. All they had done was get everybody there to hear what we were doing. Then we went to Texas Instruments. There the head of that division called me out; he told me, "Don't do this," he said, "In the first place, it won't work. In the second place, it's the wrong level of integration, it will have no advantage to you, so it was pointless, and the third thing is, you will spend all of your money trying to make it work; it won't work, and you'll go belly up." There was one other company we went to which had been started by a guy that had been part of our group, called Advanced Memory Systems who was doing the first successful CMOS chips for memory. And he ended up doing a lot of replacement memories on IBM equipment and he was doing both the CMOS memory and ECL fast memory and he'd completed the designs for them and he had this design group and no way to employ them. So he agreed to do the chip for us and he made that agreement and some five months later, he delivered the first chips to us. We had analyzed their performance with the 1103 and they turned out the

performance was within 2% of a projected performance, which I was informed was totally accidental <laughs>, but it was heartening nonetheless <laughs> and they worked like a charm. And it was that and a simplified structure for handling the instruction types in 360 that made it possible to make a machine with better technology than IBM had and cheaper to make. And that was the IBM, or most of the world actually thought we were foolish in trying to compete head on with IBM. So it was almost impossible to get money, not just because it was the _____ venture capital but this foolish thing of going head to head with IBM, and they were pointing out that RCA did it but they couldn't match the architecture and that GE had spent 5 billion dollars and were not profitable and Xerox had acquired a computer company and they'd finally disposed of it at a big loss.

Aspray: Scientific Data Systems.

Amdahl: Yep. And here this upstarts, but there was one thing we knew and had put together exactly what we were up against, and what was in our favor, and fortunately one venture capitalist got us two million dollars, they added a half million as soon as they learned that Fujitsu had an interest. Fujitsu who I'd had relationships with for probably three years before- two or three, they stopped by and check every once in a while, how we were doing and they finally informed us they were interested in pursuing what we had. And so they set up a week of presentations of what we were going to do. We got them to sign non-disclosure and non-competitive agreements. So we felt reasonably safe and we presented for three days and then all of a sudden Doctor Okada [ph?] who was in charge of the groups said, "That's enough. We're convinced." They put in 5 million, and we put in an escalation clause; we'd had an escalation clause with the venture capitalists, so that set the price we had to ask Fujitsu. We sent them another escalation clause, and we had a totally unexpected call from Nixdorf.

Aspray: From Heinz Nixdorf himself.

Amdahl: One of his people first, and then he came. He decided right when he came that he wanted to do it too. So he put in 5 million, and that made Fujitsu concerned that they were going to lose their prime position so they put in another 5 million with the escalation clause that was in place <laughs> for Nixdorf and so we ended up with 15 million there, and we got some more venture capital money at that point.

Aspray: I have a whole series of questions for you at this point. Let's go back and talk about organizational capabilities of your startup firm for a moment. So even if you have an excellent design as some startup companies have, there are all kinds of other organizational capabilities you need. You talked about capital now, that it was a problem. You don't have a customer base established, which means you have a harder marketing job than you might otherwise have, and you had no marketing organization set up. You had no manufacturing capability, though you could license this out to be done by others, and there's also a question of leadership. You had been a technical leader all of these years, but now you were starting to run into all of the business side of operations. How did you handle all of these various things?

Amdahl: It was new to me. I handled it reasonably well but I didn't really like it. I wanted the design part, that is the part that always gave me the most satisfaction so I considered myself not a manager, I was more of a thing-a-ger, I could visualize what was happening, and design something. I would visualize what was happening in our organization and work on that basis, but I didn't like to manage

people. People are not always manageable, they have their own mind and they also don't have the same meaning for words. You learn that very quickly; that you tell them something and they hear something somewhat differently. We found that out in spades when we talked to England. But the thing is, I wasn't really a guy that liked to manage at all, but I was the man that understood all of the aspects of what was going on, which was the only one in that situation.

Aspray: So how do you reconcile that problem?

Amdahl: I tried to get people who were managers in place, and I wasn't always selecting the right person, but I did most of the time. The number two man got us involved in doing too many things, and we got stretched a little too thin and we began to slip a bit on schedule. Number four man in the company who had most of the engineering stuff under him, had a man under him that was not really able to do his job adequately but he was kind of the man that this manager liked very well and we had trouble. That caused us probably six or seven months in our schedule, we had to re-do the memories. That caused a real problem with Fujitsu and of course, I was the one responsible for having those people there, and getting that situation so they decided they had to bring in a new Chief Executive Officer, Gene White. We got along reasonably well, except that he was-- kind of shot from the hip. He always thought he could negotiate something to get out of any problem he'd get into. And he was good at it, but he didn't have any long range plans, unfortunately and that was a problem for the company.

Aspray: And how did you handle manufacturing?

Amdahl: Fujitsu became our manufacturer. We had a manufacturing organization. We made all of the first things, but what we found we couldn't seem to do was wire up the big back panel. We used little coaxial and somehow or other even though we made tools to help, the people that actually did the work made too many human errors. It turned out that it worked well to do it in Fujitsu because people there were trained never to make an error. They had this zero defect thing that was really working. So we ended up basically relying on them for that part of it, which served us well in the beginning, but later it trapped us. When we wanted to do the next round of machines for the 580 series, I had worked on a new way of doing a design that was going to cut down the number of boards projected for it by a factor of 7 and it didn't do that. But Fujitsu was the one that was going to provide the technology and they demanded if we took the technology, we'd have to take 75 percent of our requirements from them, which meant that we didn't have a chance of getting a second source. And I knew at that point, if we took that, we would lose our control over costs. And that happened, and I left the company at that point, because I viewed it as, it's now part of Fujitsu; it isn't going to be an independent company any more. And that's turned out Fujitsu decided to charge the same amount per circuit, per gate for this new technology that had four times as much in a chip, so there was no cost saving as far as the transfer price.

Aspray: Right. Would there have been any way to avoid that over time?

Amdahl: Yeah. Not over time. If you took it, you were hooked. We took it. That is what I left over. And I didn't blame Fujitsu over it; I blamed our engineering managers for it. They were much more concerned with being a less risky company and they didn't have any particular qualms about not being an independent company.

Aspray: What about marketing issues, customer support issues, how were those things handled?

Amdahl: Well the first thing we ran into was, I decided we should make a test, and make sure that IBM understands it has to give us the operating system. We were about a year and a half old; we ordered the operating system to go on the machine of one of our model numbers. It took IBM three months to make up its mind that it really had to <laughs> but it worked and we got it, we tested our machine on it.

Aspray: I remember, I think correctly, that there was a lot of concern about your company letting the Japanese and the Germans into the domestic marketplace by the relationships you had with them.

<crew talk>

End of Tape 5 / Beginning of Tape 6

Aspray: I'll start with a question. And gentlemen, I am ready when you are. So in 1974, 1975, there was a lot of concern expressed about whether your new company was really opening the door for the Japanese and for the Europeans, especially the Germans, to enter the home market of the United States. Will you comment on that, please?

Amdahl: Yes, there was that concern and I was called to Washington. I pointed out to them that they made it possible for this technology to come into being. Without them, we had been totally unable to get the funding to do it. And as far as allowing them into this country, they had ownership in our company, but they did not have the rights themselves to come in. Fujitsu was limited, they could not make a machine more than a certain performance level, which in the very first generation we came up with a performance level that they could've had was below the level that where IBM was continuing it's 360 architecture, so it was not a meaningful opportunity for them at all. As far as Germany was concerned, they never had anything more than rights to market our product in Germany. So basically, this big jump in computer capability would've been lost to the world if we would not have had the support of the Japanese and the Germans, because there was no other source of financing available.

Aspray: And did this argument fly in Washington?

Amdahl: It did. I spent probably three or four hours talking to the group that were trying to establish what the situation really was, and they ended up deciding that, in fact, what I had to say was right.

Aspray: Was the concern widespread, or do you think it was something that was coming primarily from IBM?

Amdahl: Well, we think it's from IBM because there was a mysterious paper distributed to all of the relevant organizations in Washington, D.C. mentioning this. And it's my belief that it was probably done by the IBM legal team or one of their law firms that they employed.

Aspray: So let's take this opportunity to talk about what IBM's reaction had been all along. When you got ready to leave IBM and form your own company, what was the reaction you received from various people?

Amdahl: Well, I'd sent a letter to resignation, explained what I was going to do, because I didn't want any misunderstanding on IBM's part. I wanted them to know this is what I was going to do. They couldn't later on make any claims I'd left under false pretenses. But when I ended up with my last interview with the President and CEO, Vincent Learson, then at that point, when I came out of the office, the President of my division, Bansco [ph?], put his arm around me, walked down the hall and told me as a friend, I shouldn't go into large computers because there was no money to be made there. And from experience, he knew this was true, that there was no money to be made there. But it was all a function of how IBM had priced its bottom line, it had nothing to do with reality.

Aspray: So would you elaborate on that point?

Amdahl: Yes. Each machine in the family was about a factor of three apart in performance and a factor of two apart in price. And so when you did a higher end machine such as we would've done in our ACS project, the price I had to go at was related to its performance, and therefore priced out of the market. There weren't enough customers that could put together that amount of money to get it. And so basically, the approach we had with the improved technology and simplified design, we were able to make a machine that was faster and cheaper. We could price it below the top successful machine in the IBM product line, but had a performance competitive with the next member up the line, if they had it there. And therefore, IBM could not responsibly respond to us because if they reduced the price of that machine they had, they'd have to do it all the way down the line, it'd be the domino effect.

Aspray: What would you surmise was how worried IBM was about your company as a competitor?

Amdahl: At first, they didn't have any worries. They believed what they said. But as time went on, it became clear to them that maybe there was something to watch. I've been told that people went into the office of Bob Evans, and around the wall were charts that showed every aspect of what we were doing. I don't know how they got all the information, but they did. They also had two different detail books by their legal organization, seeing if there was anything that we had taken from IBM that we shouldn't have. And both studies came up with we were as clean as a hounds tooth. That's the information I got from one of the legal people. So I know that was correct, it wasn't a rumor.

Aspray: And point in fact, how much did you cut into IBM's sales?

Amdahl: At the peak, we got 22 percent of the large systems market. When we first went out, we shipped our first machine in June. Starting the next January, that full year, we managed to make 30 percent pretax profit, same as IBM was making. IBM heard about this in early January, I suppose somebody in our company leaked it, and by March, they had announced a new machine that was a little faster than what we had and cut the price by 30 percent. I figured they were mowing the grass at ground level. We went to Fujitsu, we talked to them that we could expand our sales if they could give us better pricing. We were able to get our and IBM had put some architectural changes, and we couldn't put the

architectural changes in, but we could emulate them. And we also introduced a lower price version. We ended up being able to match the 30 percent reduction and we again made 30 percent profit pretax.

Aspray: How much of your sales effort was embodied in a feeling of confidence of you personally?

Amdahl: I think that was probably a large part of it. But people still wanted some kind of proof. For instance, in Germany the Max Planck Institute in Munich, I knew one of the people there quite well. He came up with a group and they tested the performance of the machine. This was some six months before we had shipped our first one. They tested the engineering model to see if the performances they'd been hearing were correct. Well, they tested it for about two days and they told me that every number we'd given them was right.

Aspray: And did your tactics as a company involve your taking perhaps a larger role in meeting clients or making public announcements?

Amdahl: Quite a bit, yes, both in the US and in Europe. I think there was one other thing. IBM was trying to discourage customers from using our machines. And so they would not run our machine to test whether or not one of their I/O devices was functioning properly. If we discovered that their tape guide had a failure, they would not run our machine. We had to get one of our people to run it and demonstrate to their maintenance people that was their problem, then they would fix it. We however took a different view. We decided if there's any problem at all, it's going to be our problems, being the new kid on the block. So anybody's equipment, if there was a failure in it, we would do everything we could to help. And IBM's posture backfired on them very seriously. That lasted about six months, after that, they adopted the same approach we did.

Aspray: Did the emergence of other plug compatible manufacturers help you in terms of credibility?

Amdahl: No, I don't think it had any effect. The only other one initially was one that made a copy of an IBM machine from the maintenance records. They just did circuit by circuit identical, but they couldn't get the performance that IBM achieved, because the circuits in packaging that they used was not up to the level of IBM. But it was cheaper than what IBM was charging, so they could be profitable. I can't think of the name right now of the company that was doing this.

Aspray: So if you look back over the years that you were with the company, how would you evaluate it over all? Did you think it was a success?

Amdahl: Oh, I thought it was very much of a success, but I got quite disappointed in how the engineers didn't want to rely on their own abilities. They wanted a less risky situation than being an independent company would put them in.

Aspray: So when you became disappointed, what did you decide to do?

Amdahl: At that point, I had no control over what would be signed or wouldn't be signed. I just was very vociferous and I was being shouted at by our management and by Fujitsu management so much so that I can still see their faces, just absolutely red with anger that I should be fighting this. And they decide to go ahead and do it anyway, so I resigned.

Aspray: And you went on to do more.

Amdahl: Yes. Not immediately, but about a year later.

Aspray: And what did you do?

Amdahl: Well, we started a company called Trilogy [Systems] which we had a new technique in which we could get voting logic that we could fix if some of the circuits were failing, we could correct it so they'd work. And we made one mistake, well, first of all, it meant we really had to change a whole lot of things because we could make a chip that was about two and a half inches on the side. It would hold many more gates than any other ECL chip could hold. But to do something that big meant that you had a lot of heat to dissipate, so you had mount each chip in a liquid cooled environment. The metal that you used had to be something that had the characteristic temperature expansion contraction as the chip did. We had to be able to bond that chip to that metal without having a lot of bubbles underneath, because you had to have the good heat conduction. We solved all of those problems. We tried to make faster gates than anyone had made before. That was our downfall because in doing that, we had longer time to get the Arison [ph?] design to say that leakage pass around where from level to level of the wiring, because we had more layers of wiring. And we had one problem for power distribution on the top. We had to have very heavy wire deposited, heavy metal deposited on it to make it very good conducting. That meant that we had to keep the metal deposition on it longer, it would heat it up more, and so the metal didn't contract at the same rate that the chip did. And so, it pulled the wiring loose, and so we finally solved that problem. We found that if we put a little layer of nickel on before we put the metal on, the nickel bonded better and that held it. So we solved that problem, but we were still getting more errors due to leakage of chemicals in the various process steps. So we had to adjust the masks a little bit. But each turnaround took eight months. We figured we had three turnarounds before we'd have the yield down to the point where we would be satisfied with it. And that was two years, would've used up almost exactly all of the money we had. We decided the better part of valor was not to do that because to get this technology, you have nothing. We couldn't talk to some of the investors. They said, "Don't refund your money. Put it into another company." So we did an acquisition and took the name of the company we acquired [Elxsi]. And they had a pretty good product, but they didn't have very good management. And it didn't succeed. It didn't go bankrupt either, it just used their losses to go into a different business.

Aspray: And you've talked only about the technical side; what about the business side of this?

Amdahl: Well, the business side, we learned about business there. And I'd got the top financial man from Amdahl Corporation and my son [Carl] who had been the designer of the products for Magnuson [Computer Systems]. And we made the financial man the President, which I think was the best role for him. I just took Chairman of the Board. Anyway, he wanted to make it a bigger deal than either my son or I thought should be. So we over expanded, we should not have done it on semiconductors. We should have gone with another company. If we would've done that, the money would've been adequate. We

would've had a product which would've been, I believe, the product leader in that field. But it wouldn't have lasted long, because CMOS came along. Before that, it was NMOS. When I mentioned CMOS memories way back in the early days, it wasn't CMOS, it was NMOS. CMOS is a different story because of very low power. No DC current flows, current only flows when they have losses, when they switch from one state to another. And that's just current up flows to charge or discharge capacitors.

Aspray: So what was the outcome of the company? You said it didn't go under, but it didn't really do very well.

Amdahl: It changed to a company that would exploit the losses and it went into the restaurant business. And they're still going. It's a reasonably successful company.

Aspray: And what happened to your relationship with them?

Amdahl: I didn't have any with them.

Aspray: And what did you do then after that?

Amdahl: I started a company called Andor [Systems]. And we found after going through Trilogy that I couldn't raise money any more. And that was a real problem. So I think we had excellent ideas there.

Aspray: What was your business to be?

Amdahl: Again, an IBM compatible, but this time using CMOS and this would've been in the lower part of the market. We had a design that we built and it worked very well. But we couldn't enough money to do the second turn of the chips to get an even faster version. So we never really quite got a product that was sufficiently better than IBM's to crack the market.

Aspray: So what happened to the company?

Amdahl: It did go bankrupt. But we had signed a contract with another group in Bangkok. And they were to take over the management of the company. They took it over and then their group fell apart. The money didn't come in. I was glad that I wasn't in management anymore, so I just left.

Aspray: I have a series of small questions that are going to go all over the place, but before I ask those questions, did you want to say more things about the various companies you've been involved with?

Amdahl: I don't really have much more to say about them, unless you have thought of something that doesn't come to my mind at this time.

Aspray: Okay. Well, let's go back to your IBM days. And there are several people I'd like to know about. <inaudible> that question <inaudible>. So let's go back and talk about the IBM days again. I'd like to ask about a couple of people. I understand that you had various contacts with John Von Neumann in your early IBM days. Could you tell us about those and about your impressions of him?

Amdahl: He would come there and sometimes we'd have maybe 20 of us in the meeting with him. Sometimes we'd have four or five. But I was in the meetings with him. One time, I had a chance to tell him he'd made an error. It wasn't very significant, but I and one other man had been having a running debate. He wanted to do controls of a computer just linking wires through cores, and I agreed that you could do most of the things, but there were some things you couldn't do with it. And he never accepted that. So in this meeting with Von Neumann, he took the opportunity to bring that up to Von Neumann and he presented it very beautiful. Von Neumann agreed with him and I raised my hand and said, "No, it can't do this." Von Neumann thought for, it must've been a total length of time of about a half a second, and he said, "You're right," and that ended the debate on that. The other things in the meetings, he talked about things like using log rhythms and exponentials, instead of floating point. And I spent quite a bit of time analyzing that afterwards on my own and decided you couldn't match the performance of a floating point. But it was an intriguing way of looking at it. He also was trying to market to IBM in his consulting meetings. His subharmonic logic and the only outfit I know that used that was Fujitsu. They made a machine, and the man that I worked with most of the time, Dr. Okada, actually was in charge of that project. They made it work, but it went slowly and it cost a lot and it took an awful lot of power.

Aspray: Do you have any sense that Von Neumann made any difference in product development or research at IBM?

Amdahl: Not much. But everybody was happy to see him, including me.

Aspray: I'd heard that one of the functions that he played at IBM was that Watson Junior was more confident because he had him there as a consultant.

Amdahl: I'm sure that was part of it. And most of the time, he dispensed pretty wise things. But they weren't necessarily directly relevant to anyone's project. And what got projects going in IBM were people having an idea and pushing it. And what Von Neumann could do was decide that some approach was not a good approach, and that could kill a project. But giving something that was a good approach wouldn't necessarily have any buyer. So he could get rid of some of the less desirable project, but they couldn't really get any instigated.

Aspray: Are you thinking of any projects in particular, or is this comment more general. We're at tape changing, sorry.

Amdahl: More general.

Aspray: Actually, why don't we just stop at that point?

Amdahl: Good enough.

End of Tape 6 / Beginning of Tape 7

Aspray: One of the people that you worked with for a number of years at IBM was one of the earliest women in the field, Elaine Boehm. Could you talk about her background and about what she did in her career?

Amdahl: Yes, she graduated from the women's university that's associated with Harvard.

Aspray: Radcliffe.

Amdahl: Radcliffe. And she was extremely bright. She hated mathematics. She was scared of it as a matter of fact, but she had the finest logical mind. She could have been a great mathematician if she just had overcome the fear. After talking to her in an interview, I was probably the second or third person to interview her, I decided we'd found a real gem there, and I insisted on hiring her, even though there wasn't any support from anyone else for it. But I did more than that, I insisted that we hire her at the same rate that we paid a man at that same position. And every year, when we went through reviewing salaries, I had that same fight. But I managed to keep her salary up to the same level that men had. She was contributing more than most of the men, but it was hard to get that message across. I thought she was just a marvelous person.

Aspray: Can you say a few words about the various tasks she had, things she worked on?

Amdahl: She became-- she was principally in programming, but kind of experimental programming. She didn't really do application programs, except to test whether or not what we were doing was suitable for that application. She was the one that was the interface between our development project on the 704, 709, 90 and so forth, and the user group that used those machines, so she was IBM's representative there. I never went to a single one of their meetings, because I felt she would do better than I could. She was really good.

Aspray: Did she stay with IBM her entire career?

Amdahl: No, she ended up leaving IBM sometime during the period when we had the advanced computer systems project. She went to Raytheon, which was going to do a computer product, and she had been recruited for that. But she ended up being killed in an automobile accident where they were on a divided highway and somebody coming in the opposite direction lost control, came across the divider and hit their car head on. Really tragic.

Aspray: I understand that the Amdahl Company donated the WISC computer to the Computer Museum History Center. Can you tell us, or did you do this personally?

Amdahl: I did it personally. We acquired it from Amdahl Corporation, after we started Trilogy. And we had to twist their arm to get it. We didn't pay any money for it, but we managed to make a trade of something that seemed valuable to them. I can't remember what it was at this time, and they realized that it didn't really belong to them, even though they'd paid to bring it off, because it was really willed to me, and they intervened themselves, not-- I hadn't asked them to intervene, because I didn't even know it was in the will until they completed their intervention.

Aspray: But it-- at some point later, then you donated this to the Computer Museum.

Amdahl: Yes. It was in-- it was in Boston at the time. I donated there, because I felt at least it would be seen there. I had a request from Stanford, and I didn't think it would be seen there. But the Computer Museum seemed the place where it would probably be on display. And then they moved it out here, and the State of Massachusetts became concerned that valuable property of Massachusetts was being given to California, and so I had to write a letter explaining that it was my property, it had been put there for display, not for any other purpose, and it was being brought out here, because this was where it would remain on display, whereas it would not be on display in Boston.

Aspray: I wondered if you wanted to make a few general remarks about the state of the field, about the importance of computers in our lives, those kinds of--

Amdahl: Let's start out way back in the beginning. People were using desk calculators, or sometimes plug board computers. IBM had a multiplier. This could be used in doing some of the scientific work, where it was just excruciating to do it manually, and you had trouble with human error, so you'd have cross footing and things like that, to determine whether you had an error, conservation of energy and momentum, and physics problems and so forth that you keep running along with it. And having a computer do it, reduced those errors a lot, except when there were failures in the computer components, or noise or sometimes change a value. But you used the same checks that you would use manually for the early computers. And what this really did was it took out all the tedious, very demanding human clerical activities that were involved in doing those things, both in the scientific and commercial worlds. One of the big problems was doing payrolls, and this improved the accuracy of doing payrolls and the time it consumed and the cost of doing payrolls that turned out to be one of the big things initially, and that caused kind of a furor in the populace, because they felt they were losing jobs. Actually, it increased the number of jobs, because more could be done by the companies and they also had to hire a lot of programmers. So you had a whole new kind of workforce, and replaced a lot of others that were much lower pay category. So I think it improved the economic times for the people involved in most of the corporate work, so I think it increased their incomes.

The next thing it did was allowed you to get solutions to scientific problems that you couldn't really consider doing before, and allowed you to understand what was going on, let's say, in star systems, things of that nature, in the spread of pollution through the atmosphere, or water. All of these things, you could analyze, for instance, what you could expect from erosion along a river flow, because the thing that happens, if you have a steep slope, the river winds a lot. That's so it can lose energy. It has to lose the energy if it goes down. It will also make the base of the stream have humps in it, just as a mechanism for slowing it down. And this can be analyzed, and you can get the statistics that will tell you what you should expect for any given slope. But it takes a computer to do this sort of thing. It also allows you to determine

what happens in flood plains. Now we may be able to do enough to tell something about earthquakes. We've done quite a bit on the atmospheric effects, we can understand a little bit more about tornadoes, but we don't know how to control them yet. Nor do we know how to control the hurricanes. But maybe someday we will, if we can compute enough and find out what small events can change the course of history. These are kind of chaotic things. A little thing can cause a big change.

Aspray: When the first numerical weather forecasting was being done out of the Institute for Advanced Study's project, Von Neumann was working on, Edward Teller was a close friend of Von Neumann's, and he had suggested seeding clouds to dissipate certain amounts of energy, to keep storms from hitting the coasts of the United States, the most severe storms.

Amdahl: Yes, this would do that, except the amount that you would have to put there to seed it would have been far greater than what you would-- could afford to spend on most storms. But the-- it's absorbing the energy, actually from the heat of the water in the ocean, and that's what you have to counteract. It would take an awful lot of ice to do that.

Aspray: Are there other things you'd like to say?

Amdahl: Well, the other thing I'd like to say is that we went from ECL, vacuum tubes, to transistor circuits that were strictly amplifier-- equivalent to a vacuum tube, but done in semiconductors. Then ECL, for high speed, and then finally to CMOS. CMOS has been the king for this-- the whole decade of the '90s, and is now up to the performance levels. They're very close to what you could have gotten from ECL, if you could find a way to dissipate all of the heat from ECL, and the cost of putting all that hardware in place. But CMOS will run out of gas in about eight to ten years, and I don't see anything yet, that's going to replace it. I've heard proposals on using the states of molecules in a liquid, things like they do when you go to the hospital and they take a scan, using-- put you in a magnetic field and apply radio waves, and they're doing what you call spin echo. That spin echo can do computing, they've demonstrated that. I don't think it can do it in a way that's competitive or-- with high end computers today. I hear people talk about doing it with light, so same sort of things we use for transmitting over glass fibers, but I don't see anything you can put on a chip that's going to be small enough to work at the densities you will even achieve with CMOS. Although you might be able to carry information faster through the glass fibers than you can through metal, you will be able to do that, because you can go at about three quarters of the speed of light in a vacuum. But you don't get anywhere nearly that speed in metal on the chip. But I don't think you can get the densities, and if you can't get the densities, then I don't think you can get the cost. I don't think it's going to really be a replacement. Another one that they are working on quantum devices. If you get down to it, the quantum devices are not really stable. They have a lifetime in a state, an expectation that it will be there for a certain length of time, but it might be there less than that, or it might be there longer than that, so you put in voting or something like that, and you find out, to get something that really is stable enough to do good computing, you're probably going to have a collection of these which are taking as much area as the CMOS takes at that limit. So I don't think you're going to get the density. It's also virtually impossible to find a process that will allow you to manufacturer them without doing it one atom at a time. So, so far as I'm concerned, the future, past that point, is, as yet unknown.

Aspray: Thank you. That's it. Super. Good job.

END OF INTERVIEW

