Oral History of Bob Garrow

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Kapoor: Well, on behalf of the Computer History Museum I'd like to welcome Bob Garrow, Sr. for his oral history interview. My name is Uday Kapoor. I'm a volunteer in the Computer History Museum's Oral Histories Program and along with me is Dane Elliot, my colleague. So welcome, Bob.

Garrow: Thank you. Glad to be here.

Kapoor: Bob Garrow, Sr. is a senior executive in the Silicon Valley with an illustrious history. He was born in 1942 in Antioch, California and grew up in Stockton, graduated with a BSEE from U.C. Berkeley in 1965. He worked for Lockheed, Intel and before co-founding Convergent Technologies. Then he joined Sun Microsystems in 1986 as VP and Manager of the Workstation Division. He left Sun after four years of extreme growth. He left as VP of the Worldwide Manufacturing and he tried retirement, which he didn't like. He then co-founded Liquid Computing in Ottawa in 2003. After a long struggle, the company as Bob would say, snatched defeat from the jaws of victory. He has been a consultant ever since and is still active in the industry. With that, welcome, Bob.

Garrow: Thank you.

Kapoor: We'll get started from your early life. You were born in Antioch as I said earlier, grew up in Stockton and your ancestry, interestingly, Italian grandparents on one side and Scot and Irish on the other. So that must be an interesting mix. Can you tell us a little bit about your background?

Garrow: Well, that was an interesting mix. I grew up at a time in the fifties which is represented fairly nicely by the movie "American Graffiti." Stockton is a town in the Central Valley here in California. I think the film was made in Modesto, which is 20, 30 miles south of Stockton and life was simple but life was very pleasant in those days. I was a part of the first generation of my respective families to go to college and get a degree. My Italian grandmother and grandfather had a small farm outside of Stockton. The family used to refer to it as a ranch, but it was a small farm. Hardworking people, big family and I cherish my childhood memories from those days. On my father's side, my grandmother was Irish, and my grandfather was Scottish. They had a small local grocery store, a little tiny grocery store that they served the community with. I didn't know my grandfather well at all. He passed away when I was quite young. But I remember my kindly, hardworking Irish grandmother. And, somehow, I think I inherited a lot of those hardworking genes, because I've always enjoyed working hard at what I do. But in my high school years I was a little lackadaisical when it came to studies. I enjoyed sports. I enjoyed playing basketball most of all, even though I was the shortest guy in my class for many years. I enjoyed football and baseball. But I didn't really take my studies that seriously, but I just couldn't help but notice that math was easy for me. I enjoyed my math classes. So somewhere along the line of probably my junior year, I discovered physics and I had my first physics class and I just, I really liked it. I loved it. So I started taking a greater interest in my math and my physics classes and in my senior year, I finally decided I wanted to go to Cal, but I clearly wasn't going to be able to present the grades I needed because of my lackadaisical years in my <laughs> early part of my high school career. And so, I applied and got into the City College there, which is known as Delta College in Stockton. And I spent two years there and was inspired by two teachers. One was Mr. Clark, my physics teacher, who was a-- he prided himself on teaching his physics class as if

it were being taught at Cal. And it was a tough class. He hadn't given an A out ever in his entire tenure at Delta College and very few Bs, but I later benefitted from that rigor. My math teacher, Mr. Simley, was a second inspiration for me. He was the kind of teacher that just loved his subject and he, it was a, he just made it fun to come to class. And I remember just really loving Calculus and differential equations, partial differential equations. And talk about being a geek, I loved to do power series solutions and if you've ever done those, you know, you go through reams of paper, you know, statement after statement after statement. And I was always amazed at the end of that process when the solution actually dropped out. Then I really thought I had my first love figured out which was math.

Elliot: Bob, what was the high school you graduated from?

Garrow: Amos Alonzo Stagg High School. Amos Alonzo Stagg is known as the father of football. By the time I was in school at Stagg, he lived in Stockton, actually, and he was just, he was a kindly little old man with white hair and his wife was still with him and he was kind of part of the pride of Stockton and people really liked to have him around, so.

Kapoor: So, after the junior college you were looking to go to university and you selected UC, I guess, and you studied hard and you got into UCLA.

Garrow: Well, yeah. In order, I'd had to take the upper division entrance exam because I wanted to enter UC as a junior. And it was a, I remember it was a two-day rigorous effort. I had about eight total hours of testing. And I did well and but what surprised me is that it wasn't my math scores that were the highest, it was my physics scores, so I have to thank Mr. Clark for giving me that skill. And I did get in. I did pass the test and I was accepted at Berkeley. But at that time in my life, I wanted to get a little bit further away from home and so I requested a transfer to UCLA and I spent a year at UCLA and it was a lot of fun, I have to say that but it was hard to keep up with your studies but because it was <laughs> so much fun. But actually, though, I discovered that the curriculum at UCLA was a little too general for my interests. They required a lot of Civil Engineering courses, et cetera. I was still very interested in math and so I returned to Berkeley after that year at UCLA.

Kapoor: I understand you also got married.

Garrow: Yes, I did. I married my high school sweetheart, Roberta, the day before classes started in my first year at Berkeley. We got married and I went to work, completing my bachelor's degree at Berkeley. She helped out all the way along. She's one of my biggest inspirations because she has always given me the confidence to move to the next step and I thank her for that.

Kapoor: Does she also have a subject that she studied?

Garrow: Yeah. She was an English major and a Communications major.

Kapoor: And I think you had a son very soon after that.

Garrow: Yes. Yeah. That was-- That was by today's standards, we were fairly young, I have to admit. I finished, and in my senior year at Berkeley, my son was born. But the circumstances were that I had to take my finals and Roberta went back to Stockton to be with her mother and I was in Berkeley taking my finals. And the day I completed my finals I drove to Stockton. The next morning my son Bob, Jr. was born and that was the first semester of my senior year at Berkeley and I graduated six months after that.

Kapoor: After your graduation I understand you elected microwaves as your subject.

Garrow: During my upper division I elected microwave. I enjoyed the math. I thought that would be pretty intensely, pretty math intensive, so that's what I did. But in my senior year I decided that I didn't want to continue because I had this senior lab at Cory Hall, and I spent hours and hours bolting wave guides together. I decided then that I wanted to finish my specialty and complete it but I decided that I wanted to go into circuit design and that's why I continued my studies at the University of Santa Clara in part. I already had a little bit of circuit design, but it was specialized in antennas and wave guides and things of that nature.

Kapoor: I understand that that basis of microwave theory and so on helped you later in your designs and concepts of designs.

Garrow: Yeah. Yeah, it came back later at Intel. But I think the theoretical grounding that my schooling at Berkeley gave me of stood the test of time and carried me through many different technical disciplines that I have dealt with.

Elliot: You had a couple of job offers, one from Hughes and one from Lockheed.

Garrow: Yes. And having my son when I did, I was highly motivated to get a full-time job. I had previously worked for five years, actually, five summers actually with what was called the Division of Highways, it is now Caltrans, and had some of the best summers and summer jobs ever. But I needed a full-time job so, yeah, I had one offer from Hughes and one offer from Lockheed and I happened to do my interview at Lockheed on a beautiful, gorgeous sunny day in Sunnyvale and I knew Roberta would love it down here and we both did. We've been here ever since. So, I picked Lockheed and went to work.

Kapoor: What was your job like, early job like at Lockheed?

Garrow: Well, I was a circuit designer in a group that was responsible for the flight controls in the Polaris and Poseidon missiles. And I learned a great deal about margin and designing with great margin. Because those circuits had to do their job, which it was an amazing job that they had to do, despite serious degradation from atomic weapon radiation and things of that nature.

Elliot: Extreme heat.

Garrow: Yeah. And you'd design with alphas and betas (transistor gains) that were like almost nothing, but your circuits had to continue to work. I think that work, made me a very conservative designer and I

think that helped me down the road. I remember that coming from my background, I was just going to be very excited to be doing circuit design. I remember being so happy in my first days at Lockheed sitting in front of my desk with a pencil and paper and it was vellum and drawing out circuits to do my job.

Elliot: Now these were the devices you were using weren't integrated circuits at that time, they were individual transistors?

Garrow: It was actually a mix of both. The technology in use back then was DTL. But I had to do a lot of research and experimentation with actual devices, to study the effects of radiation on the circuitry inside the chips. These were little tiny flat packs that were actually welded in a three-dimensional circuit.

Elliot: Yeah, ceramic, flatbacks, welded designs, right. What do you think the date was that you started at Lockheed?

Garrow: It had to be 1965. That's when I graduated**,** June, July? I don't know the actual date.

Elliot: Okay.

Garrow: It was too far back, Dane.

Elliot: Yeah. My background was much like that except I started with RTL not DTL.

Garrow: Well, I have an RTL story, too.

Kapoor: You also participated in the underground atomic tests in Nevada.

Garrow: Yeah, that was really something. You probably know those missiles had to, they're intercontinental missiles and tens of thousands of parts, they had to, fly those great distances and zero in on targets with amazing accuracy. So, the reliability that the whole system had to maintain to do that was just incredible. So, so yeah, we did live testing, underground testing, and I was assigned to lead one of the big tests outside of Las Vegas. I spent, commuted in a sense, and spent seven weeks out in the Nevada test site, which used to be known as Jackass Flats. And that was quite an experience. it was one of last underground test series that was ever done.

Elliot: So that was in the '65, '66 timeframe as well?

Garrow: Probably '66. I was at Lockheed about three years.

Elliot: Is that now known as Alamogordo? Or is that a different test site?

Garrow: I don't know, it has a different name when you hear about it on the news. There's a different name. But I can't remember what it is.

Kapoor: Looks like you were also continuing to educate yourself, you were taking early bird classes at Santa Clara University.

Garrow: Yeah. I wanted to move in a different direction. I wanted, I needed, more digital design background and logic design because I hadn't taken that many courses at Berkeley, so while I was at Lockheed, I took advantage of the Early Bird program at the University of Santa Clara, which was fantastic. My oldest son later, many, many years later, did the same thing. So, I think it's still there.

Kapoor: Yeah, I took classes there too. In fact, I was asked to teach a class there. So, then you moved from Lockheed after three years, to a company that designed instruments for lab testing?

Garrow: Yes.

Elliot: And what was the name of that company?

Garrow: It was called El Dorado.

Elliot: El Dorado.

Garrow: It was up in Concord. I felt I needed to move out of aerospace. I thought I was going to get typecast, if you will, too narrowly. After a while I was beginning to figure things out and so I wanted to do some commercial, I wanted to work on some commercial products. And I'm still a circuit designer. I'm not a computer designer by any means. But I took advantage of this to help me move in that direction.

Kapoor: And you worked on an, I understand, a ten nanosecond time interval meter.

Garrow: Yeah, that was another, I refer to it as, like, a career change motivation. And to your point earlier, Dane, about the RTL, this 10-nanosecond time interval meter was quite a rough prototype. My task was to turn it into something that a little company could produce. So, I wasn't going to invent the thing, but I inherited it. It had a tunnel diode discriminator to catch the edge of the signal. And it had an ECL stage at the front end. Then it went through TTL for a stage, you know that the frequencies were coming from 100 megahertz down, you know. Then it went through DTL and then it ended up at RTL because, if you remember the (output) transistor, it's just exposed to the outside world (open collector) and you can put a load on it. I had to drive these ancient, they weren't ancient at the time, they were contemporary, but those little Nixie tubes. And the instrument had about nine or ten Nixie tubes in front, so it went from ECL all the way through RTL. I had to design a power supply for it and I had to get it working. It wasn't generating stable 10 nanosecond light. That 10-nanosecond light had to be stable, you know; it couldn't be moving around because they couldn't sell the things if it wasn’t stable. So I worked on that tirelessly, hour after hour. And I remember working in the lab many long hours and many a night. You've experienced that, you know, if you've done circuit design, that all kinds of things can happen, and things go up in smoke from time to time. Well, things (the circuits) were pretty stable. It was about midnight one night and I'd been doing this work for weeks, basically, and I was looking at this, looking into this little box. It was about 8 X 10 inches. And I'm not touching it and I don't have any probes in it, I'm just

looking at it. And all of a sudden, just I hear this little tiny pop and a little, you know, a little whiff of smoke comes up out of the open box. And I'm thinking, "What the hell went wrong this time?" You know, circuit designers, they know that solder ball's cause this and if they change the circuit it might smoke, but I wasn't doing anything. I hadn't changed anything, and I leaned over and I looked into the box and the printed wiring board was, was blue. I remember it was blue. The traces were kind of a silver color. And I saw this little black spot and I recognized that it was between the 110-volt Nixie trace and some low voltage logic and I said, "Oh. What caused that?" And as I looked closer, and I swear to God this is true. It was a flea. A flea had landed and straddled those two voltages and got electrocuted.

Elliot: So, there was a bug in your design.

Garrow: There was a bug in my design, exactly.

Garrow: I remember thinking right on the spot I said, "I've got to move into digital logic design now." I did my job. I finished, I finished the instrument, got that instrument working, but it took me to the next stage of my career. It took me to the first digital, real digital, stage of my career because the company shortly thereafter decided it wanted to get into the computer business and they wanted to do that by designing and manufacturing an intelligent terminal. Now back then, this is 1970, something like that, they hired an architect from Los Angeles by the name of Dick Pasternak. He had been, like Dave House, working in the mini-computer industry. Back then there were microprogrammed minicomputers on the West Coast. On the East Coast DEC was a big powerhouse in minis. They were going strong. But all their instruction sets were proprietary. But there were two, companies, maybe more than two companies and in the L.A. area that built a basic minicomputer but allowed customers to program the instruction set using nonvolatile memory. But it was, this is way back. The Random-Access Memory was literally (magnetic) cores sewn together.

Elliot: I assume the code was in a bipolar PROM or something like that.

Garrow: No, no.

Elliot: Not even that.

Garrow: The one product I can remember for sure is the Microdata 1600. And actually, I have to thank Dave House for helping me remember that design (name). It was the Microdata 1600. It was built with, 8 X 10-inch card or 8 X 11-inch cards and the core memories were really core. These were boards with very tiny cores handstitched together. The read-write lines were literally handstitched together. The microcode memory was a board on which you soldered diodes vertically. The presence of a diode was a binary “1” and the absence of a diode was a binary “0”. <laughs> Oh, and I think the memory capacity for the board was like 4 kilobytes. And I don't remember what the read only memory capacity was, but you could imagine it wasn't very big with individual diodes stood up vertically.

Elliot: Yeah. My first computer was 4K.

Garrow: Yeah. <laughs> Yeah, so, to give you a picture of an intelligent terminal back then, the keyboard was an IBM Selectric. <laughs> Electronic keyboard technology wasn't that common back then and you didn't just buy one.

Elliot: Well, Selectric was a big step up from the old clunking KSRs that we used to have, so.

Garrow: Yeah, that was the Microdata 1600 computer. The removable storage happened to be these Sykes Datatronic reel to reel tape drives. And they were designed pretty well. They weren't like automobile audio cassettes. They were designed to be rugged. I was given the job of designing a controller for the tape system and I was happy to be away from the fleas, though, because I didn't have to worry about bugs anymore.

Elliot: I hope so. I guess one thing I'm not quite clear on, so you could customize your instruction set in these minicomputers.

Garrow: Yeah.

Elliot: And put the microcode into the diode array, so that became the instruction set.

Garrow: That's your firmware.

Elliot: The microcode, the firmware as we think of it today.

Garrow: Yeah.

Elliot: Was that a manual task? Was there any assembler? Were there any software tools to develop that?

Garrow: No, no. They came along within a year or two. At this point, I should tell you about how I discovered microprocessors. Dick Pasternak had taught me how to use a state machine for doing control and that was the basis for my tape deck controller. I was becoming, more aware of computing and how things were done. I'm sitting there as I usually did and I was reading my EDN magazine and I picked it up and I looked and on the front cover was a picture of a wafer with a whole bunch of circuits on it, you know, big die (it was a wafer with several die). And but the headline was something like, "Four Phase develops microcomputer." The term microprocessor I don’t think was used back then, and I remember my thought then, too. I said, "My God." You know, this tape controller took two boards. One board for all the logic, one board for the tape controls. And I said, "My God, the work I've been doing the last year for that one board to control it is what engineers are going to be doing that work in a totally different way very soon because of this microprocessor and I've got to get involved in that.

Elliot: Now, to be clear, Four Phase was a multichip design if my memory serves me correctly. And they weren't selling chips.

Garrow: That's right.

Elliot: They were selling the computers that they built those chips into.

Garrow: They were doing a storage system. And I discovered that later that those parts were not going to be offered for sale in the merchant market. They were for their own core system.

Elliot: But it was pretty obvious that somebody would.

Garrow: Yeah. But I realized I had to do at least one thing. I had to get back into the Santa Clara Valley. So, Nick Nichols, a Ph.D. double E from Stanford, hired me to work on a Microdata 3200 I think it was. Because he, too, was doing an intelligent terminal and he had some ideas about how to extend the instruction set for word processing. Now I can't remember exactly what he was targeting, but he needed an engineer that knew (microprogrammed minicomputers).

Kapoor: So, this was a small company.

Garrow: Yeah, so I came back to Santa Clara to work for him. And while I was there, I wasn't there very long, I'll tell you why. It's kind of a funny story. While I was there this Intel salesman and I believe it was Jess Unruh would call on me to show me Intel parts and things of that nature and it was through him that I discovered Intel, and the 4004. And I said, "That's it," you know. I've got to get to Intel as a next step. And, you know, we didn't have Google or the internet. Things weren't that, readily available to us in terms of what was going on in the world. I had a job to do for Nick. Nick was a really nice guy and a great boss and a very smart guy. And so, I'm working to extend the instruction set from a hardware point of view, not just firmware, of this Microdata 3200. And by then, these ROM simulators were available. They were pizza-sized boxes, maybe double pizza-sized box and you could simulate the firmware (microcode) using the ROM simulator. You didn't have to, solder diodes in and out. So that was a factor. I went to work adding the instructions and I forgot exactly what instructions I added, but I needed to add some instructions to the hardware itself. Nick had hired a firmware designer, a young lady, to do his firmware for his application, whatever it was. I was busy doing my hardware design work and he was having her do the firmware. And I'm moving along, and I finally get my part of it done and I want to test the box. So, I start testing. And first thing I think of is, well, let's see how a No-Op works, right, that's pretty simple. And so, I'm running the No-Op, you know. I get it working with my scopes and whatever and I think, wait a second; this is kind of slow. And it turned out the No-Op took 17 microseconds. <laughs>

Elliot: So, the whole project was a No-Op at that point.

Garrow: Well, not yet, but it became one. As a system engineer, I was testing other things and <laughs> I also realized that the system was consuming a kilowatt of power. I didn't want to be the bearer of bad news because Nick was a really nice guy, but I really had to tell him that his No-Op was running 17 microseconds and his system was consuming a kilowatt of power. And that was the end of the project. He went on to test it himself and test more of the firmware. Ultimately, he, he was forced to cancel the project, which freed me up to leave and so that led me to Intel.

Elliot: You don't recall the name of the company that Nick had at the time?

Garrow: It was Sylvania. It was a small company that had been purchased by Sylvania. It's not just Sylvania, I forgot the full name of Sylvania back then. This was it had to be 1972.

Elliot: How about the name of the firmware designer?

Garrow: <laughs> No, I can't remember.

Kapoor: Then you went to Intel, tell us about how you went into Intel.

Garrow: I've forgotten how I got my interview, but I was interviewed by this, it turned out to be this dinky little group in Marketing under Mike Markkula, I believe, about 10 or 12 people. Dane, I don't know if you were there before me or not.

Elliot: Well, I was confused about that too. I started in May of '72.

Garrow: Well, you were there a (one month) few months before me. (I joined in June of 72)

Elliot: Yeah, the only thing I can mark it by is that my son's third birthday was celebrated up here instead of in L.A.

Garrow: Okay, yeah. And Phil Tai was the leader of this group, a very peppy, it turns out he was the Singapore National Badminton Champion, but he was a peppy guy. I liked him. He told me that Bob Noyce wanted to hire a system engineer to follow up on at least one of the many RFQs for custom jobs using the 4004 that were coming into Intel so that he could maybe understand what the microprocessor might mean in the future. Phil needed to hire a system engineer, so I actually interviewed with Bob Noyce. And that was one of the highlights of my career, not only just interviewing but getting to know him, and well, he was quite a guy. I got the job and so I started looking through these various RFQs that were coming in and I decided to take one on from a Texas company called "Fill-em' Fast". And what they wanted was a controller that would go into an existing housing that they had with a keyboard and a display that would run 16 pumps, gas pumps, amongst other things, go online through an RS232 interface through an AT&T CBT access arrangement, upload data, download data and also run a game that allowed customers to win credits if they could guess how much gas a fill-up would be. It also had to have a secure part of memory that was uploaded every shift because there were shenanigans going on between the shifts at the gas station that the company had to protect against. I don't know what the shenanigans were, but these, all these crazy requirements. It had to be very compact. I think the board sizes had to be maybe 3 inches by 6. I could fit two of them into the housing and I had to sell them for $250 dollars both fully tested. It was a perfect

application for the 4004. And that was my choice and I remember DRAM overhead was overkill, too expensive. Static memory would have been too power consumptive and too expensive. And there was a, maybe you can remember for me, there was a serial RAM memory in the 4004 family.

Elliot: Oh, yeah; the 4002.

Garrow: The 4002. One board became the controller with mainly the 4004. The second board became a serial memory with the 4002, I guess. And I made them work and it was amazing. It just astonished me that all that functionality at that low cost in that compact space was handled by these two boards. And the company sold them for years. Intel sold them to this Texas company, “Fill-em’ Fast” for years. They worked and I guess they were, the customer was happy.

Elliot: Do I remember quickly that you ended up putting 4001 ROMS in that too, for the code?

Garrow: Probably. That certainly wasn't an EPROM. <laughs>

Elliot: No. But I assume you had an EPROM to develop with.

Garrow: Oh, sure, sure.

Elliot: Okay. But yeah, there was a 4004 with the processor. 4001 was the ROM memory with I/O pins.

Garrow: Okay.

Elliot: The, 4002 RAM also had the serial I/O. Then there was one more device whose name-- number escapes me, must have been the 4003, and that was an I/O expander device. (the entire memory was serial and it was, essentially, a big shift register)

Garrow: I was going to ask you about that. I needed an RS232 interface. Did the family have that chip?

Elliot: It did not.

Garrow: That was a USART we did later, right?

Elliot: We did an 8251.

Garrow: Oh, yeah.

Elliot: Matt Miau did that many years later.

Garrow: So maybe some of my circuit design experience helped me get the RS232 done, I'm not sure.

Elliot: I'm sure it did because nobody was doing that in chips at the time.

Garrow: But I never heard anything about what that project taught Bob Noyce. I never did. <laughs> I went on to work on the development system.

Elliot: Now prior to that and right up there you mentioned some of the early stuff that you worked on at Intel before you actually created or worked with, I don't know, there was a SIM 401.

Garrow: Okay. I don't know who built that. Was that a Ted Hoff design?

Elliot: I don't remember the product code, but when I got there, Ted Hoff had developed an EPROM programmer. (Yes, but Ted's box, whatever its name had to sell for around $5,000, too expensive for Mike Markkula. I'm pretty sure that was why Mike had Phil Tai create the product that consisted of a PWB, a bag of parts, and some instruction which, when assembled, allowed for programming a 1702 using teletype paper tape as the source for the code. That must have been the very first product done by what became the Development Systems Division)

Garrow: That was an MP703.

Elliot: The MP703 was an MCS project. Prior to the MP703, MSO (Memory Systems Operation) developed an EPROM programmer. It was packaged in a small suitcase and designed to support the 1601 EPROM. Probably worked for the 1701 since the only difference between the two was the package. Before I got there, Phil Tai, was selling two EPROM programming alternatives. One was a bag of parts which included a bare, printed circuit board and a paper tape reader. Customers would buy them very cheaply, solder all those parts onto the board, get it working and they could program 1702s with it. You would punch a paper tape using a teletype, run it through the paper tape reader. I think that might have been called the MP703 or something like that?

Garrow: There was a higher end version. Phil took what was basically that board design and put it in aluminum housing and finished it for the customer, so the customer didn't have to do any of the assembly or soldering. So, there was in the very beginning of Phil's work, the bag of parts with the PWB. But then right behind that, right by the time I was there, they had this other fully assembled box that were tested that they were selling.

Elliot: Right. I had one of the original kits.

Garrow: Oh, yeah. What was it called?

Elliot: I can't remember. But I do remember Intel had the aluminum box with boards mounted on top.

Garrow: Yeah, that's the one.

Elliot: And that was it had a 4004 running it with the tape reader.

Garrow: Yeah.

Elliot: And there was a programming board that plugged in. I thought it was an MP703.

Garrow: Good. Yeah.

Elliot: Okay. And that was the programmer.

Garrow: Yeah.

Elliot: So, you could write code, get it programmed into an EPROM, take the EPROM and plug it back into the board.

Garrow: Yeah.

Elliot: And then execute the code to see what worked.

Garrow: Right, right, correct.

Elliot: Okay. It was a pretty confused situation back in that day. It was very difficult.

Garrow: Yeah. But weren't you responsible for writing the application notes that described how to use all that stuff?

Elliot: Well, I wrote it. I wrote a bunch of those documents, but I do not recall which ones.

Garrow: I thought so.

Elliot: And not on the original stuff, because I wasn't there when the board came out.

Garrow: Yeah, yeah. Oh, okay.

Elliot: You know, and the kit of parts came out and I bought one, but later on. And that was one of my impetuses to come to Intel, because you had your Jess Unruh. I had my Dave Neubauer, who was sales in Southern California.

Garrow: Yeah.

Elliot: And Dave was trying to convince me that they had this part coming out called a 4004 and I could stop designing computers.

Garrow: Yeah.

Elliot: But I asked him all these questions about where were my development tools, where's my software, where's this, where that? Where's the documentation and all that stuff. And that led me to come up to Intel a year later

Garrow: Yeah.

Elliot: But that's another story, not your story.

Kapoor: Then you went on to development systems.

Garrow: Yeah.

Kapoor: Tell us about that.

Garrow: Okay. So, let's see. The 8008 was in development. I think Federico Faggin was leading that effort.

Elliot: No, actually Feeney was the designer, he was working for Federico.

Garrow: Oh, Hal Feeney, that's right. Hal Feeney. So, so I finished my “Fill-em’ Fast” project and there was a development system for the 4004 that was beyond what Dane just talked about called the Intellec 4 (no “t” was deliberate). And a similar system for the eventual 8008 was being developed call the Intellect 8. And I wasn't involved in either of those except I gave it the name. I came up with the name Intellec and back then, the Intel used a dropped "e" in their logo. And I remember taking a couple of my business cards out and cutting out the letters and taping with tape, creating the logos for the Intellect 4 and Intellec 8 with the dropped "e." And the marketing guy there, I think it was Jim Lally, he just, he liked it. He said, "That's, great, I like that name and I like the logo." So, my only contribution to those first development systems was the logo and the name.

Elliot: Ed Gelbach joined Intel in May of 1971 and quickly became a promoter of the microprocessor marketing efforts. Mike Markkula worked for Gelbach until his departure and Hank Smith worked for Mike. Phil Tai worked in Applications for Ted Hoff. The MCS-4 (4001, 4002, 4003 and 4004) was launched in November of 1971 and the MCS-8 (8008) in 1972

Garrow: Micro Computer Systems was created in May of 1972 and Hank Smith was put in charge reporting to Ed. After Hank Smith, Bill Davidow became an early visionary leader for the group. Bill Davidow was hired to lead the group in August of 1973, reporting to Gelbach. Phil Tai reported to Hank Smith and left when Davidow replaced Hank. I have never figured out what happened to him after that, he was just gone. I was at Intel 7-1/2 years, but I don't know all the details. The 8080 development followed the 8008 and the group wanted a more robust development system for the 8080. And Bill Davidow had this, I think it was Bill's idea, because Bill came from a company he joined after HP. Just prior to Intel, worked for Signetics Memory Systems. To support their bipolar microprocessor, they developed a ROM Simulator which may have influenced the development (conception by Bill Davidow) of the In Circuit

Emulator (ICE). I kind of attribute the notion of the In Circuit Emulator for the 8080, to Bill. I'm guessing it was his idea.

Elliot: In August 1973, just before the 8080 was being launched in 1974, Hank Smith decided he had to move back to the East Coast.

Garrow: Yeah.

Elliot: He and his wife did move to the east coast and Davidow replaced him.

Garrow: Yeah, he had all the systems, all the chips, everything.

Elliot: It was now a much more official organization.

Garrow: I think you're right. Probably no longer just Marketing but maybe its own organizational entity, I'm not sure.

Elliot: Yeah. When I joined it was called “MCS”, Micro Computer Systems.

Garrow: Yeah.

Elliot: We also had “MSO” Memory Systems Operation. It wasn’t a division but what Intel called an “Operations”.

Garrow: But what I'm remembering is that somebody, I believe it was Bill, conceived of this notion of doing an emulator for the 8080 itself and that emulator needed a system to run in and I was given the job of designing that system. With my minicomputer background, quasi-minicomputer background, you know, I thought in those terms. I thought of it in terms of backplane slots into which you can easily load a board, take it out, a bus, you know, control buses, you know, data and address buses. Hap Walker, our colleague, was given the task of designing the emulator. It was called ICE, in-circuit emulator. And I kind of wanted a general-purpose system into which the emulator would go so that we could reuse it in different applications, different industries. We had to design kind of a general-purpose computer. Fred Coury, an architect from Hewlett Packard who may have been a consultant at the time, was hired to help do a bus design. The first engineer I ever hired at Intel, Rich Boberg, a really great engineer, became a part of the team that defined this bus and I was a part of this team.

Kapoor: This is the multibus?

Garrow: This is, this became the multibus. And it became the general-purpose bus for the MDS 800 development system, you know, had. And I think Fred provided the architecture and Rich provided the, you know, the logic. And my microwave training finally came into bearing on this project because I focused on the guard bands within the bus. My idea was that I wanted the bus to be very compliant. I wanted less experienced engineers to not have trouble with it. They'll plug in multibus compatible boards and have an easy time of it and get things done rapidly.

Figure 1 MDS 800 with ICE andSBC80/10

Kapoor: You said Bill asked you to represent Intel in the IEEE.

Garrow: Yeah, Bill told me that Gordon wanted me to represent Intel in the IEEE Standards Bus effort for making Multibus a standard. But just to finish, Jim Lally didn't want this thing to be called the Intellec 80. Jim had lost interest in that name and he named it the MDS 800.

Elliot: Yes, he did.

Garrow: Yeah. And so that's fine, you know. What I was going to say was that my microwave training came into use for me because I worked hard to make sure that there was a generous guard band in the time domain for all the specs on the bus so that risk conditions would be hard to develop. And I made sure the memory bus was terminated with perfect impedance. And I just wanted it to be really easy to use and also, with my conservative design background, I wanted it to be reliable. I'm kind of proud of that box because it was the highest volume development system box sold and it was reliable all over the world. It got good grades.

Elliot: Well, it was unique, and I have a couple of questions about that. All of the minicomputers out there at the time had one big motherboard.

Garrow: Yes.

Elliot: They all had the cards that they started out with and then when they got to the point of building bigger machines, they built single motherboards instead of connecting their boards.

Garrow: Yeah.

Elliot: And then they had a few plug-in cards. So, the fact was that you put a backplane motherboard in this thing and then even the processor was plugged into it.

Garrow: Yeah.

Elliot: It was completely unique, I think in the industry, at that time. What I'm curious about is, was a board, I don't know where it fits timewise, called an SDK-80.

Garrow: Oh, man.

Elliot: I recall the SDK-80 had the form factor of the boards that you plugged onto that backplane, but it didn't have Multibus to do that.

Garrow: Oh, I know what that was.

Elliot: The SDK-80 was a kit and it was only sold through distribution.

Garrow: Okay, I think I know what that was. It came from Bill Davidow.

Elliot: Is that where it came from?

Garrow: Well, we had this form factor, the multibus form factor was worked out and we did all kinds of boards for our customers. But at some point, Bill felt that he had to put a price point out in the marketplace that was really low. What he wanted to do is protect Intel from, you know, Motorola coming in and underselling it. I don't know what the background was for that, but he came to me and he says, "I need an SBC card that I can sell for $250 dollars." I'm making that up, but it was a really low price. And I was like, "I can't do that, Bill." You know, these cards were, you know, about 8 by 11 across, you know, something like that.

Kapoor: This is the single board computer.

Garrow: Yeah, these cards eventually became the single board computer format but back in the timeframe-- Oh, no, you're right. This was a single board computer. I'm getting to it. So I couldn't figure out how to do it for $250 bucks except if I lopped off that one section of the board that was for I/O and that's what I did. I made this-- And the MDS-800, the multibus cards were say this big. This card was about this big. And it wouldn't have worked for anybody because you couldn't-- <laughs> you couldn't control anything with it really unless you came right off the board. But Bill got his price point and he was happy as can be because it--

Elliot: And what, it had an 8080 on it?

Garrow: No. Well, it couldn't have had an 8080. It had to have something really cheap.

Elliot: 8008 or a 4004

Garrow: It was a 4004, I'm pretty sure.

Elliot: Okay, okay.

Garrow: So cheap, cheap, cheap.

Elliot: Yeah. Well, now the board I'm specifically talking about was an 8080-based board and it was full Multibus form factor. (The first production “Single Board Computer was dubbed the SBC-80/10. We also did an 80/20 which probably had more memory)

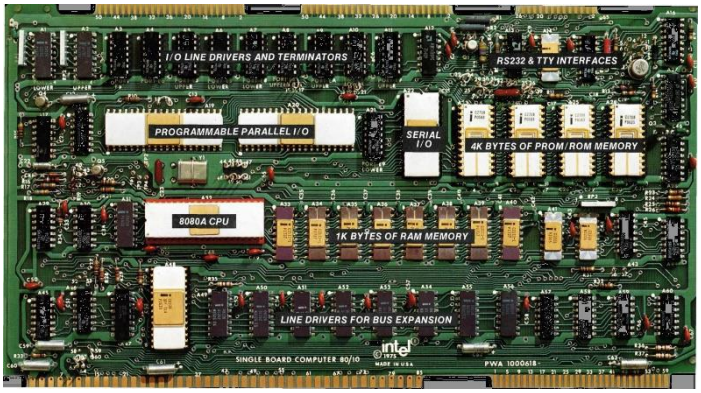

Figure 2 SBC 80/10

Garrow: Oh, okay.

Elliot: Ken McKenzie, and Scott Dixon developed System Design Kit and I've been trying to chase it down for a long time. Ken donated a complete SDK 80 kit to CHM, but I’ve been unsuccessful locating it there. There was also a System Design Kit 85 and a System Design Kit 86 later.

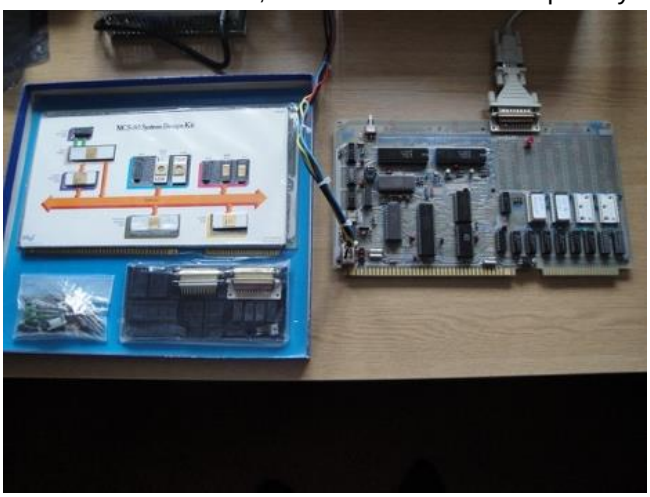

Figure 3 SDK 80

The SDK 80, the original one had the form factor of your board, but it didn't have the multibus interface on it. (The cheap $250 board mentioned above did connect to the Multibus but only for control, data, and address. The I/O section had been lopped off)

Garrow: Oh. It didn't have the multibus in it, huh.

Elliot: No. It did not have the multibus interface. And it had a little area on it that you could put your own circuitry on it.

Garrow: Oh, okay.

Elliot: And it, so it sounds to me like that must have happened after you came up with that Multibus form factor. The low-cost board you're talking about must have been a predecessor.

Garrow: I think the name of the card that I was describing was the SBC-04.

Elliot: Okay.

Garrow: But it was really just a marketing ploy. So that was its main purpose

Elliot: Well, that's what Bill thought about all the time.

Kapoor: So, you also ran into Andy Bechtolsheim at the IEEE standards meetings.

Garrow: Oh, yeah. Thank you, Uday. Appreciate that. I would go to these IEEE meetings for the multibus and I couldn't help but notice this very, very young blonde very young German gentleman, very active in the meeting, very keenly interested in everything that was going on. It was Andy Bechtolsheim. I didn't strike up a relationship with him or anything like that, it's just that he stood out and I remember him being intensely interested in multibus. I found out a little bit later why he was so interested. I did my job and the multibus became an international standard and it had a good run. It had a good run. Multibus was used across multiple Intel product lines, 8080, 8086 and 8086 and microcontrollers. It supported ICE for at least the 8080, 8085, 8048, 8051, 8086 and 8088.

Elliot: So relative to that also, Intel got into the single board computer business at some point in time.

Garrow: Yes, yeah.

Elliot: Same form factor. Same bus.

Garrow: Yes. Yeah.

Elliot: All right, okay. And Rich?

Garrow: I led that group. I remember I led not only Engineering, I started a planning process that brought Marketing and Manufacturing together to support development systems and SBC.

Garrow: We started in California. Oregon, that was the group, that was another career adjustment that I'll address later.

Elliot: Okay, so if it was in California, that was after Davidow had started development systems as a division.

Garrow: Somebody got the idea, probably Bill, I think it was probably Bill, let's take these multibus boards and let's configure them or take the form factor and create this thing called a single board computer. We've got everything we need, and we can get it all on one board and let's start a family of computers that way. And one of the important things I remember about that is that I was told that Bob Noyce was loath to compete with his competitors. Just, any talk of a computer system was not going to go over well.

Kapoor: It's still a chip company.

Garrow: Yeah, he was right about that. I remember Bill telling me that. I had to get this single board computer line approved by the executive staff. And Bill warned me about, the attitude, that I might run into some headwinds when I asked for approval. I remember tailoring my pitch such that it characterized the single board computers as merely components. They're merely components of a system, they're not a system. It won the day. That the SBC line was approved, and the group started cranking out various family members. Then Andy, Andy Grove, decided that it was a nifty little group. There were about 35 of us plus some Marketing people that were part of this planning process. It was a nifty little group to pick up and move to Portland, to Hillsboro in Oregon. That didn't sit too well with me. <laughs> Being a native Californian and just loving this area, I just I couldn't move. The thought of living in soggy Portland was not good. But, you know, the funny thing is because I was part of these planning committees, I had to go to Oregon, probably once every six weeks or so. I traveled up there for several years and the weather was always absolutely beautiful. <laughs> So except for one ice storm that I got caught in, that was horrendous. But the weather was gorgeous up there. And I worked hard to get my team to decide to move up. About 65 percent of them I remember moved to Hillsboro and they loved it there most of them, except for Jim Lally. <laughs>

Elliot: No, Jim did not like it up there.

Garrow: <laughs> Jim did not. But most of my team retired from Intel in Hillsboro. But Dane's right, Jim Lally was picked to be the general manager of that single board computer group that went up and it didn't sit well with him. He lasted, about a year, I think. I don't want to say he lasted, but I guess he kind of put up with it for a couple years and then he came back and I think he left to join Kleiner Perkins around that time.

Elliot: That's right. No, he and Lynn did not care for Hillsboro.

Garrow: <laughs>

Elliot: He quit and came back and joined Kleiner Perkins.

Garrow: So, I was back in development systems for a couple years.

Elliot: You made a couple of comments in here about the 1702 and the profitability of 1103s, 1702s and static RAM. Because that was the primary business, we were in.

Garrow: Yeah, that's when I joined in '72.

Elliot: It wasn't 4004 microprocessors.

Garrow: That's right.

Elliot: EPROMs got me started with Intel because I had built a computer that used those for main memory.

Garrow: Yeah, yeah.

Elliot: And I was paying $200 bucks a copy for them.

Garrow: Wow. Wow. <laughs>

Elliot: They were a very profitable product that they kept out of everybody else's hands.

Garrow: Yeah.

Elliot: You also mentioned Ted developing the bit slice machine, the R3000 nicknamed “Wildfire”.

Garrow: R3000, yeah.

Elliot: And I was wondering if you had any other thoughts or comments about that and the viability? Because AMD went on to build a bit slice that made a big business for it.

Garrow: Well, the thing I remember, I remember two things. I remember Justin Ratner was assigned to do the marketing, I think, for Ted's bit slice machine. And the other thing I remember is that the code could not be compiled to completion. You couldn't write a compiler that was deterministic for that particular architecture.

Elliot: You mean to create the microcode.

Garrow: To create the microcode or to compile applications code since every set of microcode created a unique computer with a unique instruction set. I think that was a big handicap <laughs> it never overcame, and I don't think it went very far.

Elliot: To my knowledge there were only two people that could actually build the microcode for the R3000.

Garrow: Yeah.

Elliot: One was Ted himself and the other one was Ed Klingman.

Garrow: Oh, okay.

Elliot: Ed did that for a long time. I believe he also wrote the course work on doing that.

Garrow: Yeah. Back to '72, I have a story about that's not in there, it's kind of fun, about the technology back then. Dane is right, the 1103, that was the breadwinner. The 1702 was probably the most profitable of all.

Elliot: Yeah, but not the volume of the 1103.

Garrow: Yeah. And but Intel had static RAMs. But back in '72 when I was hired, Bob Noyce would always, there was only 500 people, by the way, at Intel when I was hired. And back then Bob would hold a lunch, a monthly lunch for new hires. And I remember being all excited about going to that, the first lunch. And there must have been about eight or nine of us with Bob leading the way. And I listened with bated breath to every word he said. And one thing he said, you know, I took away as, like, Gospel. And <laughs> what he said was, "It's the static RAM. Watch the static RAM. That's going to make Intel." And so, for a while, quite a while, I kept watching for the static RAM to take off. They were good parts, but that was not the ultimate breadwinner. It turned out to be the microprocessors.

Elliot: Well, we did make a hell of a lot of money on 2102 SRAM. Because we were the only guys that produced them. And Hank got $50 bucks a device for them.

Garrow: Oh, wow. <laughs>

Elliot: And I've talked with Hank about this several times. Nobody else could make them but everybody claimed they could. There were about ten companies who claimed that they made 2102s.

Garrow: Okay. Yeah.

Elliot: 1K static N-Channel, SRAM.

Garrow: Yeah.

Elliot: We never had any backlog on the books, because everybody else claimed they could make them, and the competition would offer sell them to you for $20 bucks. Every month the sales guys would come in and say, "But I can't sell any of these things at $50 bucks." And Hank would say, "Too bad. You know,

let me know at the end of the month how many you want." He built the hell out of this very profitable SRAM

Garrow: <laughs>

Elliot: He said, "The first time I lose a 50,000-piece order, I will drop the price."

Garrow: Well, yeah. Okay.

Elliot: And that went on for two years.

Garrow: Wow.

Elliot: True to his word, somebody else came in and delivered a large volume.

Garrow: Yeah.

Elliot: And I think the price on them was $23 dollars or something like that. Hank dropped the price to $9 dollars the next day.

Garrow: <laughs> Wow.

Elliot: And put everybody making static RAMs out of business. Because our cost was very low as we had just moved to plastic packaging.

Garrow: Yeah.

Elliot: And our cost was somewhere around 98 cents.

Garrow: Wow.

Elliot: So, it was-- It was still a hell of a deal.

Garrow: <laughs>

Kapoor: So, around this time I guess you were approached by Hank Smith about the Apple--?

Garrow: That's a good one. It was I guess about my sixth year at Intel roughly and I was really happy. It was a great company and actually the best company I ever worked for. I get a call from Hank Smith. He had joined Venrock, an east coast venture capital company, managing a lot of Venrock (actually the name of the firm), Rockefeller money. He told me that Mike Markkula had hooked up with a couple of guys in Cupertino and they wanted to talk to me about some management job. I said, well, what are they doing? And he said, "Well, they've figured out how to hook up a, you know, a keyboard and a

microprocessor to a television set and create a, I forgot what word he used, "desktop computer for a very low cost." And the word "PC" hadn't been invented then, but I was very, you know, kind of got on my high horse a little bit because I'm at Intel. We're the king. And I happen to know, because I was at Intel, that there were about 19 or 20 of these types of startups out there. In fact, Rich Boberg, the engineer I mentioned earlier, had left in part to do one. He and his good friend had one of these things. He was using Intel. So, I knew there was a lot of them out there, and so I put my Intel proud hat on and said well what processor are they using, Hank, and he said, "It's a 6502."

Kapoor: "Oh, Apple huh? <laughs> Oh no way." was not me.

Garrow: I thought oh, Motorola, huh? Hank, I'm pretty content right here at Intel-- and I declined to take the interview, and of course it was Steve Jobs and Steve Wozniak that wanted to interview me for God's sakes. So that was a couple of years before I left but it had a lot to do with why I left.

Kapoor: So, then the opportunity came about Convergent.

Bob Garrow: Yeah, I was back in development systems and I was a department manager, and to tell you the truth I can't remember what I did those last two years, but a couple guys from Dec came in, one was Allen Michels, one was Kal Hubler. Both were sales guys from Dec and Phil Kaufman, right. Phil Kaufman had hired them. I was on Phil's staff, and this was before Phil left to found Silicon Compilers. I worked with Allen for a year as a peer, and when Phil left and Allen got his job, so I'm working for Allen, and unbeknownst to me, wait, let me back up a little bit. Allen comes up with this notion called the universal terminal computer, and it's a general-purpose system, and I'm not involved in it. I'm just managing hardware engineering for the development systems proper. Terry Opdendyke happened to be my counterpart doing all the software. Allen needed to present this system idea to the executive staff, just as I had to present the single board computer to the executive staff a couple years before, and Allen, I think I was in the meeting just as an observer because I was on his staff, presented it and it was rejected. The concept was too competitive with minicomputer companies and the computer companies that Intel served, so it got shot down. Unbeknownst to me Allen pulls a team together. There was Alan, (Kal), one of my engineering managers Eli Alon, and Allen's secretary Donna Hass. They were working secretly on this plan to do a startup to do the UTC, the universal terminal computer, and Eli was a really smart guy, but managing him was challenging. I think it's probably the biggest management mistake of my career. I thought with my great management skills I could harness this great talent and teach him how to manage others himself <laughs>. Eli was invited to do engineering for Allen's startup. Something happened, I don't have any idea what it was, but Eli was out of the deal. So, one day Allen approaches me and tells me that he's going to leave the company to do a startup. The Apple gun was sort of cocked in my head. <laughs> I missed out on a big startup opportunity in that case, and I was kind of primed to want to do something like this. There was one other thing as I mentioned in my notes. By then I knew that Intel was first and foremost a silicon company. Whatever decisions were made they were going to be made with respect to semiconductor products, and I would probably never be able to do general purpose computing inside of Intel. I told Allen I've got to think about it, but I didn't think too long. I told him okay I'll do it with you, and so I left and cofounded Convergent Technologies shortly thereafter.

Kapoor: It was located here.

Garrow: And it was located here, yeah.

Elliot: You got a date for that?

Garrow: Yeah. Well, August 1979. I want to say August 1, 1979, but I should check.

Elliot: I'm sure that's in the web someplace.

Garrow: Probably, yeah. We had to wind down our responsibilities at Intel. I met with Roger Borovoy and he asked me not to hire from Intel, and I promised him I wouldn't, and I never did. And we started Convergent Technologies with only three of us at that point. It was me, Allen and Kal, and we didn't even have an office, and we didn't even have a business plan frankly because Allen had garnered commitments from three notable angel investors at the time, Dick Riordon who eventually became mayor of L.A., John Freidenrich who was the founder of the Ware, Fletcher, Freidenrich law firm, and Bill Rolnick who was the founder and CEO of a Rental Electronics. And I think this is one of the classic Silicon Valley stories, and I wasn't a part of this, but Allen truly sketched out the deal on a napkin and got the handshake from those three guys for a 12.5-million-dollar series A. They were the investors and that was pretty exciting for me. I'd never leaped off the cliff like that before.

Kapoor: So, this is for the first multipurpose workstation for business applications.

Garrow: Yeah. The basic concept was with the power of the 8086 16-bit computing and the affordability that a system surrounding it could support, plus a real time multitasking operating system that was yet to be invented, a workstation could be created that could support multiple business applications. And at the time Wang sold a desktop system but its sole purpose was word processing. Aryeh Finegold and Dave Stamm and V.K. Khosla had created Daisy Computer which was a single workstation that could support schematic capture but there weren't any systems out there that could handle multiple applications on the desktop for an affordable price. So, the idea behind Convergent was to create a multiapplication desktop system.

Elliot: But in a professional environment, not in as a home computer.

Garrow: Oh yeah, not in a home, in definitely a professional environment. On the East Coast, Apollo Computer had been created to do a desktop computer, but its goals were for engineering, technical workstations. They became a competitor to Sun. Convergent was a little different, it was going after business applications. And so, within a week or so two Xerox people were hired, Ben Wigbright and Jay Spitson, both brilliant software people to join Convergent in order to build the software. The challenges at Convergent were very substantial in hardware because we had to build a complete computer system hardware, desktop and it turns out pedestal because we couldn't get it all in the desktop back them because of the size of the disk drives. Do all of that on probably a half a million dollars and build an

operating system from scratch plus build a word processor from scratch. Ben reported to me as VP of software and it was his job to get that software done, and so it was pretty challenging.

Kapoor: Did you have a pretty rapid hiring as well?

Bob Garrow: Well we didn't have a big staff. We didn't have that much money. We started out with about 10 or 15 people at the most and got started. I remember sitting down with Ben after he came on board after the initial start trying to figure out how long it will take us to get prototypes done, and I think Allen wanted it done in 12 months and to me it looked more like 18 months and Ben said he had to have 12 systems or "I'll never get this software done". I'm thinking I've got to build 12 prototypes not just one, and so I came up with a plan and committed to 18 months. I told Allen I can't do it in less than 18 months, and he accepted that. We got started with an 18-month plan to finish the workstation, and honestly, we only had about 10 or 15 guys in engineering total. Most of them were software engineers <laughs> because that's where the 12 prototypes came from. And I came up with this notion of a plywood workstation, and this comes from my aerospace background. I was familiar and comfortable with wire-wrap techniques, and by the way, back then we had to design our own CRT controller and CRT analog system. You weren't buying them off the shelf anywhere. Andy had to do it on his Sun workstation, and I had to do it at Convergent, and Dave Stamm had to do it over at Daisy, because it was a world of terminals primarily. I'm just thinking of the plywood workstation, so in 18 months we had 12 of those done. No, before 18 months we had them done because the software guys needed them earlier. But the first hardware engineer I hired into Convergent was a fellow by the name of Richard Lowenthal from Berkeley. He happened to be comfortable and familiar with wire-wrap techniques, and he did a beautiful job. I mean it was pretty hairy trying to get all that stuff done and working reliably, but we were kind of experienced at it, so it wasn't like a crazy risk that we took. Rich by the way ended up cofounding Stratacom and Coulomb the battery charging company.

Elliot: Right, that's where I got it, okay.

Kapoor: How long did it take to get the first prototype done?

Garrow: Oh, I don't remember. I know we met our goal of 18 months, but I can't remember the details. Here's something that's kind of interesting, intervening thing, that first workstation was to be a single node, single workstation. An ex Xerox Parc guy, Don Massaro, came to us and wanted us to create a clustered version of this thing. Don Massaro, also Xerox Parc, was the head of the office products division, and when Allen signed him up, he agreed to pay us $300,000 if we would extend our 18-month program to include a clustered version of the workstation. I checked with Ben and we figured out maybe we could do it, but we need more people. With the extra money, I increased the size of the team to maybe 20, the numbers are rough, and so we not only completed the IWS which was the single node workstation, Richard helped me extend it to a cluster of 16 terminals. The pedestal that contained the eight-inch disk drives was turned into what we called a Shared Resource for the desktop terminals, and so we literally completed two types of systems in the first 18 months.

Elliot: What was the communications protocol between the 16 units?

Garrow: Interesting you should ask. Rich came up with this. He used a gate that had a differential output, not a one and zero, and so he used it basically like an amplifier, and I can't say how that he did that, but he did use a gate as the basis for the network that stitched the desktop things together, and I can't remember exactly what he did.

Elliot: Was there one cable from each desktop terminal into the management pedestal?

Bob Garrow: I think you're exactly right (I misspoke). It was daisy chain. Output from one would go into an input from another, and the output from that one would go to the next, the next, the next, the next, and supported ample bandwidth I don't remember the numbers, but the system worked fine. We got some very interesting customers eventually. We got Burroughs, we got NCR, we got Savin, we got Thompson CSF, and Honeywell was looking at us. What had happened in the computer industry is the Bunch Group, many of them the ones I'm talking about, they fell behind when it came to utilizing microprocessors to advance their terminals. They ignored the desktop too long, and so they didn't have a product and others were coming after them. The IBM PC was not out yet, but I guess they knew that IBM was coming along, and so we came along with this beautiful design, I hired some great engineers from Hewlett Packard for mechanical design, we had these beautiful injection molded parts. Trying to think of the design team that designed it. We produced the first articulated display where the plastic enclosure wrapped the display very, very closely. I wish I could remember the design company that did all the work. (It was IDEO and, in particular, co-founder Mike Nuttal)

Bob Garrow: Maybe I'll think of it, but we had a beautiful design. Ben did a great job with the software, CTOS was the operating system.

Uday Kapoor: You're saying pretty high-profile people were coming and talking to you about it.

Bob Garrow: Yeah, and they became our customers.

Elliot: But I think the other interesting thing is that this is in some sense a predecessor to the original serial communications Ethernet where we tied everything together through vampire connectors on cables?

Garrow: Oh yeah, Ben and Jay were from Xerox Parc. We knew all about the Alto and they weren't commercializing that. They weren't doing it.

Elliot: No, they weren't.

Garrow: We knew about that design. The CRT concepts were based on it, the mouse concept was based on it. So, we borrowed all those designs and incorporated them in our design. It was a pretty cool system, and it met a need. It was the right product at the right time because these big computer companies had kind of fallen behind.

Elliot: They really fell behind, yeah.

Kapoor: So, you had five generations done?

Garrow: Yeah, at Convergent, I'm very proud of the fact that we completed five generations of workstation in four years, and with a team of about 35, 40 engineers, that I just told you about two of them (The standalone workstation and the cluster version). The next one took advantage of 5 ¼ inch drives to eliminate the need for a pedestal. We were able to put a hard disk into the desktop design, which was novel, well you had to see it. It's a novel design with the CRT beautifully articulated on the left and a work panel on the right, but the work panel was actually a housing for a bus that supported the computer cards and the storage drives, the 5 ½ inch floppy and a 5 ½ inch hard drive. So that was the second generation, it was called the AWS I remember. IWS, "Integrated Workstation" was the first one, AWS was the 5 ¼ inch drive-based system. Then we did the first color display, and I hired a fabulous engineer to bail me out actually <laughs> on the CRT design, he was Mike Ramsay who became CEO and founder of TIVO. My first analog engineer on the system wasn't making it and Convergent wouldn't have made it weren't for Mike. Mike came from Hewlett Packard and fixed that problem, and he went on to design the color display, which was the fourth system, and then he led the team that created this beautifully modular system called Ngen based on a 3 ½ drive technology, so that was the fifth generation. That was just a gorgeous system. It was 186 based. The Convergent workstation team was so productive we were known by some as "The Marine Corp of the Computer Industry".

Figure 54Desktop for IWS and AWS

Figure 45 NGEN Modular Workstation

Elliot: You mentioned Vinod and Daisy in your outline and the interactions that happened among all of you.

Garrow: Oh yeah, thanks for reminding me. At Convergent, I became the general manager of the workstation division, and I was managing all these customers and their products and making sure that we were moving forward generation after generation. Dave Stamm and Arey Feingold had started Daisy Computer, I knew them from Intel, and V.K. Khosla was at the company, but he wasn't a founder or anything, he was just there, and Arey and Dave would ask to visit with me from time to time. They wanted to learn how I was designing for manufacturing and how we were doing the desktop because they were building Daisy Computer and they were trying to figure out on their own how to make their product more manufacturable, etc. So that's just something that was going on at the time that involved some people that you may have heard of before. And then the other thing that was kind of ironic is that one of my engineers, Drew Hoffman, came to me and said Bob you ought to go over to Stanford and take a look at

this workstation that's being bread boarded over there, and I was okay, let's do it. We go over and we met in Forest Basket's office although Forest wasn't there, but Andy Bechtolsheim was. I walk in the room and Andy's there, and we say hello, and on the desk is one of my little Intel SBC Lexan motherboard products, it was like a slice of the multibus mechanics and so you could put in about four cards, and behind this thing was this gaggle of wires coming out from behind a CRT, the CRT was facing the other direction, these wires were coming out all over the place, and I recognized it right away, it's the CRT controller design because that's what we did at Convergent, and of course going up the wall and across the ceiling and down to the desk is this big yellow cable which was of course Ethernet, and Andy's telling us about the system, and I'm listening with great intent as he described it. I said what are those yellow cables, and he said that's the Sun (I misspoke…It was Stanford not Sun) University Network. <laughs> Actually it was ethernet, but that was the first Sun bread board I believe, and it wasn't an Intel product, it was based on Motorola, but Andy had taken that interest in Multibus because he wanted to use the Multibus and initially intended to use Intel as a processor but somewhere along the line he and Vinod decided on Motorola, but Andy was still showing people what could be done.

Kapoor: Yeah, I was going to ask you what the reason was for showing, yes.

Garrow: No, the reason for showing is that here's another workstation being developed, and we were a pretty high-profile workstation company, and Drew, my engineer, just thought it would be sensible for me to go visit with Andy.

Kapoor: So, they were pretty open about it.

Garrow: Yeah, very totally open about it. I think after viewing Andy's oral history I can piece this together a little bit better. I think at the time they were looking for someone to fund them or they were actually looking for people to sell it to or license the design to. So perhaps the invitation came for that reason that Convergent was one of a few companies that Andy was looking to license the technology to, and after listening to his oral history I realize that he eventually just decided he'd just better do it on his own. He and Vinod. and Scott left to do just that, but that was a just a coincidence, but it takes me to a story. Little did I know that I'd be meeting Andy again just in a couple of years. <laughs>

Kapoor: You were at Convergent for a couple more years and then Sun, what made you think about looking at Sun?

Garrow: RISC technology. Well first of all, I tried to retire after Convergent, and as it still does retirement doesn't agree with me very well. I don't care for it. One thing I've come to realize is that I enjoyed being an engineer in the beginning, I enjoy working with engineers, I enjoy working with the technical community, I have all my life, I still do, and so it's been an enjoyable profession for me, I'll put it that way. I tried to retire, it didn't work, and I was intrigued by RISC technology. I'd heard about it, read about it, and lo and behold it was like the microprocessor, I sensed something afoot that I should latch onto somehow, and so I figured out that Sun was going to pursue it or was pursuing it actually, and got interviewed by Bernie Lacroute, he was the executive VP under Scott for all the workstations and everything, and I eventually got hired. I joined Sun in December of 1985.

Kapoor: Had you met Bernie before that?

Garrow: No. No, I hadn't met Bernie. Actually, I was sought out, I just remembered that. A fellow by the name of Russ Bick, who was the first VP of manufacturing at Sun worked at Intel in the development systems group manufacturing group. He recommended Bernie seek me out, and Vinod knew me from Daisy, so I guess I had two sponsors at Sun, Russ who was just leaving, and Vinod who it turns out was just leaving as well. You know that whole story where Scott came in to run the company. So yes, that's how I ended up meeting with Bernie. I met with Scott, was interviewed by Scott, and they hired me. So I was back in the workstation business again. That was a lot of fun. Sun was just a lot of fun.

Kapoor: I understand you had an interesting very first day when you went to Sun.

Garrow: Oh yeah, the first day. The first day was Scott's staff meeting, so Bernie goes there with all of his reports, which included me now. We go into this big conference room, and I walk in and Bill Joy's at one end of the room yelling and arguing with somebody at the other end, I can't remember who it was, and they go on and on and they're back and forth and these people (Like Wayne Rosing, Carol Bartz, and Jim Bean all VP's now reporting to me), are chiming in, and Scott's just sitting there kind of with a grin on his face taking it all in, and I was hey what the hell, this is wild. So, Scott quieted that group down and I forgot the rest of the business. I was just wondering what the hell were they arguing about. I think it was actually the next day, Bill Joy comes into my new office and he plunks down a stack of Xerox copies of his emails about eight inches high and slams them on my desk and says, "Read these". And what am I going to do? So I really didn't have the time to read them, but it was the first kind of a clue to one of my first big decisions at Sun that was coming up. I'm still just trying to get the lay of the land. So, this is within the first month to six weeks at Sun. The next thing that happened, not immediately, but shortly thereafter Scott comes into my office and the picture starts to clear up because he says "Bob we've had this project going on for four and a half years, it's a Gate Array it's our RISC chip, and I'm getting tired of it. It's not going anywhere after four and a half years. Bill Joy's behind it and Fujitsu's the vendor and I don't know what to do. I want you to decide whether we finish this or shut it down."

Kapoor: It was called the Sunrise project.

Bob Garrow: Sunrise, okay, Sunrise, and so I started trying to figure out what the hell was going on, and I learned a couple things, I learned that it was a big Gate Array, and that some section of the design had to actually behave like an analog circuit, and that wasn't consistent with Fujitsu design rules. So, I'm thinking oh that's not good. But the other thing I learned was that the next tape out was in about eight weeks, and from my experiences at Intel I knew a little bit about the psychology of chip design, and when they're making progress and each tape out yields more functionality, the psychology's kind of positive, but when it stalls out and doesn't go anywhere it gets negative pretty quick, and so I went back to Scott and I said okay Scott here's what I've learned, here's what I'm going to do, and I told him the next tape out is in eight weeks. I'll tell you what, if that silicon works fine, we just keep going, but if it doesn't work, I'll shut the project down, and he said great, fine, do it. I didn't know what was going to happen, I had no idea. I'd only been there about six, seven weeks, and you know what happened. That was the first silicon that worked after I guess four and a half years.

Kapoor: Right. Anant Agarwal was the manager.

Garrow: Yeah absolutely.

Elliot: And I think part of the design problem was the fact that a quarter of that Gate Array had been cut out and was replaced with static RAM, for the register array. That may have been part of the analog problem with sense amplifiers to make that work.

Garrow: Could have been.

Elliot: We were amazed when we saw it at Cypress.

Garrow: But I figured that was probably the basis of the argument that I witnessed when I walked into my first staff meeting at Sun.

Kapoor: I think the target was 15 megahertz or 18 megahertz, something like that.

Garrow: I had a very talented team at Convergent. I had a Harvard professor, I had these great analog designers, etcetera. And you know, a couple other notable people from Convergent, I don't want to forget them is that Bobby Johnson, he was a Software Engineer, Networking Engineer, software engineer, became the CEO and Founder of Foundry Networks. Pretty big play. And one other notable CT Engineer, maybe I'll think about it later (It was Mike Ramsay co-founder of Tivo), but back to Sun. (I didn't complete my thought at this point. What I meant to add was that although I had a very talented team at Convergent, when I got to Sun, I realized that it had one not only as talented but about 10 times larger! The engineering talent at Sun was incredible)

Kapoor: So then after the gate array, Sunray was the project with Cypress.

Garrow: A year later or so, I got involved in what I like to say has been my favorite project of all time. Because it was, in fact, a full custom chip design. Code name was Sunray, and I got to Co-Lead that project with T.J. Rodgers, one of my favorite personalities in the computer business. And the project was enormously successful, but to get it started, I had to somehow get T.J. and Scott McNeely to spend more than a few minutes in a room together without blowing up into an argument. They were two extremely bright, competitive guys, and my office was just a couple of doors down from Scott's. Occasionally, I'd see T.J. come by and sure enough it'd be a little mini-explosion and they'd be walking out. So, I kind of wanted to do this project, I thought it was pretty cool, but I had to resolve the T. J. / Scott problem to do it.

Elliot: Who else was being considered besides Cypress as a source?

Garrow: You know, I don't recall. TI might have been one. I don't know, but T.J. apparently wanted to do it, Uday, confirms that at the time, he changed his mind later, but came around.

Kapoor: But I think the broker was John Doerr.

Garrow: Yeah, yeah, yeah.

Kapoor: He was on the board of Sun and Cypress.

Garrow: That makes sense. Yep, that makes a lot of sense.

Elliot: I was in there on the other side.

Garrow: Yeah.

Elliot: Okay, because I was sitting there saying, "If we want to be in the microprocessor business, then we ought to go with MIPS."

Garrow: Oh, yes. <laughs>

Elliot: And my rationale for that was that Sun was a big strong company, and that's great, and we sold them tons of static RAM. Because that's how they built all of their cache memory, was with our CMOS static RAMs. But if we want to control the business, MIPS was a small company with as good an architecture, but we could be much more in the driver's seat if we went with MIPS.

Garrow: I see.

Elliot: T.J.'s ultimate decision? It wasn't it John Doerr, it was that he couldn't afford to alienate the company we sold the most static RAMs to in the entire world.

Garrow: Well, so knowing what I had observed about T.J. and Scott, I decided if I wanted to do this project, I was going to have to get them talking to each other. And I reckoned that T.J. was the more mature of the two. I think they were about the same age, but T.J., I figured was the better to work on. I invited T.J. to come up to my house one time and just to have a heart-to-heart talk. And I convinced him that if he wanted to do this, he had to somehow be able to work with Scott and they had to be able to stay in a room together long enough to continue to work. So, he left and he must have taken it to heart, because he and Scott came together and we put a 30-man team together. T.J. and I put a 30-man team together, 15 from Cypress, Uday was from Cypress, 15 from my side, and we started— (T.J. Later dubbed me the Henry Kissinger of the computer industry)

Kapoor: But there was not a manager from Sun's side. I was running the whole thing for some time. And that caused some issues when we first got started with Wayne Rosing bringing Joan Pendleton in, asking us to do the design using the Berkeley tools.

Garrow: Yeah, yeah.

Kapoor: And I think you came in to solve some of the problems at that time, too.

Garrow: Yeah, I remember hiring Jim Slager from Intel, he was the 286 designer, to lead my side of that project. And it was kind of coming full circle. I'd worked for Intel for seven years. I'd never done a full custom chip of any kind. So here I was part of a big project to do a full custom RISC processor, which was great. And for some reason T.J. and I set the same goal, about 18 months, to get to first silicon. And he was just a masterful leader. We would run these weekly project meetings, like two project leaders, but it was him, it was his show. And he would drill down on guys like Uday, and with all kinds of minutia that they needed to address.

Kapoor: He was very much involved with details all the time.

Garrow: Oh, he was just amazing.

Kapoor: But what was interesting was that we had heard that there was talk of bringing the teams together by offering stock options of the other company to the other team.

Garrow: I know, that must have been between him and Scott. I had only seen this once before in my career, and what I'm talking about is 100 percent functionality on first silicon, and it was Masatoshi Shima, and it was 8080 while I was at Intel. He accomplished that. And it was amazing. And T.J. and the team did actually accomplish that in 18 months, the first silicon was perfect.

Kapoor: Right, not only that, but the target was 33 megahertz. And when it was announced, it worked up to 50 megahertz.

Garrow: Yeah. Before the project finished, Sun had to reorganize all its VPs. We had something like 50 VPs and Bernie asked me to run worldwide manufacturing, which was an amazing assignment, one of the most interesting assignments in my whole career. I don't think I was still in the Workstation Division when Sunray was completed. But I certainly got it started. That was pretty cool.

Kapoor: There was an interesting note that you mentioned that in one of the staff meetings, Bernie's staff meetings, you discovered that the products were not FCC compliant.

Garrow: Oh, yeah, that was an issue in the first six weeks of my tenure at Sun. During that staff meeting, product compliance and Sparc, it wasn't called Sparc then, but the Fujitsu problem. Within probably a week of that or so, I'm at one of Bernie's staff meetings, and I'm listening to the conversation, and I realize that the entire Sun product line is completely non-compliant with FCC EMI regulations. And that is a pretty serious problem because if you remember, maybe it's still that way, FCC was self-certified back then in those days. At Convergent, we did all that work. We did all that and made sure we were completely compliant with all the basic safety and EMI standards. I discovered that Sun systems were completely untested. The problem with that is if a competitor had gotten wind of it, they could have gone to the FCC and created all kinds of hell for Sun.

Elliot: Literally shut you down!

Garrow: Could have shut us down. And I had a veteran engineer by the name of John Garmen from Hewlett Packard who was a Compliance Engineer, a really solid well-versed engineer, many disciplines, running Engineering Services for Sun. The answer, the technical answer to the problem was something called “spring fingers”, which we used at Convergent on that very first system, the IWS, because it had a pedestal. Spring fingers are long pieces of stainless steel that are shaped so that they have a springiness to them. You bolt them or rivet them to the side of your front panels in the chassis, and when the two are mated, you get a complete electronic seal, and everything's fine. But getting those spring fingers into the Sun product line, which by then, was a very complicated line, took about 15 million dollars and 18 months. We were exposed for about 18 months. John got it all done, and we got all the testing done, and dodged a giant bullet. But that was surprise number two at Sun. There were many, many surprises now that I think about it.

Kapoor: So, a lot of the manufacturing was moved to Milpitas after that.

Garrow: Manufacturing was done in Milpitas at the time. Actually, you know, the original Sun headquarters was very close to the Computer History Museum. It’s, just a few blocks from the Google headquarters. And our manufacturing was originally there, too. But we kept growing and growing. Sun was at the time, judged to be the fastest growing computer company in history. And Scott drove that. He believed in driving revenue kind of in an unqualified way until the company hit the wall. And the company had such great talent and hard-working people, it just kept meeting its quarterly goals, quarter after quarter after quarter. It was a combination of, as it was then and always is, engineering handing off product to manufacturing, manufacturing being able to get the product smoothly into production. It was anything but smooth at Sun, though, like all companies. But I'd learned some lessons at Intel, and at Convergent, and the manufacturing team over here (i.e. In Mountain View vs. Milpitas) with engineering makes it too easy to transfer the product and still keep engineering engaged, so not a real transfer of responsibilities. We moved manufacturing to Milpitas, and there’s a funny story associated with that. Coincidentally, Joe Roebuck, who headed all U.S. North American Sales, moved the Sun salesforce from Mountain View to Milpitas, but he didn't refer to it as Mil-pee-tuhs; he referred to it as Mil-pit*ahs*. And I think the sole reason Joe did that is because he lives in Lafayette, right? Or he lived in Lafayette back then, and it simply reduced his commute. This reminds me of something I didn't mention earlier, I'll just throw it in really quick. Do you remember Adam Osborne?

Elliot: I do.

Garrow: Osborne Computers? First time I met him was back at Eldorado, back up in Concord. He was a Technical Writer, living in the East Bay, and he visited us, and we brought him on, because we needed a manual, a User's Guide for that, quote, "intelligent" terminal that I told you about. But Joe was his first VP of Sales at Osborne Computer. Joe was originally with either Datapoint or DEC, not sure which.

Elliot: I think it was with Datapoint.

Garrow: Datapoint, I think. He came out West to join Osborne Computer, and you know, they created almost immediately chaos because of product problems, not because of Joe.

Elliot: Did you meet Adam back at Intel?

Garrow: No, I didn't.

Elliot: Adam had written a book called "The Value of Power", focusing on Minicomputers.

Garrow: Yeah, probably did.

Elliot: Following that, he wrote a second one called "The Value of Micropower".

Garrow: I probably did meet him.

Elliot: And we hired him to write the first 8080 Users' Manual. And when we got this manual, it was Federico that had contracted him to do that, it was one of the worst things we had ever read. I mean, He took terminology like DIP and gave it a completely different definition. It was just terrible. Here we had a product ready to go. Adam had written this Users' Guide and we didn't have any documentation for the product, because that was supposed to be the documentation.

Garrow: Not good, not good.

Elliot: I think McKenzie sat down and in four weeks and wrote the entire set of documents for that thing.

Garrow: Oh, yeah.

Elliot: But Adam was just *incensed* that we didn't like his manual.

Garrow: You know, there was another neat guy back then, and I won't get into, because probably going too long anyway, but I just want to mention Gary Kildall. Cool guy. Very cool guy. And I had some great times and interactions with him when I was at Intel.

Elliot: Well, his compiler, his PLM compiler for us made the day, just phenomenal effort.

Garrow: He was just another of my favorite personalities in the computer business. So back to Sun. Where was I at Sun?

Kapoor: Yeah, we were trying to move manufacturing in Milpitas. And then I think you also initiated outsourcing.

Garrow: Yeah, let me tell that story. It wasn't me initiating it. I kind of regret doing that. But this is 1987/'88 maybe? By then, we were manufacturing at Milpitas and Sun was very vertically integrated. We had 600,000 square feet of floor space over in Mil-pi-t*ahs*, and about 2,500 people. There were another 500 people in manufacturing spread around the world, but about 2,500 jobs, if you will, over there in Milpitas. When I say 'vertically' integrated, we had surface-mount board lines for all the desktop products.

We had material highways going all over the place for the desk sides products, which were typically built to order. There were so many software releases per month. I think there were about 25,000 releases a month out of Sun. We had a manufacturing line set aside just to crank out whatever the media to deliver these. The media was CDs at the time. But what a complex product line. It was too complex. So, I moved over to Milpitas and I'm running the Worldwide Manufacturing from that location. And we ended up in a pickle. A real pickle in the third quarter of 1989. The company used an MRP system consisting of a bunch of spreadsheets.

Manufacturing used this MRP system called MANMAN from ASK Systems. If you knew about ASK and MANMAN back then you would say, "How in the hell could you be running a 1.9-billion-dollar operation on MANMAN?" Well, it wasn't just MANMAN, it was MANMAN and about 1,000 spreadsheets that all the manufacturing team maintained. But it all worked. It all worked, because the team was experienced and hardworking and kept at it all the time, but this pickle we ended up with is that we had to cut in this new ERP system to Sun called Cullinet. And for these things you need to train all the various organizations. You take years to get them ready to make this cutover. We weren't ready. So, we kept delaying the change-over.

Coincidentally, we needed to introduce five new hardware products into the manufacturing process that same quarter They weren't intended to be introduced all at once. They were scheduled out over some reasonable sequence. But things ended up having them all come together at the same time. Plus, we redesigned three processes within the manufacturing line. So, three processes and 5 new products had to take place in one quarter. Up to this point, Scott had driven the company perfectly linearly, quarter after quarter. Most aggressive possible revenue objectives every quarter, and he met them, time after-- quarter after quarter. This time we had bit off more than we could chew. And as it turned out, a simple thing called a “material transfer form” shut the whole company down. Shut the whole manufacturing process down. Because Cullinet demanded stricter authorization compliance to transfer material from one building to the next. The team, no matter how much they had trained, they weren't ready for it. We couldn't move material from one building to another that quarter for *five* weeks. For five weeks! And, I didn't know what the hell was going to happen. Things got really basic that quarter. And I started tracking the processes. I had my staff report to me every day, "How many systems shipped?" And shipment, back then the rule was you moved the fully packaged system across this big yellow line at the back of the manufacturing buildings, and you were officially shipped. It was just the policy then. I got nothing for five weeks. We needed to ship about 35,000 systems total that quarter. What I was doing was calculating the run rate that we'd have to achieve once we got going, and of course, it was going up and up and up and up, because we weren't shipping anything. Finally, after five weeks, they started shipping, they had solved the problem, material began to move. I forgot to mention what happened before that. The about nine/ten months before that, the CFO of the company bailed out, he quit. I don't know if it's the reason, but Bernie left, my boss left. Then my VP of manufacturing left. And I think there was one other senior exec who left. Everyone was bailing out. I’m thinking "Oh, my god, we're going to hit the wall!" And I decided that I was going to stay. I didn't want to leave Scott in the lurch. I wanted to stay and hang in there. Didn't know what the hell was going to happen, but the team was just amazing. They kept working at it, kept working at it. The shipments started up and my calculated run rate started to drop, drop, drop. I'll be damned if we didn't ship all 35,000 systems that quarter, but we didn't make our revenue, because all the stuff that was

supposed to go to Japan, didn't get through customs. So, we couldn't count those as shipments, and we had to report our first loss in I don't know how many quarters. So that was the quarter that Scott finally hit the wall. And it was quite a quarter. But the other thing that I need to say in thinking about this, that happened during that period. I stayed for another quarter, and then I tried retirement again. Actually, I did another startup, but not an important startup. But I think about all those jobs that we had at Sun, and all that manufacturing capability that we had knowhow we had. That was 1989. Not too long after, a manufacturing engineer by name of Jim Otts came to me. And Dane, do you remember him from Intel?

Elliot: I do not.

Garrow: Yeah, he was at Intel. Maybe it was at Convergent. But he came to me one day with a request. He wanted to change how Sun manufactured products he said, "I found a contract manufacturer," and I can't remember whether it was Taiwan or China, but he says, "These guys can manufacture this motherboard," and it was a motherboard for one of the desktop systems, "You know, cheaper than we can, and they can do it in volume," blah-blah-blah. "Do you mind if I just try it as an experiment?" And I thought about it and I said, "Well, it's just an experiment, you know? How much is it going to cost?" We talked about how it wasn't going to jeopardize any of Sun's manufacturing ability. But I said, "Okay, good, give it a try." But within ten years of that, that entire complex in Milpitas was gone! I didn't understand the significance at the time. That was the start of the big outsourcing. That was the time of the big outsourcing moves that manufacturers made back then. And at least that decision was not political or anything of that nature. It was just cost-cutting via an enterprising manufacturing production manager.

Kapoor: There's still one building that you can see the faded sign, Sun, still.

Garrow: Yes, you can.

Kapoor: On highway 237.

Garrow: Yeah, the faded sign, those were the buildings I ran. So that was an interesting time.

Kapoor: So, then you said you retired. You tried to retire and then again you started, cofounded Liquid Computing.

Garrow: Yes, I tried to retire again. By the way, it was Bernie Lacroute in my original interview that told me what I'd been doing in my career was following discontinuities in technologies. First the microprocessor then RISC Microprocessor. I was lured into my last major startup by the same phenomenon. And it was a company that ended up being based in Ottawa, Ontario, Canada, and I was a founder, but I was the only U.S. person. The rest of the founders and the board, save a friend of mine from Intel, were from Nortel. And the architecture was really exciting! It was basically to remove the conventional network between nodes of a mainframe computer and replace them with a switching fabric. Not just any switching fabric, a fat-tree point-to-point super high bandwidth switching fabric between all the nodes. It's really a phenomenal architecture and I know that because (didn’t complete the thought until later) I ended up converting myself into a business development guy then, because what the hell

was, I going to do here in California? Ottawa's more than 3,000 miles away. I ended up being responsible for the National Labs in North America, and all the high-performance computing labs in Canada at various universities, and some of the National Labs in Europe. So, I was selling to some of the biggest, you know, and best HPC customers in the world. And Liquid was highly regarded by most of them. Lawrence-- Mark Seeger at Lawrence Livermore Labs had an evaluation system, NASA Ames right next door to you guys took a system in. Lawrence Berkeley National Labs, same thing, and many other labs around the country, and we're-- Liquid had a very enticing concept. But there was a fatal flaw and it kills me to this day, because I picked the right architecture, but I ended up, as you said earlier, snatching defeat out of the jaws of victory in the end, because the fundamental problem was the thing cost way too much for the computer industry to accept. Even in the High-Performance Computing (HPC) community, it was about twice the acceptable cost.

I proved that on two occasions at Lawrence Livermore Labs, and the guys in Ottawa could just wouldn't accept it. But the reason for the high cost was that it was designed to be NEBS compliant, because for the guys in Ottawa, the backup strategy to the whole thing was to sell it to Nortel if they couldn't sell it elsewhere. Of course, Nortel went off a cliff and ultimately went under. So that strategy was not a good one. But talk about beautiful hardware! My god! It was a Quad Opteron, the motherboard, liquid cooling onboard, you know, beautiful hardware on it, great big system. The problem was Mario Mazzola over at Cisco got the same idea a couple years after we started. We started in 2003. And he spun out a group, a small group to do silicon for the switching fabric. And being good system builders, you know, system architects, they crafted a working system and they were very, very shrewd, because they made it modular so that they could offer entry level versions, starting points. For instance, the Liquid system had these gorgeous giant, 14 inch by 15 inch liquid cooled boards. And they also had a backplane, which was the heart of the switching fabric, which had 56 layers; 56 layers and over three miles of wiring inside of it. Super high bandwidth and the software was good. Our system worked; it was just way too expensive. The entry level price for a Liquid system was about $900,000 The entry level module that Cisco sold, was about $42,000. Cisco sells tens of billions of dollars of those systems every quarter! It turned out to be the UCS, Cisco's UCS, the Unified Computing System. The Cisco project that Mazzola started was called the California project, I believe. And he spun it out as a startup, and when they got the chips working, Cisco bought the company back, and the engineers came back. A very smart strategy.

Kapoor: They've done it many times.

Garrow: Yeah, I made a serious effort with Liquid. I was there a little over six years. We went through about 88 million dollars, at least. And I sold the first system. But it was for naught, because it was too expensive.

Elliot: Wow.

Garrow: And the Ottawa founders and board, they just they wouldn't accept it.

Kapoor: So, that came to an end, and so now?

Garrow: Oh, yeah! That was when I said to myself, "No more all eggs in one basket!" And ever since I've been consulting. And I'm very happy to be doing that, because that kind of hurt. That was a serious effort and should have succeeded.

Elliot: Those basic flaws.

Garrow: That was a big one! And it's really frustrating, because at Lawrence Livermore, I demonstrated very obviously within six/seven months of having the system under evaluation that that cost problem was there. And they just wouldn't accept it.

Kapoor: So, anything notable now that you're working on?

Garrow: Nah, Grandkids!

Kapoor: Okay. What are you most proud of?

Garrow: Grandkids. My sons. I have one son, I'm proud to say is a veteran Software Engineer doing great work. My other son is truly a world-class athlete, doing good work in his field, which is tennis. And two adult granddaughters, very proud of them. And two teenage grandsons doing great things at the high school level now. My wife, Roberta, who keeps me on the straight and narrow.

Kapoor: Any advice for the people that are starting their careers right now?

Garrow: Yeah, I guess if you can find a profession that you love, focus on it. Find work that you love. The other thing is, if that's working for you, be bold when it comes to looking for the next challenge. Don't be afraid to go into an area that's beyond our past experience, push your envelope. Just those two things, I think, help people stand out and get ahead, and enjoy their chosen profession, whatever it is.

Elliot: Bob, thank you very much for your time.

Kapoor: Thank you, Bob.

Garrow: Well, thank you for inviting me to do the Oral History. It's been a pleasure working with you guys and remembering, recalling all of those old connections that we both know so well, but can't quite dredge up that easily anymore. This was fun.

Kapoor: Thank you.

END OF THE INTERVIEW

