Oral History of Robert Belleville, part 1 of 2

Interviewed by:
Robert Garner
Chris Garcia

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Garner: All right, well, it's August 22nd, 2016. This is Robert Garner interviewing another Robert, or Bob as I know him, Bob Belleville. And, Bob, you've got so much fascinating history and I just love it all. We're gonna try to do absolutely everything, so don't think of any time limit or anything that's gonna cut us off. We're in this great space. We won't get interrupted. So, you know, your life, I guess you want to start with the simple stats like when and where you were born and what life was like growing up there?

Belleville: Yeah, I was born in 1946 in St. Louis, Missouri, and grew up across the river in Belleville, Illinois. It's really weird to grow up in a town that's the same as your last name. <laughs>[1]

Garner: Makes filling out forms easy.

Belleville: <laughs> So things were-- yeah, I learned how to spell it early--

<laughter>

Belleville: --which has always been a problem for me. The most important event in my very early life was about 10 or 11 years old is when Sputnik went off. Sputnik was such an important event. It hasn't really happened quite like that since because the country just got together and said, "Oh, my goodness. What has happened? We better train all of our kids to do better in school and do math and do science, and we better figure this out." I got sort of sucked up in a wave of educational fervor, and by the time I'd finished high school I had all my calculus done when I got credit for that at Purdue, so I was almost a semester ahead of the rest of my students at Purdue.

Garner: Were you interested in science before Sputnik, do you think?

Belleville: Yes, absolutely. Yeah, I was interested in all kind of-- experimental science has always been my interest.

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[1] [Interviewee's note] I have reviewed this transcript and added numerous updates, clarifications, and references. I am sure some errors remain but hopefully these are not serious. Many people are named in this document. I have taken care to get the spelling correct and have in many cases added links to web resources. Please forgive me if any errors remain. This was an unscripted dialog between Robert Garner and me. Robert was working from an outline I prepared beforehand. Appendix II contains that outline. Also the piece I wrote at the time of Steve Job's passing is included in Appendix I. I used the words 'cause, wanna, and gonna quite a lot. These should be: because, want to and going to but have not been changed in order to match the video. A large numbers of 'and so' and 'so' were just deleted from this text. In Appendix III are a number of pictures of people and terminals discussed in the interview.

Garner: How about explosive things as a young kid?

Belleville: We did a lot of explosive things although--

Garner: <laughs> We all seem to have that background.

Belleville: --having talked about that with other people, I was a piker--

Garner: <laughs>

Belleville: --compared to people that I know who really and truly exploded to the max-- fortunately, I survived all those experiments <laughs> like heating gasoline to a high temperature and finding out what happens--

Garner: <laughs>

Belleville: --those sorts of things.

Garner: Now, did you live in a rural situation?

Belleville: Basically, yes. Belleville is a town of about 30,000 people and it serves the farming communities in that region.

Garner: Did you have a farm? Was it a farm?

Belleville: We didn't have a farm. My father was a general practitioner, a country doctor, basically--

Garner: Oh, wow, okay.

Belleville: --my father would be called in the middle of the night by some farmer and out he'd go into the countryside to help somebody out. He was a busy fellow. He'd make--

Garner: Always problems to solve. I mean it's a very engineering-like approach, right? What's wrong with these animals? (Humans not a vet.)

Belleville: And my father and I worked together on various projects, like we built a little boat together.

Garner: A boat. <laughs>

Belleville: Yeah, <laughs> a gasoline-powered paddlewheel boat we built together.

Garner: Oh, wow. So there was water nearby you could try--

Belleville: Ponds, lakes, any water we could get near to. The river, Mississippi River, was very close by as well, but that's not a good place to play.

Garner: No. Now, you mentioned Sputnik. Sometimes people in the Midwest have talked about seeing it going overhead at night. Did you actually ever see it--

Belleville: Absolutely.

Garner: --going overhead?

Belleville: The newspapers and television would show when to go see because it would come up. You had to see it as it came up, while it was just barely dark and the sun was the right angle so you could see it. It was quite bright and it went through the sky very, very quickly because--

Garner: Did it blink or was it just a solid light?

Belleville: No, just a solid light. (Sunlight reflected from the spherical body of Sputnik.)

Garner: A solid light, yeah. Did they ever broadcast the beeping sounds that occurred?

Belleville: Yeah, we heard the beeping sounds that came from the little radio, which apparently was transmitting its temperature slightly coded, but it really didn't do much. And it was battery powered, and so in a few weeks the batteries ran out. It had a one-watt transmitter.

Garner: Did any of you have any fear that this could lead to the next step of a satellite dropping weapons on America?

Belleville: I don't think we thought of that so much because that was the days of the intercontinental ballistic missile, and so we were more concerned about that, the coming threat that was coming from that. Those were also the days of the strategic air command, I think, and we had these bombers that would scramble themselves and fly over the pole.

Garner: Yeah, so, basically, there was just this feeling that, hey, we need to get up there. We need to learn enough science. Now, when was your first exposure to computers that you recall?

Belleville: The very first computer I saw was at Washington University in St. Louis.

Garner: At what age?

Belleville: I had just-- on the tours you make for colleges as you're a junior or senior. (In high school)

Garner: Okay, so after high school.

Belleville: So right at the end of high school.

Garner: Right at the end of high school, okay. And it was--

Belleville: I saw one, I don't know what it was, but when I got to Purdue in '64--I'm gonna have trouble with my voice--Purdue had one IBM 7094. Purdue also is a funny campus, and it had a power station right in the middle of the campus.

Garner: Right.

Belleville: It has huge smokestacks, which, as you can imagine, was the brunt of many jokes.

Garner: <laughs>

Belleville: So that actually generated power for the campus. And the 7094 was built in a shed adjacent to the power plant. I don't think it needed that much power, but it certainly needed enough.

Garner: It probably used 50 kilowatts or so.

Belleville: Something like that.

Garner: Yeah, yeah, yeah. So then you also, as a young kid seeing the Sputnik overhead, you probably saw things on TV, and there was something about the Vanguard, that they were not doing well at the time.

Belleville: That's right.

Garner: <laughs>

Belleville: I can just remember being a kid, you know, like your favorite baseball team or whatever, and so NASA was launching these Vanguards which were gonna put up little tiny satellites, and they'd have pictures. I'm not sure they were live. They may've been live. But those Vanguards went up and just exploded right on the launch pad, and there was just like, you know, mighty Casey had struck out. <laughs> And for years and years they could not get that thing together, and it was just sometimes they could and sometimes they couldn't. And it was so disappointing, and that just built up a fervor amongst all of us to go and help. It was how can we help do this better? <laughs>

Garner: And some people may have responded differently and gotten discouraged and said, "I'm not gonna associate with that," but instead, you wanted to go out and try to figure out how to make these things work, in some sense.

Belleville: Right.

Garner: Okay. Now, did any images of atomic bombs or H-bomb tests bother you at all, or did you see any of that as a young--

Belleville: I did, as about a first grader.[2]

Garner: First grader? You remember. Yeah, that's amazing.

Belleville: That first hydrogen bomb test was broadcast, and that thing which has become an iconic image, this great globe of glowing awfulness, came on the television. And I'm not sure what people were thinking about, to show that to children, but it was a traumatic event. I thought, this is just destroying

[2] It was November 1, 1952 and I was 6.

everything. And then there's that picture that we've seen 100,000 times of the blast coming through and wiping out the little wooden house, setting the whole entire--

Garner: With the dolls and stuff in it, yeah.

Belleville: Knocking over the-- yeah. We were just bombarded with those things, and hiding under your desk, practiced hiding under your desk, which would've done a lot of good. It was a time when we accepted that fear as a part of life, which was-- I took a very strong inclination to keep on going and try to learn how to do things, but at that age, I didn't understand the social ramifications that were really going on there. When you're little, you know, you're like a fish. You don't understand water. You're in an environment that's essentially toxic but you don't know it because that's the only thing you know. I wanted to get out of Belleville, Illinois, as soon as possible, and the first step on that journey was to go over to Purdue, which wasn't that far away, but it seemed an exotic and romantic place.

Garner: In the fall of '64 you began your journey there? And did you already have an idea what you wanted to major in when you entered?

Belleville: Yeah, as a Midwest kid you do cars.

<laughter>

Belleville: You know, it wasn't until so much later when "American Graffiti," the film started. And after I saw that film I thought, oh, now I have a culture. I know what my culture was.

<laughter>

Belleville: s a kid we would work on cars all the time, and many of those scenes from "American Graffiti" are scenes that I've had. The scene in that movie where they went out to the junkyards and the guy had a motorcycle in a box showing this sort of shrine of how this guy wiped himself on the motorcycle, I've actually been in that barn, you know, a different one but the same experience. So mechanical engineering I understood. I had a natural feeling for machines, and I thought I would study something like high-speed automatic control or something like that. I didn't even know what that was, but something that had to do with machines and the control of things by using machines. So I went to Purdue, an ordinary bachelor's degree in mechanical engineering, but Purdue is a pretty remarkable place, a big engineering school of course. But in those days-- and I don't know whether-- I don't think it was because I was special because I wasn't special, but we were assigned a faculty advisor as an undergraduate, which I think doesn't

happen anymore. And I had a dear man, Bill Cottingham[3], who sort of guided me through the whole way, and he became very important to me because I was-- the mechanic engineering department had a building right on the main center part of Purdue, and in the back of it was a huge factory-like place. And it had a gantry crane where you could bring a locomotive into this building and take it apart, which had been done in earlier years. They had stopped taking locomotives apart, but the gantry crane was still in there, like a 50-ton crane, a huge crane. And up on the sides of this building were sort of balconies, and that's where the laboratories were. On the end of this building, at the end of the building there was a couple of tables where you could sit down between classes and work on whatever you needed to work on next. And I was sitting up there one day and Bill Cottingham came by and he says, "Do you want a job?" And I said, "You bet I want a job."

<laughter>

Belleville: He said, "Well, I'm consulting for a company called Inland Container Corporation," which had a research operation up in the research park north of town, and he and I went up there and they gave me a job (at $4 per hour) as kind of a utility person to help them solve problems, and that was my first nonacademic (job). I think I started that as early as '65 or '66. Problems that I had to solve there were things like when you make cardboard the little 'flutty' (serpentine) part in the middle is done with a machine that has a huge physical roller that takes the craft paper and rolls it out into that shape. A mechanic engineer would have the question of, what's the strongest shape you could make to do that? So it costs a fortune to make one of these wheels to actually test this, for example, I built a finite element model of the shape of that cardboard and modeled how the-- the model is flat crushed. When you put a pressure on it and it's run on an Instron tester, you find out how strong it is to crush. I tried to get my model calibrated against different flutes that they actually already had made in order to allow them to redo the flutes to make the most efficient use of the paper and the greatest strength.

Garner: Yeah, I think that's a very difficult problem. I think it's actually an unsolved problem today, which is if you arbitrarily crush paper, what kind of strength does it have?

Belleville: I'm sure it's still unsolved. It was a hard one.

Garner: <laughs> Yeah, you got a doozy on that one.

Belleville: But one of my instructors was I think an aeronautical engineer, I think, and he was an expert on finite analysis. And you remember that. That was pretty primitive computing in those days. That was done on (the) 7094.

[3] William B Cottingham 1933-2009

Garner: That machine was good for that. That's what it was used for, yeah.

Belleville: Yeah, but small memories and not very fast.

Garner: You just ran off-the-shelf programs, I assume.

Belleville: No, no, I wrote all of my own programs.

Garner: Oh, you did?

Belleville: Yeah, all mine.

Garner: In FORTRAN, I assume.

Belleville: In FORTRAN, FORTRAN II, and then I studied assembly language for the 7094.

Garner: Just to make the program go faster or just for fun?

Belleville: I wanted to know everything. For me, Purdue was like a candy store.

<laughter>

Belleville: You know? It's just like, wow, they know everything here. I wanna learn everything they know, and so I wrote all these programs from scratch. There weren't as many packages in those days as even 10 years later. So we wrote it in FORTRAN. I took my first FORTRAN class in the spring of 1965. I was looking at a physics book over the weekend and I saw my clock projects. And I found a job card--

<laughter>

Belleville: --you know, an 80-column card from the IBM. And you'd put that job card in front of your deck and hand it to a person and come back.

Garner: And hope that it ran, yeah.

Belleville: Oh, well, you know, it didn't run most of the time--

Belleville: <laughs> Of course.

Belleville: --but you learned debugging skills in a very interesting way when you have to debug on six-hour or twelve-hour schedules. So, no, I wrote all those programs. And I tried all kinds of things and they had problems, optimization problems. For example, how do you get the most size X out of this size stock kind of problem, which are good differential equation problems. Any sophomore can solve all those problems. And I learned a very important thing there, and that was experts in those fields, the people that actually did that work, they were always very close to those optimums. It wasn't like they didn't know what they were doing. And that gave me a really strong sense of how important interfacing with real people was and how important their work was, and whatever I could do to help them, that was what was interesting to me.

Garner: And did you see examples where people weren't able to communicate what they wanted? That was such a gigantic impedance mismatch between solving a cardboard paper crushing problem and assembling language or FORTRAN compiler and punching decks. <laughs>

Belleville: Yeah, that's the stuff I love. You know, that was just the stuff I was just naturally good at, and I knew enough physics to try things out. And in those days there weren't a lot of people running around saying, "No, no, you don't know what you're doing," because nobody knew.

Garner: Yeah, but the 7094 you had did not have a display device of any sort, right?

Belleville: No, no, that was all printout.

Garner: So you always had a line printer printout, right, giant printer printout--

Belleville: Right, right.

Garner: --and you had to punch cards. So, again, it was that very primitive interface to the computers of that era. So when did you first get an inkling that you might want to move beyond those primitive interfaces? Was it after your PhD?

Belleville: We got a CDC 6500 a few years later. I'm not quite sure how that deal was cut, but that was gonna be the main computer for the computer science department. And a few years after that, somebody hooked a few model 33 teletypes to it or something. I don't know what they were using for a front end or

how that worked or something, but there was a bit of a timesharing system set together on that. Saul Rosen, really an important figure in computing, he was the head of the department, also another just marvelous person, and I think the computer science department at Purdue was like six people or something like that.

Garner: At that time it was only six people, wow.

Belleville: Yeah, everything was brand new. I mean it had started while I was first there.

Garner: Yeah, yeah.

Belleville: Maurice Halstead was there, for whom the Halstead distance is coined. But I was taking courses from all those people even though they were graduate level courses because by the time-- you know, there wasn't much undergraduate computing stuff. It was all from scratch. Saul just said in his class, he said, "Go on down and play with it and see what you can do."

<laughter>

Belleville: It was like that. I don't know whether we were programming it in BASIC, possibly, or just some made-up language. Everything was tentative in those days, so we tried that. But I didn't have a computer of my own until--

Garner: But that was still a TTY terminal, with the ASR 33, but was there a graphics terminal that came? Not until later, it sounds like.

Belleville: Not until much later. There were no graphic terminals even in the army, and we'll get to that later, but even then. It wasn't until I came back to (Purdue where there was an) IMLAC on my PhD in '71 that I actually saw an actual terminal.[4]

Garner: Okay, so like many folks who were really charging ahead in their field, you had some summer jobs while you were--

[4] The CDC 6500 has a display called the CDC 252 which I programmed for my masters degree in 1968 and 1969 before I went to the army in mid 1969. (https://en.wikipedia.org/wiki/CDC_6000_series ; https://en.wikipedia.org/wiki/IMLAC

Belleville: I did. I had a wonderful family friend, a chemist from Great Britain who'd moved to the United States, and he worked for Monsanto, and he worked in one of the heavy industrial chemical plants down by the river. It was actually in a town called Monsanto, Illinois, which they changed because political correctness was failing. And they had little IBM 360/20, which was just one step up from unit record equipment, right?

Garner: Yeah, very similar to the 1401, actually. <laughs>

Belleville: Yeah, I think because it was meant to replace the 1401.

Garner: Oh, yeah, in a way, absolutely.

Belleville: It wasn't really a full-fledged computer, but they were running payroll and stuff like that, and so the first summer I had in real computing environment, commercial computing environment was there. And I had a wonderful boss who taught me pretty much everything I needed to know about computing. He said, "When you want to solve a problem, figure out what your result is gonna have to be and then figure out what all inputs you will need to solve that, and then write the program, which will then turn the inputs into the outputs."

Garner: <laughs> Ta-dah!

Belleville: And we were programming some of the work in RPG.

Garner: Oh, you learned RPG, yeah. It's an elegant thing, people tell me, yeah. <laughs>

Belleville: I was struggling with it because as a FORTRAN programmer I was used to loops and doing what you want, stuff like that. And one of the more experienced-- he wasn't an old-timer by anybody's judgement. He was a young man that was more experienced than I was. He says, "This is very simple, Bob." <laughs> He said, "You have one line of code. You take something and you change it to something else. That's all you can do."

<laughter>

Belleville: "You can't do anything else." So it was just like the tabulating printer.

Garner: That's why they created it, to help transition those people.

Belleville: Yeah. We had a 1401 printer on that machine--

Garner: A 1403, as it's called.

Belleville: Or 1403, yeah, you're right. And you still have one so you know. They have this huge-- the print head is on this sliding mechanism that goes back and forth, and there's a lever that you turn to release the lock so you can align the thing to the forms. They would've printed payroll and paychecks, for example, on that machine. And one of the jobs that I ended up with there was, -- Monsanto of course was a union shop, and the unions all operated on a set of union rules, and there was a little handbook and every union employee had the little handbook stuck in their pocket. One of the things that was there to protect the union workers was a grievance procedure. If you found that your work was unsafe or anything you wanted to grieve about (or) that wasn't quite right you could go to your shop steward and you could start the process of filing a grievance. In order to adjudicate a grievance because of the union rules, you had to have a shop steward, you had to have the griever, you had to have somebody from management and you had to have somebody from labor relations. You had to get these four people in the same room at the same time. And the union wasn't happy with Monsanto during that period, and so they were making a few more grievances than they probably needed just to kind of plug up that system. They were gonna show they weren't happy. I was assigned the job of trying to write a program that would schedule those four people into the same room at the same time more efficiently. I wrote that program in 360 assembly--

<laughter>

Belleville: --if you can believe that. RPG I don't think was up to that job. And they subsequently put it in production. And I was told the following summer that after they put it in place the union upped their stress level on the system to see how it'd go and they said it worked beautifully, and over the course of a couple of months we completely removed the backlog of grievances and met the union's requirement and off it went. But that was all written on that 360 in assembly language. And during the development of that I was having trouble. I'd done something wrong. You know, it's not that easy to debug assembly language.

Garner: Yeah, all you got is core dumps usually when something goes wrong, right?

Belleville: Yeah, and worse. I mean and so we got the CE (an IBM customer engineer) over from IBM in St. Louis and he spent two days with me, just to show you how the world has changed, and we fiddled around and we poked at buttons and we-- what it was -- the assembler put its warning messages as a single character on the very left-hand margin, and the printer print head had been moved over and it wasn't on the paper.

Garner: Oh, my goodness. <laughs>

Belleville: It took us two days. And that was how that world was.

Garner: Yeah, indeed, wow. Yeah, you've experienced it firsthand. Now, so that was the only summer job you had or you had a couple others?

Belleville: I was there three summers.

Garner: Three summers, okay.

Belleville: And one summer, well, the next two summers after that first one I spent in their laboratory. They had an 1800, and the 1800 was the IBM thing that ran the spectrum analyzers, so they were--

Garner: Yeah, a process control-type computer.

Belleville: Yes.

Garner: Very large, actually, too.

Belleville: A nifty, nifty machine.

Garner: <laughs> Designed in San Jose, actually.

Belleville: Really?

Garner: Yes, yes.

Belleville: It was a neat machine, and I can't even remember what I programmed that machine in, but they gave me all kinds of interesting problems. One was Monsanto was blending motor oil, so motor oil that you buy or used to buy in days when you worked on cars is made for the various people who sell it by companies like Monsanto, and they ordered it in gigantic train car containers. And each company has a formula. They take the oil base that they use and they add the magic ingredients to make their special Pennzoil or whoever's oil, Standard oil's oil or everybody's oil, then they buy it by the 50,000 gallon tank carload. They were having a quality control problem, and they'd get these tank cars all the way to the other end of the United States and they'd pull these samples out of them and they weren't to spec, so they'd take this train car back, send it all back to Monsanto to fix it. Well, of course, that's pretty expensive, and my job was to try to figure out how fix that problem. I was able to tap into the spectrum

analyzer part of that 1800, which was running real time, find out what was going on inside the storage tanks, these huge cylindrical tanks that are two or three stories tall. And they have in them just like your kitchen mixer, they have this gigantic propeller in the middle of it that stirs around. And I was able to determine what was happening is they weren't mixing it long enough. I presented these results and I said, "The only thing you have to do is wait three days and the tank will be sufficiently mixed and you can load the tank car." And they said, "We can't do that because that's three days' worth of inventory. We have that on our budget and we can't manage that. That wrecks our financials." And so that's the first thing that taught me that this was gonna be a very complicated game, solving problems for people because you had to solve money problems, technical problems all at the same time, so I learned a lot. I had good experiences there.

Garner: Was there any possibility of making it stir faster?

Belleville: You know, it had a huge electric motor on the top and it would've required a capital expenditure to do a new thing, and who knows what would've happened? But that was a heavy industrial plant, and we made all kinds of horrible things there.

Garner: And I know, Bob, that later you ended up with a fascinating hobby, which we'll get to, but did that hobby begin during this summer?

Belleville: It did, <laughs> the first clock I built, and this is very important to me, not because of the clock so much, just because in a basic college freshman physics class you learn harmonic motion. And I said, oh, I could do that. That's easy. Bill Cottingham actually helped me borrow some equipment and so forth, and I built my first pendulum -- also for Inland Container. The chief engineer at Inland Container said, "You're a mechanical engineer but you don't know how to use machine tools." He says, "We got this big shop out back. Help yourself." I thought, wow, this is very cool.

<laughter>

Belleville: I was like a kid in a candy store.

Garner: Just don't cut off your fingers, right?

Belleville: Well, you know, I think in those days they thought people were smart enough not to do that--

Garner: <laughs>

Belleville: --and I was very careful. I went out and made my first pendulum in that Inland Container shop in my spare time out there.

Garner: How tall was it?

Belleville: A meter pendulum. I still have it.

Garner: And what caused the motion, a little motor?

Belleville: I had a little tiny electromagnet up at the top and some little photocells on the other side, and I'd watch it move and I'd try to put a little pulse in there. And so that didn't really work very well, but it became the organizing principle of my life. And I'll tell you this and you can see how embarrassed I might be. I learned all of my electrical engineering building stuff for that clock because that was just at the very beginning of small scale integrated logic, and there was a store in St. Louis where I could buy it. And I learned how to design in that very early--

Garner: So these are TTL chips, you mean--

Belleville: Just TTL chips.

Garner: --like AND gates and OR gates.

Belleville: AND gates, OR gates, simple flops, things like that. I taught myself all how to do that design. One of the things that I've been thinking about in sort of thinking about with this talk is--and you'll remember this very well--and that is how hard it was: 1), to get this stuff even if you're in a company, and 2) how hard it was to get information about the things, things that happened with DEC where they handed out the little flip-chip catalogs to all the college students. That was extremely clever and we could all learn that we learned--you probably did as well--learned an enormous amount from the manufacturer's data catalogs and so forth because the academic side was not really concerned about that stuff at the time, and if you wanted to build something you had to learn how to do setup times and figure out what your propagation delays would be and how that clock was gonna flow.

Garner: they kind of felt like manuals for how to create the future, all these little parts, and if you could just figure out how to put the parts together in some interesting contraption you could create something of interest.

Belleville: And you probably did it, too, the erector sets and the Lincoln Logs, before Lego, you know. All this thing is -- I thought of the world as a kit of parts. I mean taking cars apart, you know, there were all these parts, and you'd go to the parts store and get parts and you make cars, so this became an extension of that same thing. But, you know, we were talking about learning assembly language on 7094. One of the stories that I tell from that period was the index registers on a 7094--and you'll have to check me--run backwards. They only decrement. I believe that's correct.

Garner: Yeah, that's correct.

Belleville: And I took a look at that and I said, "This is silly. Why should you design a machine that could only decrement? That's the hardest way to think about it." And that was what got me into machine design because I thought, I could design machines as well as these guys can. It's not that hard. And machine designers tend never to be programmers, and programmers tend never to be machine designers, so I'm a fairly rare character in terms of-- now, not I'm not the quality of machine designer that you are and I never would claim that, but there have been so few people who cross that divide who could actually take a machine from scratch and figure out what it really did, write the assembler for it, things like that.

Garner: So what's interesting to me is that the pendulum ended up being a transition for you for mechanical into the electrical space.

Belleville: Yeah.

Garner: And also you decided not to treat it as like a linear control theory with all analytical electronics. You actually decided to make the transition to digital as well--

Belleville: I did.

Garner: --which is very interesting.

Belleville: Yeah, I did because I was weaker--

Garner: <laughs>

Belleville: --on the analog side.

Garner: Well, but you understood differential equations and integrals, and so that must've been some-- I think maybe you just felt-- I would guess that it gave you more control because digital control is very definitive whereas maybe--

Belleville: That's true. Also, I wasn't in possession of adequate test equipment. I didn't own an oscilloscope, for example. I was working on a little kit voltmeter that I'd made from Heathkit or something when I was a kid, and I could only design based on what I could do on a voltmeter, so you have to--

Garner: That sounds familiar. <laughs> You kind of wish your parents, "Can I just have an oscilloscope, please?"

Belleville: That was out of the question. As we talked about, my father was more likely to get a bushel of tomatoes than a fee.

Garner: Yeah, brave new world. Okay, in '68 things happened in the world politically.

Belleville: Oh, golly, yes. Yeah, that was-- people remember where they were ordinarily when John F. Kennedy was shot and I don't remember that exactly, but I do remember what happened when Bobby Kennedy was shot, but I was with that 1800 working on some problem in that summer. It was on the 6th of June in whatever year I wrote on that paper.

Garner: Yeah, '68.

Belleville: The world was getting-- that scariness of the world was being replaced with a sense of we're internally not okay anymore. The Vietnam War was ramping up. I was--

Garner: You were draft age.

Belleville: I was draft age. I was living from semester to semester on a student deferment, and during my master's-- I'd finished Purdue, the undergraduate part, in seven semesters, so I was a half a year ahead of my colleagues, and so I could get the three semesters for a master's done in the additional year, and Bill Cunningham was able to find me some kind of funding or another so I could do my master's. But I had that done, and during that time students were pretty much abusing--I don't know if I was--but pretty much abusing that student deferment thing, and so I was drafted kind of as a backlash to that student deferment thing. The reason that I got the job at Aberdeen Proving Ground that I got was I was drafted and I thought I was going to Vietnam and I thought I was gonna be killed. It was as simple as that. When I got on that bus to go to their recruitment (reception) center, I thought that was the end of my life. And we

got off the bus and we're in this huge place with hundreds and hundreds of lost souls, and a guy came running out of the-- I have such a strong image in my mind of what a two-story army building looks like. They were built to the same architectural plan all over the world, and they're everywhere and you can still see them. But he came running out of one of those buildings, which was built at Fort Leonard Wood in Missouri where I was, and he said, "Anybody here got a master's degree?" And about half of us raised our hands. And he said, "You know, I work here. I just got myself assigned to the headquarters company. I'm a clerk here and I've been reading the army regs, and there's a program you can sign up for. It's called science and engineering. And if you have a master's degree you can sign up, so come in and I'll show you where all the forms are and you can sign up, get this other job." 30 or 40 of us--I mean it was a huge number--went inside and filled out all the forms. I went through a full basic training program, which was a lot of fun. Yeah, fun in quotes.

<laughter>

Garner: There was no aspect of trying to break your sense of who's in control?

Belleville: Absolutely. (They did try to break your sense of who's in control.)

<laughter>

Belleville: And they challenge that a great deal. I was in terrible physical condition at those times, but I got plenty of physical training and I passed.

Garner: <laughs> You got a lifetime's worth of exercise.

Belleville: No, I didn't get a lifetime's worth but I got a lot.

<laughter>

Belleville: When I was graduating, we had graduation from basic training and my wife came down--I was married then--and she didn't recognize me. She walked right past me. That's how much my body had changed in the eight weeks of basic training. Hair gone. Fat gone.

<laughter>

Belleville: Brown as a berry, as they used to say. So at the end of basic training, you get orders and you usually go to a second eight weeks of additional training, but I had no orders and so I sat in one of these buildings I just described for some weeks. And they sent us out in the morning to do things like pick up trash or repair bayonet targets or something like that, and finally a guy came around and he said, "You have orders but they've been lost, <laughs> so go down to the headquarters thing and fill this stuff out again and they'll be able to hook that up and you'll have your orders." So I went down. I typed them up myself. I wouldn't trust anybody at this time. I got a stamp, put them in a mailbox, and sent them to the pentagon. And a week or so later the orders came through and I was to go to Aberdeen Proving Ground, and so I had to go back to the post library and find out where in the world that was. And I called my wife and I said, "We're going to Maryland, so get ready." So I went to Aberdeen Proving Ground with just a mechanical engineering degree, assigned to the material test directorate, and their job was to test trucks. The trucks were being purchased by Detroit for the use by the army. They had been bought against a certain spec, and we had to test them to see if they met the spec. It's a huge, gigantic facility where we tested everything, tanks, trucks, trailers. And I went into the XO's office when I finally got there, and he looked at my resume, which had all the computer stuff on it, and he said, "I see you got a lot of computer stuff here." He says, "How would you like to broaden your horizon? How would you like to test trucks?" <laughs> And so my first job was as a projects manager, basically, for truck testing, and it was another really good piece of experience because I was doing a civilian job, my boss was a civilian, his boss was a civilian, and I had to test a thing called the M561 Gama Goat, which was a six by six tactical pickup truck, which is articulated in the center and it was amphibious.[5]

Garner: James Bond movie.

Belleville: And we had to take it out on the-- it was required to go swimming on its test cycle, so we would go swimming with this truck. (In Chesapeake Bay.)

Garner: Yeah. <laughs>

Belleville: And my boss took me aside before the first swim and he said, "Son, don't sink the truck." And I said, "What do you mean?" And he says, "The last test they sank the truck."

<laughter>

Belleville: And it turns out it didn't float that well.

Garner: It's not supposed to fail the test.

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[5] https://en.wikipedia.org/wiki/Gama_Goat

Belleville: I rode along in the back and kind of balanced to make sure it didn't sink. But at the end of the test, like one of those tests, the other people that did the same job I did for everything else in that building or a very large number, was we would do a fuel economy thing because the army needs to know for logistics how much fuels this thing's gonna need on certain kind of terrain to plan how much of what kind of fuels they need for these vehicles. We'd sit there three days on a Friden calculator, holding a mechanical Friden calculator and do all the divisions and get this thing done. I went to my boss and I said, "You know, I know how to do this. You know, there's a 360 upstairs and it will do this." He took me up to the guy who ran the IT and the guy said, "That's fine. Just don't bother the programmers." I got the IBM manuals. It was a 360/30 or 40 or something like that and wrote fuel economy reporting thing, typed up the things on cards and was able to run a fuel economy test of course in a few minutes, and they liked that a lot because that got three-man days per test back. And the other one that I did that I learned a lot on was every time a truck broke, I would get called, sometimes in the middle of the night. "Truck's broke. What should we do?" I'd say, "Well, put it in the garage. Get them to start fixing it and I'll be over in the morning and take pictures and write the reports," so we wrote these little reports. I found the description in these reports used a very stylized language so there were a lot of prepositions. And I could take the prepositions and find them, wrote a little Fortran program that found the prepositions in the text of these reports, and on one side of the preposition there would be a verb and the other side there would be a noun, and I could then make a catalog of the nouns, the parts and the actions we were taking with the part, and I could write a subsequent summary report off of these things just by automatically processing these text reports automatically. Well, they were running a very high profile test of a kind of a Jeep truck that the congress had-- there was a fight in congress between the guy whose district was making one kind of truck and the guy whose district was making the other competitor for this truck. It was very high profile and there were generals all over the place and a lot of people looking at this thing, and that test came to an end and we ran that data out extremely quickly using that program, and they just thought that was incredibly neat. They took me off of testing trucks-- <laughs>

Garner: Too effective, huh?

Belleville: --and I spent the rest of my war, you might say, I spent the rest of my war. (with the computer)

Garner: Well, you did very innocent early data analytics, what today would be called data analytics, just analyzing text and certainly one of the first examples of that I've heard of.

Belleville: Yeah, that would've been 1970. I went in the army in '69 and I came out in summer of '71, so it was done in '70.

Garner: So you were definitely ready to get back to school, so then you went back to Purdue?

Belleville: I was unsure, but, again, I followed the wisdom of one of my bosses there--

<laughter>

Belleville: --and he says, “You know, Robbie, you’re too good for this place.”

<laughter>

Belleville: “You go on to your next thing.” I wrote back to Dick Garrett and kind of begged to get back into the program, and they were kind enough to take me back in. And at that point the two years had passed. Dick had-- a real mover and shaker, is Dick. I just spoke to him a few months ago. He just knew this was exploding. He had done his doctoral dissertation by generating four bar mechanisms. You probably don’t know mechanical engineering a lot, but if you take four bars and you tie two of them down or you tie one of them down and move one in a funny way, you can generate all kind of motion, so lots of complicated machines have these four bar mechanisms. They’re not intuitive. Only a real super mechanical engineer old-timer can sit down and pretty much figure out how you’d get a kind of a motion generated for a machine. So these are machines like-- especially agricultural machines. They’d have to do these funny motions to pick plants out of the ground or do these kind of things, so he’d done that. And his gimmick is he printed that out on one of the--you’re gonna have to help me here--one of those electrostatic printers, one of the very early ones. They were made up here right on El Camino at the corner of Page Mill. You know that company?[6]

Garner: HP, you mean.

Belleville: No, not HP. Well, anyway, we can easily look it up. But they made a--

Garner: Not CalComp?

Belleville: No. <sighs> It’ll come back to me in a minute.

Garner: We can always put it later, <laughs> come up with the name later.

Belleville: We’ll come up with the name later. They had a printer, and I don’t even remember the output from those printers. It was very low contrast. It deposited small electric charges somewhat like xerography. You ran it through and you heated it, I think you heated it, and out came this printing. He

[6] The company was Versatec which was later purchased by Xerox. https://archive.org/details/TNM_Versatec_printers_and_plotters_-_Versatec_a_X_20180227_0009/page/n1/mode/2up

printed his dissertation on that because this was all gonna be new. No more Selectric typewriters. We were done with that. So he somehow rigged up a deal with Imlac to get this little workstation gadget, and the Imlac was a 16-bit derivative of the PDP-8 by some guys who had worked at DEC. I don't remember that history. I bet other people remember that much better. It had a tiny little memory. Had core. We were not a wealthy research laboratory, and I remember that Imlac loaned us a 4K memory stack and we had to hand it back—

<laughter>

Belleville: --because we really didn't have the money to buy it and we were doing okay in whatever amount of memory had, which was like 8K or something like that. There was also one night when it failed and I actually manually repaired a core memory stack by resoldering--

Garner: You did.

Belleville: I did <laughs> 'cause we just didn't have the money to do anything else.

Garner: Requires a steady hand. <laughs>

Belleville: It required a good guess of how it worked.

<laughter>

Belleville: 'Cause, you know, you study coincident -- well, we did. You don't anymore, I'm sure, but you probably did, studied how coincident core memory works. I just thought this was great, and I was interested in all kinds of things, in how the engineer would relate to these computer things. How is that gonna work? In the early days I was there at that lab trying to figure out all kinds of things that would help an engineer. And it was a CAD lab and I wasn't specifically interested in CAD, per se, because really and truly that kind of software was only possible with a lot more hardware than we--

Garner: What you had, yeah.

Belleville: --anybody had except GM, who was making some custom stuff for themselves and probably--

Garner: Evans and Sutherland.

Belleville: Evans and Sutherland was making equipment for some people.

Garner: Military. <laughs>

Belleville: Yep. Like we said at SGI, we give it to them. We don't ask them what they do with it. And then Boeing. Boeing and General Motors were the two big CAD players. e were trying to figure out more about how would you do some of that stuff, solve interesting problems. Dick Garrett's wife was a-- I'm not sure quite what her title was, but she was teaching in sort of the physical education department and was real interested in kinematics. Just as the Olympics are saying now is how much computer studies have been done on running, for example? She was one of the pioneers of that. They used their son. They made films of him with little lights on him so they could digitize his limb positions and find out how he is moving. We were cooperating with that and trying to make that kind of stuff work better. Then we made the trip out to-- one of our field trips was out to here in Mountain View. We had a contact with NASA Ames (so they would have early access to our research), and Dick Garrett had a lot of graduate students. Usually, a major professor will have one, two, three.

Garner: Yeah, two or three, yeah.

Belleville: Yeah, he had 12, and so it was very, very unusual and it made a funny dynamic as well because there was a lot of competition amongst us and very different interests.

Garner: So you visited SRI?

Belleville: We took the day and went off to visit Doug.

Garner: Doug Engelbart.

Belleville: Doug Engelbart, and got into his laboratory.

Garner: He had a reputation already. It's like, that's where I wanted to go, because you had somehow heard about him already?

Belleville: I didn't know where I wanted to go. I'm glad I did get to go there. I always thought I would probably go to Intel or Tektronix.

Garner: Did you know about Doug before you got there?

Belleville: Huh-uh, no.

Garner: No, okay.

Belleville: I had never seen the famous mother of all demos, which was done in ’68, and I got to SRI in ’74, so it was a little bit after that. But we were still doing interesting things. When I saw Doug, I have to tell stories a little bit of what that was a little bit like

Garner: I’d love to hear that, yeah.

Belleville: --because here we are sitting on-- we had an Imlac, right? Everybody else was working either on a teletype or some dumb terminal of some sort that wasn’t doing anything at all. Or, you know, Stanford and MIT had made machines from scratch that had some graphics on them, but nobody--

Garner: Limited, very limited, yeah.

All right: --nobody else had anything. Nobody had seen it. And so here we go into this thing and here’s these marvelous television monitors with such lovely text on it. And this keyboard and this funny little cord set on your left hand, and I thought, wow--

Garner: Five individual keys, yeah.

Belleville: --that is perfect, yeah.

Garner: Like a piano, like five piano keys, almost.

Belleville: Yeah, and it’s just a binary code and you just to A, B, C, D, E, F, G. And turns out you can learn it in about a week. And you just remember certain things like P is your little finger on the fifth key. That’s how you remember that P’s the 16th character.

<laughter>

Garner: I have to say that I kind of gave up. I was one of those people that thought it was quaint, but... <laughs>

Belleville: The reason why it's cool and a whole train of that was lost, and we'll say it here so it'll be less lost than it is now--

Garner: <laughs>

Belleville: --NLS was a-- well, I have to say it right. The design of the interface language was a-- you gave a noun first and then you gave a selection. We don't do that anymore. You give a selection and then you give an action. Doug's system was built the opposite way. As far as I know no systems except for occasional microwave ovens are built the other way, and the reason for that is you have a command which would be like transpose word, so how often have you wished there was a transposed word command in any text editor that you've ever seen? There are no transposed word things in anything that we use today even though people that wrote before that, we wrote the little squiggle symbol to transpose a word.[7]

Garner: Well, it's a common human failing to accidentally put two words out of order.

Belleville: Yeah, that's right, that way or just, you know, you just want it the other order. And so when you hit the keyset your command would be transpose, the T, and the second command would be W for word, and then your selection would be two words, so you didn't have to drag across them. You just had to hit them somewhere in the middle, so you got away with one easy click, and you hit the command accept, which was one of the mouse buttons. One of the things that people don't understand is those three mouse buttons were not because Doug liked lots of buttons. It was because with five and three you get all of ASCII, so you do case shift on your right hand and a few commands on your left hand and you get the full alphabet, all the numbers.

Garner: I never realized that.

Belleville: You can have your hands on the two things, never leave for the keyboard, watch the screen, and do all of your work. And there are very, very powerful notions inside that. For example--

Garner: Yeah, I'd always assumed, Bob, that you get all 32 characters with the chorded keyset and then the mouse, so you're saying that the mouse was also used to enter characters.

Belleville: Yes, the three button were part of that, so you get the eight buttons that way. And it was very, very close--

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[7] NLS was oN Line System (because there already was something called OLS)

Garner: So that means it was really trying-- you could have 256 characters. Was it trying to encode ASCII or was it--

Belleville: Yeah, you could do a full ASCII set.

Garner: Was it the ASCII set?

Belleville: Just the bottom set--

Garner: Just the bottom part of the ASCII code.

Belleville: --or whatever it's called now, but just the 128 set, and, you know, left out all the control characters that you don't-- well, some you need but not all, tabs and line feeds, things like that.

Garner: So back to the first time you showed up there. So what did he show you when you first got there?

Belleville: hey had a conference room. On the floor they had workstations, which of course we were all drooling over, and then we went into the conference room for Doug to give us a talk. Doug had bought-- he found some $50,000 or something like that and bought a video projector. The video projectors of that era were made by having an electron beam in a vacuum with a disc that rotated with oil. It picked up oil--I mean it was a real monster--picked up oil and the electron beam wrote on it, and they put this God-awful high intensity of a light through it and it projected up on the screen. Not very many people had these things, as you can imagine.

Garner: Was it black and white then?

Belleville: Black and white, yeah. Nothing was color.

Garner: Grayscale, in essence.

Belleville: Not even grayscale. It was just binary images. It was hard enough. Well, it may've been grayscale 'cause television was, but it would've been three or four bits at the most. So what he could do was-- his lab, basically, was one of the first nodes of the ARPANET, and so we could sit in that conference room with that projector with NLS running on and putting its output to that projector and have an audio conference with somebody at BBN in Boston in real time in 1974 or '72, you know, and sit there

and trade ideas with people all the way across the country and just sit there and do that. And then Doug would stand up and do his thing, and his thing was a little bit like this. I'll set it this way: "The world has become a very complicated place. If we don't learn to work together and participate in the solution of solving problems, we're not gonna be able to solve the problems that we have because they're too complicated for one person to solve, and so we need to figure out how to augment--and it's the Augmentation Research Center--the ability of groups of people to work together to solve hard problems that single people can't solve." And that was the whole essence of Doug's

Garner: Greater intelligence through people working together.

Belleville: Yeah. And once you have the chance to do it in that environment with this keyset and mouse arrangement, that system becomes completely transparent. You don't think you're using a computer. The only thing you'd have as a similar experience is people that touch type well. I don't know if you touch type well. You probably do. But you don't think about what your fingers are doing. You just do. And people, for example, can run EMACS,[8] you know, without-- they've got it built into their brain in the sixties. Those people have had this experience, but very few modern people have had this experience of having a system where they're not using a computer. They are working on their problem.

Garner: But how much-- it sounds like you had a chance to experience it for sure--

Belleville: Absolutely.

Garner: --how much, though, was let's say the increased collaboration or the augmented'ness of it due to the voice aspect and what's being projected aspect versus running the NLS commands to show things on the screen, I assume? I mean what part is actually through the computer and what part was just through the humans interacting?

Belleville: Well, you know, the real advantage of the TV-based system that we had in the lab there was we could draw a bunch of workstations together and have the three people kind of sitting together. We did this very often. Say we're working on a proposal, for example. There'd be people with some aspect of the problem in their heads and other people with their aspect, and there'd likely be somebody along who was just thinking about the English of the document. Dirk van Nouhuys[9] was ordinarily that kind of a person. And we would sit there and say this and this, and we'd be talking, but we'd be sharing access to the same screen and all of our cursors could be consolidated onto all of the screens. In that mother of all demo things, Doug says, "Mine's the pretty one."

[8] A text editor on steroids popular in the Unix world and beyond with many incarnations.

[9] Dirk van Nouhuys' website is https://www.wandd.com

Garner: <laughs>

Belleville: Remember, they were actually identical, but if you moved them you would know which one's yours. You're sitting there and you have this voice link telephone to the east coast or whatever plus a bunch of people working together plus this completely fluid system, and so we could work with incredible fluidity, I think.

Garner: And so pointing and changing texts, let's try this; let's try that, I guess people would overrule each other or maybe talk before they'd make the change or make the change and talk.

Belleville: Absolutely.

Garner: But voice was the key component, though.

Belleville: Voice was the key component, and you had structures inside of NLS to do whole things like-- NLS is all outline oriented. They're paragraphs but everything lives in an outline format. You could say paragraph, so very often you'd need to flip two paragraphs around or a branch of a document, you could take a branch out or you could take a whole group of things, which is called a plex, so you could just talk about high level structures very, very quickly, flip them around, see how they went.

Garner: Yeah, these days someone tends to write like a version and then other people edit it separately in time.

Belleville: Yes, it's rather inefficient, and then there's a huge amount of--

Garner: Back and forth.

Belleville: --back and forth, which if we can do it in parallel-- humans do that very quickly in parallel, but if they have to do it in sequence, then there gets to be a lot of this is my territory kind of thing, which stays in the way.

Garner: So you visited there as a field trip from Purdue and you stayed there for just one day or a week and then all of the sudden someone offered you a job?

Belleville: Pretty nearly.

Garner: <laughs> You forgot to get a return ticket. <laughs>

Belleville: I think we got to go there like one more time, something like that, and they were using a PDP-10, which had been modified with a virtual memory system. I can't remember what that was called.

Garner: Down at SRI they added a virtual memory?

Belleville: No, I think BBN did it, so there was a big clump of hardware that was stuck on the side of the PDP-10 that made it into a virtual machine. And we were programming in a language called L10, which was developed there. Don Andrews was the designer of that. But it was just sort of a structured, some restructured, relatively simple kind of language, which was just set up for the PDP-10. So back at Purdue we were interested in it all. They were using a metacompiler for that, and then the thing that was of most keen interest is there was a metacompiler for the command language for NLS.

Garner: Yeah, makes sense.

Belleville: Dave Anderson (graduate student in Dick Garrett's group) particularly got all that code because it was the good days and everybody shared everything, just like it is now, except that was when most companies did not. And he tried to get it running. I don't know how successful he was because we just didn't have that level of equipment. But we were working with him on and off and just admired that work. When I was just about to finish--I was gonna finish my degree in early '74, just accumulated all this work and write the thesis and be gone--I applied to Doug and--

Garner: Before you get to that step, what was your thesis, so we don't leave that behind?

Belleville: My thesis was entitled "Man-Machine Communication, an Examination of the Machines." I knew the human part was harder.

<laughter>

Belleville: And so there was joysticks and keysets and light pens.

Garner: That's all that existed at the time and you tried--

Belleville: Everything that existed at the time I built a copy of and tried to see what its characteristics were.

Garner: Pros and cons, kind of?

Belleville: Yeah, pros and cons. One of the slides in this package of video or slides that come with this kit has a slide of all the devices I could identify.[10]

Garner: You didn't have a mouse. You didn't know about--

Belleville: It absolutely had a mouse.

Garner: You had a mouse.

Belleville: We had a mouse on an ARDS, which was another storage tube display, and it just had a mouse on it. But of course as soon as we got out and saw Doug, well, we knew all there was to know about a mouse.

Garner: Do you think that they got inspired from the mouse at SRI?

Belleville: Oh, yes, absolutely. They licensed it.

Garner: It creeped in that way.

Belleville: We had one (mouse) there (at Purdue) but I got them and hooked them up to my video terminal 'cause it was hard. They have a resistor, the two wheels.

Garner: There's two pots.

Belleville: There's two pots. You had to run it out to an A-to-D converter, which was esoteric technology and then to an A-to-D converter.

Garner: Well, they were expensive back then. A-to-D converters were still expensive back then.

Belleville: Sure, and the mouse was $300 cost.

[10] Unfortunately, the interviewee was not able to find the slide he is talking in this interview.

Garner: <laughs> In today's dollars that would be $3,000, almost.

Belleville: Yeah, at least, and now you can go down and get one for--

Garner: Eight-thousand, yeah. <laughs>

Belleville: --$8 or $10. We had the mouse and that was just-- you see a mouse and you know immediately why that's interesting and you stop there. There were some people at Xerox PARC later on who were doing a good deal more analytical work with respect to how efficient those devices are, so I can't really point to my PhD as really that foundational. It was more like a laundry list kind of a deal. It was so early days and there were so many things that had to be done to do anything that just sitting down and saying is a mouse actually faster than devoted keys, you know, that was research for later people.

Garner: What about light pens? You must've felt that they were great.

Belleville: Tried a whole punch of light pens.

Garner: You must've thought they were pretty effective but maybe the response time was slow from the system on it?

Belleville: None of them were very good, for one, and I always hated the idea that you had to put your hand up in front of it.

Garner: Because that obscured the--

Belleville: Obscured what you were trying to point at 'cause they were all big. I built some. I found a box not too many months ago that had one of them I built in it. I didn't think that was gonna be the wave of the future. Holding your arm up like that--

Garner: Got tiring, yeah.

Belleville: --was very tiring when you have your nice place where you can rest your hands on these two devices.

Garner: <laughs> Okay.

Belleville: So we sorted that out fairly quickly.

Garner: The PhD in hand, then, you visited SRI two or three times, and then somehow they gave you an offer to work.

Belleville: They did. They found some money--

Garner: Found some money, <laughs> okay.

Belleville: --'cause that's commercial research, you know, and it was--

Garner: You were out there for how long?

Belleville: I was there for three years, from '74-- well, two plus years.

Garner: And your roles, then, that you played there? Did you find a way to-- was it a bunch of A-type personalities, or what was it like in terms of the whole space, not just Doug.

Belleville: The whole space was a lot of really special people. Doug had the thing divided in half and he had two managers. And Dick Watson was my immediate manager and a guy whose name I'm not gonna resurrect (Jim Norton), which I know better than Dick Watson's. I don't know why--

Garner: It wouldn't be Bill English?

Belleville: Bill English had already moved to PARC.

Garner: Oh, by then, okay.

Belleville: We would meet Bill English occasionally when we'd have reunion things. Smokey Wallace was over somewhere else. I don't know if he was PARC. But kind of legendary figures from my point of view. But the people that were there were developing the system, so probably most important was Charles Irby. He was the sort of central architect of that system. Do you know Charles Irby?

Garner: Yes, yes.

Belleville: Okay, good.

Garner: You know, he played a big role at Xerox, SDD.

Belleville: At SDD, yeah, certainly. But he was the principal architect of the modern NLS. He understood those.

Garner: But you did not work directly for him.

Belleville: I did not work directly for Charles. I could've when I switched from-- we're gonna get ahead of ourselves, but I was supposed to tell you what I was doing at SRI.

Garner: Yeah, right, exactly, yeah. <laughs>

Belleville: Ken Victor was there. There were several-- who were those people? There were some system guys, you know, guts of the PDP-10 guy. The operating system we were using, I'm not sure what it was.

Garner: Were people living from year to year to get grants?

Belleville: Absolutely.

Garner: Yeah, so they ran into a lot of--

Belleville: We spent half of our time writing grants to get more money to keep going. But one of the things they wanted done was-- the earlier systems that they had, I think it was a (SDA) 940 or something like that, what was that, who was into manufacturing such a thing? But they had a graphics terminal of some sort, a very early one, and it kind of died off. Whatever company went out of business or whatever it was, and they had had some graphics on that machine and they switched over. I don't know if I'm gonna tell this story correctly or not, but we can always check. They had a thing which I thought was called a "Tasker," and it was a specialized piece of hardware hooked to the PDP-10 that could do a really high resolution image on a five-inch long persistence -- not a storage tube but long persistence phosphor CRT. They had a set of like a dozen of those with the machine room, and then there were-- a nice quality video camera looked at it. It was a dark box, and that video went out to the television monitors and that's how we used the system. So all the graphics was not at a CRT terminal per se but got pressed out as video, which allows you to do all kinds of other tricks.

Garner: (1:10:44) That allowed them to do the demo in ’68, basically, right?

Belleville: Yeah, and do a microwave link, for example--

Garner: And a microwave link, yeah.

Belleville: --which you couldn’t have done, which they couldn’t do, really. I mean that was a one off and couldn’t have been repeated, probably. So this thing had a vector graphics capability but it had declined because it was a stroke system and the letters were all strokes is why they had that characteristic. Dick Watson said-- when I came in he said, “You can't work on graphics. I know you’re a graphics guy but you can't work on graphics. We don’t have any room for that.”

Garner: <laughs> Okay.

Belleville: <laughs> So two or three weeks pass and he says, “We found the money for the graphics. Now you can go ahead and start the graphics.” I owe long-term apologies to Dick Watson ‘cause I was not very nice to him, and he didn’t deserve any of my behavior. But he did find the money and I went to work on that.

Garner: Did anyone ever tease him for his ironic name? <laughs>

Belleville: No. Nobody teased him at all I don’t think. He’s a very serious fellow.

Garner: Serious guy.

Belleville: Very talented fellow. He left there, he went out to Lawrence Livermore Laboratories.

Garner: But not related to the Watsons of IBM, I assume?

Belleville: I don’t know. Could be. I got started on doing-- I had done on my Master’s degree I had-- you had a CDC 252 display. I think the museum has one.

Garner: We might.

Belleville: And I had written all the software for that on my Master's. And there's a movie of that which I lost showing stick figure 3D done on that display. I know when I lost it. I don't really know when it-- or where it went. There's not much documentation on that work but I knew a lot about—

Garner: So back to SRI, what did you actually end up doing?

Belleville: I put the graphics back into NLS. Put-- Harvey (Lehtman) and I added the stuff to the file system so we could stick-- that kind of graphics, you remember, was all kind of display list-y kind of thing. You'd start down and you'd draw a vector from place to place. If it had a character generator you'd evoke the character generator, and you'd put that in a certain place. So it was very similar to like running a plotter. So the storage language for the graphics would be some sort of a front end and what we were all familiar with at the time was the thing that you'd draw plotters with, the Calcomp package which you had thing for drawing an axis of a plot, or a line or whatever. But it was very very-- it was very simple, and since you didn't have color and you didn't have grey levels it wasn't-- never got very complicated. One just sat on the top of things so you had to have some way of pointing on the display, and drawing out a line, and then storing that into the structure, and then identifying where the line was subsequently and moving it around in the structure. I wrote all the code to allow you to interact using that Tektronix 4014 display, and hooked to a thing called a line processor, which was a way of connecting terminals to a TIP. So not on the PDP-10 system directly, but coming in through a TIP through the PDP-10.

Garner: Remind me what the TIP stood for.

Belleville: Terminal Interface Protoco (Processor)l. It was a BBN thing. It was how everybody got on the original ARPANET, basically you got on acoustic modem to something, to a TIP, and that was how you got on the Web.

Garner: As it were. <laughs>

Belleville: Yeah, as it were. Well, it was pretty powerful. I mean it was--

Garner: Well, by then there were several--

Belleville: FTP.

Garner: There were several dozen sites.

Belleville: Mail was there.

Garner: But there were many dozen sites by then I think on the ARPANET.

Belleville: Yeah, and it was growing very quickly and we were communicating.

Garner: Did you have any feelings about the ARPANET at that time as a phenomena? I noticed the first people that were using it had a lot to say about what good restaurants were to eat at. <laughs> It wasn't being used to collaborate necessarily on scientific research.

Belleville: This is a quick story there was I was at SGI--

Garner: Later.

Belleville: Just up the street from here about 1992 or 1993, 1993 I guess probably because that was the first year, and I went to a kind of a group presentation and it was all about the newfangled Internet, and some guy said, "How many of you have used the Internet?" Everybody in the room raised their hand except me. I didn't know it existed. <laughs>

Garner: It made a transition. Okay so at SRI.

Belleville: I took away from Doug that story that I just told. Humans have really hard problems. Computers would be really useful to help solve those problems if the people used them to work together and solve problems.

Garner: Was that too idealistic on Doug's part?

Belleville: Was that too idealistic?

Garner: Yeah, do people really want to work together to solve problems?

Belleville: Well, if you--

Garner: Is he trying to do group therapy? <laughs>

Belleville: We always said Doug is really a closet sociologist is what he was. It was too idealistic for him, it was on the borderline for me, but I knew the first piece that had to be built.

Garner: The computer stuff.

Belleville: Everybody had to have a pretty good terminal, and I thought I knew how to do that, and so everything I did through basically the whole rest of my career was to try to get a pretty good terminal in the hands of just about everybody, and then I had hoped that-- all of our hopes are based on things which are just too idealistic, as you just pointed out. I had hoped that people would realize how valuable that collaborative work was, and I think what history has now shown us it that people don't really much care to collaborate, and there's too much turf war and there's too much this is my idea and you can't have it.

Garner: Even though the world is so interconnected now so easily, still there's not a lot of online collaboration, it seems.

Belleville: A lot of the sadness toward the end of Doug's life was to do with the fact that it just didn't catch on, people just didn't get it. It became-- he was so wedded to his base technology that it was a problem. That was-- that was what slowed him up. I would keep going visiting him and saying, "Doug, it's already happened. Now why don't you jump out ahead of it, say you're the leader."

Garner: Do the next thing.

Belleville: But he didn't like that. But my-- but my sadness about that is things like-- and I always get in trouble for badmouthing these people, but there's a "Third Man" movie, the Orson Welles movie. In some scene or other in the Ferris wheel or something like that, the bad guy and the good guy are in the Ferris wheel and one of them says, "Three hundred years of peace and what do you get from the Swiss? Cuckoo clocks." And three decades, four decades of really hard work by an awful lot of really clever people, and what do we get? Facebook.

Garner: <laughs>

Belleville: And while I admit certain value to that, it's not unvaluable, it shouldn't be the main thrust of our entire society. We're spending how many-- how many hundred million man hours a day deciding what breakfast looked like. It just doesn't make a lot of sense. When we're dying basically as a-- as a people.

Garner: At least maybe we could create more peace in the world. Okay so SRI. So how did you end up deciding to be recruited at PARC? Did someone reach out to you or did you reach out, or maybe you shouldn't say. <laughs>

Belleville: We were constantly trying to find money, and when I was there the second-- the second year I was there was the seventh year, and there'd been a kind of idea inside DARPA, ARPA at the time, that seven years was long enough to feed the seed process. If you didn't succeed in seven years they would move on. Doug was going to run out of his ARPA funding, and that was the big piece of what we were doing. We had some group meeting and I think Ann Duvall -- Ann Weinberg -- looked at me and said, "What do you think, Bob?" And I says, "I think we're done for." <laughs> And that part wasn't the right thing to say.

Garner: Someone's got to call the shots.

Belleville: She and Bill Duvall were dating at that time. He was-- he had joined Bill English and they were over at PARC and they were building the J STAR -- not the J STAR but the original J--

Garner: Machine.

Belleville: J Machine which was an Alto with Kanji fonts and to do Japanese. Now Bill English was just madly in love with the Japanese. It's a culture that's very easy to fall in love with. Their aesthetic is so beautiful; their craftsmanship is so amazing. They're amazing people.

Garner: And there really wasn't any Kanji workstations in the world at the time.

Belleville: There were very few and on our-- so Bill said "You can come and work on this J-Star thing. I went over and I was lost over there. I mean I really and truly was lost.

Garner: This is 1977?

Belleville: 1976 or-- '76, maybe.

Garner: 1976.

Belleville: All of my skills are really rough and ready. I'm not a refined academic by any stretch of the imagination. I have a PhD but that was just pure grit. I had been kind of hacking things out of whatever I could get ahold of, and PARC, as you remember was very refined.

Garner: I seem to recall two aspects, one was-- two cultures almost concurrently. One was the like Chuck Thacker throw it together, get it to work, and then there was the Butler Lampson, more academic. They somehow would coexist and feed off each other. So I guess Bill was more on the--

Belleville: He was more of a hack it together kind of guy. Bill English was more of a let's put some stuff over there and do it.

Garner: Which would fit with you.

Belleville: It would fit with me, and it fits with Bill Duvall as well. Bill is very much of a let's do it.

Garner: So you felt some pushback from the-- is it fair to call it the Butler Lampson culture?

Belleville: Yeah, absolutely. There was always a struggle. It was mostly clarified things like in the period that you will remember was when I was doing the character set work. I don't remember if you remember I was doing that.

Garner: I vaguely remember that. Yeah.

Belleville: The problem was with Star we had this problem was that nobody had thought about it properly, was as soon as we got multiple languages and not the same character sets we had a problem because ASCII just didn't do that, and I was trying to figure out how we were ever going to do.

Garner: Unicode didn't exist yet.

Belleville: Unicode-- I'll tell you the story that--I've lost another name; I'll get it back. I worked with Bill for a long time. Bill wanted to be in Japan. He and-- he and his wife went to Japan, Roberta, and lived there, and his difficulties were that--

Garner: He lived there you said?

Belleville: He transferred himself to that. Bill Duvall, I, and two Japanese men and two Japanese women were on this side. And Bill Duvall is a very private programmer. He's a-- he's a guy who works by himself, and there wasn't-- I never figured out quite what I was supposed to do in that environment and so I ended up doing some very menial kinds of jobs like writing customs forms so I could ship stuff back and forth, which wasn't going in the right direction. I went over to Charles Irby and I said "I got to transfer from there.

What else can I do?" And Charles said, "Do you want to do hardware or do you want to do software?" And I said, "I'll do hardware for a while and then software for a while." He says, "Okay, work for Bob Metcalfe." Charles transferred me.

Garner: For Bob Metcalfe you said.

Belleville: For Bob Metcalfe. I don't--

Garner: And this is SDD.[11]

Belleville: SDD. So you were also working for Bob, and I'm not quite sure what you were doing when you first got there.

Garner: I was doing Ethernet for the--

Belleville: So you were all doing Ethernet.

Garner: For the Dolphin.

Belleville: Right. Because that was going to be the STAR [workstation].

Garner: Potentially. <laughs> At least Chuck Thacker thought it might.

Belleville: So we're going to have to talk together to get the transitional history. I was in Bob Metcalfe's office one day and I don't know what job he had given me to do. I can't remember. And I was complaining basically not about Chuck Thacker per se because I have a lot of respect for Chuck Thacker. But I was complaining about how can you possibly build this big huge complicated machine at this point in time that's going to use-- I forget what the number was, 5 or 10 percent of all of its CPU cycles just to track the mouse? And Bob was not listening except half 3-dB of his bandwidth was being used for listening to me. And he just looked at me and he says, "What are you going to do? Are you just going to whine about this?" <laughs> And I said, "No, I'm going to fix it." And so, as you know, Butler Lampson had roughed out the design for the Dandelion and I thought I knew about that because I had gone to the [Wildflower] talk--

Garner: Roy Levin was involved in that too.

[11] [Interviewee's note] Xerox System Development Department, not actually part of PARC but co-located at roughly the same physical site and sharing resources.

Belleville: Yeah. And I thought it sounds good to me. I knew about 2901s, I knew about bit sliced processing design, I knew how that was going to go, and so I thought, let's just do this in CMOS instead of ECL, this is going to work a lot better. I don't remember how I approached each one of you. You will remember hopefully. But you and Dan [Davies] and Roy [Ogus].

Garner: And Ron Crane.

Belleville: Ron Crane.

Garner: And Dan Davies.

Belleville: Dan Davies.

Garner: You became our manager.

Belleville: I just rounded you up. I just said, "Let's go-- let's go fix this, let's go do this." I don't know how you felt about it because you were closer to Chuck than I was.

Garner: I thought you were wonderful. I thought you were very gracious. You were the type of manager that you know you're not really being managed. It's like--

Belleville: Let's do this thing.

Garner: You just, you don't let politics get in the way, and you solved-- isolated us from all those problems.

Belleville: I did. I mostly did. Roy helped a lot on that too.

Garner: Later.

Belleville: But actually through the whole thing. Because Roy and I worked on the proof conclusively that the 2901s was the right way to do it as opposed to getting a Motorola 68000 for example to solve that, that machine. And so we had to take a lot of flak from the other side on the subject of: "If you were as good of engineers as we are, you could get the D setup time below a hundred nanoseconds and this thing would run at 10 megahertz, just like I told you it would when from the guy from AMD was saying, 'No, we can't build that machine.' "

Garner: Do you remember Chuck Thacker's would be-- his kind of hubris in design, he would build a circuit, then later see if it actually met setup and hold time requirements. I don't know if you remember a talk he gave on the Dolphin where he apologized for trying to violate Maxwell's constraints. <laughs> So that was the climate that we existed under.

Belleville: It was. It was a tougher climate because we were just a skunk works and didn't count, and there were only what, the six of us. Was there six?

Garner: Yes.

Belleville: Don Charnley.

Garner: Yes and Don.

Belleville: Was in there too. And also Pitts Jarvis. I knew all that there was to know about little processors at that time and so I wanted us to use a small processor to run all the junk, floppy disks, and--

Garner: Which we did. IOP.

Belleville: Which we did. Roy designed that. That one from my point of-- you got a little bit out of hand. I didn't think we needed quite as much hardware to do that but I have infinite respect for Roy. So he must have done the right thing, I don't know. You built the CPU.

Garner: And the Ethernet yeah.

Belleville: All of the Ethernet.

Garner: Yes, the Ethernet.

Belleville: Roy didn't help you on the Ethernet?

Garner: No.[12]

[12] [Robert Garner's note] "Roy and I worked together on Dolphin Ethernet adapter. I did the Dandelion adapter. Ron Crane did the analog sections of both.

Belleville: Okay.

Garner: Dave Boggs did.

Belleville: Oh, okay good.

Garner: Dan did the disk controller and Ron did the display.

Belleville: Yeah, Ron did the display, and Ron was chomping at the bit to go off to 3Com, and I asked Ron very politely, I said, "Finish this, go to 3Com, make your millions and you'll be fine. It's great. But you have to finish this for me." We had this deal that you'll probably remember because you must have worked on it yourself hard, and that was I promised Dave Liddle or somebody like that that I'd have a picture on the screen by Christmas or something like that, you remember that? And you took-- Ron or you took a scanner <laughs> and ran the bits into memory and put it on the display.

Garner: Ron. Clever idea. <laughs>

Belleville: We had a picture on the screen when there was no possible way we could have done that from anywhere as near as complicated as code as that STAR system.

Garner: The project moved quickly.

Belleville: It did.

Garner: I mean we had startup hours, no one went home before 1:00 or 2:00 A.M.

Belleville: Right. That was a great time, and we built a great machine, no question about it.

Garner: Well one thing I liked about the design that came from Roy and Butler was the fact that we knew if we hit the cycle time we knew the I/O would work.

Belleville: Yes. That was genius, and I recognized that as the most important part because the Thacker machine was getting to be-- each one of those controllers was getting to be a monster computer on its own. This idea that we could time slice the processor, more like the Alto and I don't know how Chuck feels about that. I know he can't feel that great about it having that thing ripped out from under him.

Garner: Oh, yeah. Well, he-- I think he really appreciated that a lot because later when he went to Microsoft and really saw the ugliness of the X86 I/O subsystem that Intel was-- that big manufacturer was doing he waxed poetically more about the design approach that had been done at Xerox [PARC].

Belleville: We in the latter phases of that project I was so much more involved with the business side, I didn't design any of it as you know.

Garner: What was that like? What were you doing? What did you have to do?

Belleville: Well, so many periods of my life I've had to stop being an engineer and be a business man. And that was one of the periods when I had to do that. Partly was the business of keep selling it, and also all the outside work.

Garner: Was there a constant threat of being cancelled?

Belleville: No, I don't think there was that. The whole thing could have just collapsed under its own weight. That was a possible combination.

Garner: There were like two hundred people total. Three hundred?

Belleville: Oh, yeah, it was awful.

Garner: Working on software mainly.

Belleville: Yeah, Dave Liddle's main job was rewriting the org chart. But you'll remember in that period we were doing the Ethernet standard.

Garner: Oh, yes.

Belleville: And the DEC-Intel thing was set up and so I was also working on that, on the text of that and the diplomatic part of it. I got Bill Gunning--

Garner: So you worked with Gordon Bell then a little bit on that?

Belleville: Not Gordon Bell but other people inside of DEC.

Garner: But I remember we didn't change very much in the [Ethernet] spec. it was just the byte ordering and something else [32b CRC].

Belleville: I don't remember even when we changed but I--

Garner: So you had to fight--

Belleville: I don't remember how much you were involved in that spec, but that was one of those things. It was Intel and DEC and us.

Garner: I heard about the skirmishes and they wanted to make changes--

Belleville: All kinds of--

Garner: And we said no, no, no, keep it the way it is. Except for the bytes.

Belleville: They didn't change. They didn't-- they weren't happy with some of the design aspects.

Garner: CRC I think changed.

Belleville: All kind of things. When you do a big deal like that there's a lot of traveling, talking to people, getting-- hearing their ideas, bringing back-- talking to other people.

Garner: My memory is we actually produced the first Ethernet spec using the Xerox STAR, Ron, I think generated most-- a lot of the text.

Belleville: Yeah, probably did.

Garner: And we had it published in terms called the Xerox Wire at the time.

Belleville: Yes.

Garner: And I think the only things that changed were the big endian, the little endian and the CRC. So you guys did a good job pushing back the heathens. <laughs>

Belleville: The other thing that was happening was the MESA Chip. I don't know how much you remember about that activity.

Garner: Oh, very much so. <laughs>

Belleville: I was going out to AMD all the time. Now what is it that was chief designer at AMD, that had designed the 2901, what was his name?[13]

Garner: Oh, yeah. I know who you're talking about. I know him.

Belleville: He and I were working all the time because I was just convinced that that byte-coded MESA architecture was the correct architecture for a computer.

Garner: I didn't-- okay. It won you over as well, in some way.

Belleville: Absolutely. It was not even vaguely hard. From my point of view, what's one of the largest bandwidth, memory bandwidth tasks in a computer? The CPU. The bigger you make the word width on the instructions the worse you make that problem.

Garner: RISC hadn't come into vogue yet.

<laughter>

Belleville: But even the RISC machines your level of things and so forth I think you survived that transition-- you can stop me whenever I'm waxing unpoetic, I think you survived that transition because the memories got sufficiently faster and you ran them so much wider, but going into that period we were not running the memories so wide. Just because the skew timing on the buses was just too hard, as I remember how those problems were. So the whole precious resource in a-- as far as I was concerned in a von Neumann computer is the memory bandwidth is the whole thing, and so we're sitting there and I'm trying to build bigger and bigger and bigger displays that are sucking bandwidth out of this thing like crazy, and there aren't too many solutions to that problem, or certainly weren't in that period. And I want these great big huge and eventually color-- because this is still a black and white world at this point-- display that just want to suck up bandwidth like nobody's business. Because nobody is going to go back to vector displays, they're all going to be raster. And so on.

[13] [Interviewee's note] The person I worked with was John Mick. See CHM AMD 2900 Microprocessor family Oral History Panel catalog https://www.computerhistory.org/collections/catalog/102658341

Garner: So here you are a proponent for displays hogging all the bandwidth so you wanted-- you were okay for this poorer central processing unit that the run whatever the control language was to have very little narrow straw. And so therefore--

Belleville: No, I--

Garner: A byte-coded instruction set was good from your perspective.

Belleville: Was. Yeah. Because I could-- you know, how many times John Wick (head of the compiler group in SDD for the MESA language in which Star code was written) ran all those numbers. He proved conclusively how fast that thing would run.

Garner: But I remember hearing stories that you must have been part of then. If you go to a chip vendor like AMD or Intel they would say, "What's your volume, anticipated volume?" If you want to do-- is that the kind of conversation that happened?

Belleville: We had those conversations. We had the "We don't believe you conversations. We don't believe your byte coded ideas." Our--

Garner: Was that because the market was too small or just because "We don't like that idea"?

Belleville: It was because they didn't like the idea.

Garner: Really. It was based on--

Belleville: That's why we never had any traction with-- I never had any traction with Intel because they just had their mind fixed on how those machines were supposed to be built.

Garner: But they had these little crummy 8-bit things and they knew their market was huge, and maybe it didn't matter so much. Maybe that was more important. But you're saying, no, it was an architectural disdain for the byte code?

Belleville: Yes. From my experience. I mean you were more close to it in that heavy period about SPARC timeframe, and I'd backed out of-- I wasn't so concerned. I mean Steve Jobs called me one time, one morning after we all got thrown out and he says-- I was telling him about the machine that I showed you, that I called the M1 machine-- and I'll remind you what you told me about it-- and he says-- I was

telling him about it and he says, “Do you want to build that machine?” That’s when he started NeXT. I could have gone over to NeXT and built that machine I suppose, but I didn’t want to.

Garner: So we’ve jumped ahead there.

Belleville: We’ve jumped all over the place.

Garner: We’ll come back. So you’re at Xerox, but somewhere in here-- so I didn’t realize that you were out trying to help try to get a MESA chip maybe done by somebody.

Belleville: I was. I just almost got that.

Garner: From who?

Belleville: From that guy we’re talking about.[14]

Garner: AMD.

Belleville: The AMD guy.

Garner: Okay.

Belleville: And we were so close.

Garner: You don’t mean the head of AMD, Jerry Sanders?

Belleville: No.

Garner: This is the guy that did 2901. (see note above)

Belleville: Yeah, the actual designer. We both know his name. Haven’t thought of it in decades.

[14] John Mick.

Garner: It'll come to us later. (It seems to have taken about 7 years to come to us.)

Belleville: But I almost got that [MESA] chip, and the other one I tried to do, and that was get an Ethernet chip, and the Ethernet chip did in fact finally happen, but I was on plane with Dave Liddle (head of Xerox SDD and my bosses' boss) and I said, "Let's don't do 10." Now your heart is sinking. "Let's don't do 10 [Mbps]. Let's do—go ahead and do the 3 [Mbps] because AMD can immediately [go] with the technology that they have today build us a 3-megabit chip that's this big (tiny), and we'll get rid of this whole huge board, and the difference is going to be minimal at 10." And yeah I was perfectly happy when things went to a hundred, and a thousand, and a million and so forth. But at that time in history, we could have had so many more machines immediately on a network.

Garner: If you'd gone to 3, you said?

Belleville: If we'd gone to 3. Well, gone back to 3.

Garner: The two vendors were S3, and what was that other one?

Belleville: Well, didn't AMD actually build it, finally?

Garner: I don't remember.

Belleville: I think so. Because I seem to remember working with them an awful lot. His name was like Nick something. (This isn't funny anymore.)

Garner: We'll get it.

Belleville: I was doing all that. Don Massaro (David Liddle's boss based in Dallas Texas) was wandering in all the time. How do we—Don Massaro, for example, had bought—he'd bought a little CP/M machine from somebody, he'd bought the design from somebody, and it became the Xerox 820. Remember that thing?

Garner: Yes.

Belleville: So that stuff was all happening all the time. As I was telling you about the character set stuff about Sproull. I did that spec for the character set that I think got actually used in STAR, and Bob Sproull just ripped it to pieces. I mean he just thought that was the stupidest thing he'd ever seen. Later—

Garner: What did he think was deficient about it?

Belleville: It was probably deficient.

Garner: Oh. <laughs>

Belleville: I probably hadn't thought the thing out as well as I possibly could because what I was doing was basically saying we're never going to have any more of the 8-bits to use for characters and so let's subdivide all the known character sets. Firstly, let's identify all possible character sets and get that set. And that set turned out to be a number that 64—that 16-bits was close enough. You get most of Kanji, you get—you couldn't get everything that was ever thought about, but you get most of it. And it was subdivide that and on the fly you would build character sets based on which—had to divide the world into the idea of a font and the idea of a symbol. So you'd have an A, A-ness, and then you'd have a huge amount of variations on As (fonts) that you could but together. I put—teased that bit apart and I teased this how do you group the symbols together so it would stay working in 8-bit, which I thought was the right thing, and he didn't like that.[15]

Garner: Well, that was NLS approach, you had the noun first, meaning As, and then you had what kind of A.

Belleville: Well, it was the coding-- it was the coding thing. We had two coding problems and I sorted them out. All that stuff was being done there and you guys were beavering away, starting to make your interface with manufacturing down in El Segundo. You were still doing that right?

Garner: Yes.

Belleville: Spent lots of time, what engineers have to do.

Garner: Yeah, I remember that.

Belleville: And I was always super respecting that kind of work. And you remember my boss (Ed Miller based in El Sequndo, CA). You probably don't remember my boss. A guy in El Segundo who I had to interface on a regular basis, he and I eventually came to terms, but he was so old-fashioned Xerox.

[15] [Interviewee's note] About 30 years later Unicode, in various forms, replaced the pure 8 bit character width. In fact, in English it is still 8 bits but the standard allows for different width characters to accommodate virtually all symbols including emojis.

Garner: This was from the old SDS company, Scientific Data Systems?

Belleville: I don't know where he was from.

Garner: In El Segundo? I mean he was in El Segundo right?

Belleville: But he had no real vision of the future. And I had a short temper.

Garner: I remember that. You had a-- somebody you worked for you didn't like.

Belleville: It was not good for them. I'm sorry about that to all those people. He just didn't think I had the gravitas to run a heavy engineering project into manufacturing. And I think I proved conclusively later on that I did, but at the time I didn't know if I did or not. He took me way from that project and then I was left with Cub.

Garner: But you haven't talked about how you came up with the Cub idea and the context of here-- okay here we are at Xerox and we have our own homegrown microcoded CPU, we have our own language called MESA, we have our own operating system called Pilot, all the golden gems right that a corporation is supposed to-- all closed. And you thought, okay, it was a pretty good design and here you're over here with an 8086. So how do these two things--

Belleville: Match.

Garner: They don't. <laughs>

Belleville: They didn't match. If you see the progression, I was building terminals at Purdue, because that was neat. I had built graphics at SRI, trying to get a machine in the hands of everybody. It wasn't going to be STAR, not at ten thousand dollars a copy.

Garner: Well, fifteen thousand dollars. Thirty thousand or forty thousand of today's dollars.

Belleville: Whatever, huge amount. The whole-- from my point of view it was a good first step but the-- I was behind it, I'm the one that got it actually to ship in a large sense. I think the ECL machine would not have succeeded in the marketplace, and so even though they only made however many of them they made a lot of people saw them, a lot of people started solving hard problems based on that kind of an idea.

Garner: You're talking about the Dolphin now.

Belleville: Yeah-- no. No on the 8010 [STAR]. On your hardware [Dandelion].

Garner: Yeah, but you referred to the ECL machine, that was the Dorado you're referring to in that case.

Belleville: Right. Chuck Thacker's machine. I had like you did the Intel guy would come around, and one day brought a box and there was an 8086 SDK board.

Garner: Yeah, they were selling those.

Belleville: No, they were giving them away.

Garner: Giving away, yeah, that's true.

Belleville: If you had the right credentials you could give them away. A guy gave it to me and I took it home, soldered it together, and started playing around with a few light emitting diodes and I could-- I don't know what I did. I might have written an assembler for it on whatever we were using, Alto or the MAXC machine, which I think we had access to, didn't we?

Garner: Yes.

Belleville: And I thought-- I knew a lot about 8080s because I'd built my homebrew machine, and I knew how to code for that, I knew how that architecture worked, I knew a lot of stuff that it could do. It could do a lot more than most people thought. Then when I saw the 8086-- I have a sort of strong opinions about the Intel processors. The 8086 was the first really good one they built. The 8080 was pretty good, the 8086 was the first really good one they built.

Garner: Because of its interfaces I assume.

Belleville: Just because it was a clean design. It had its limitations but it was really up front about its limitations, and it looked a lot like a computer. Then they built that silly 286 thing which I've always-- I never had one, I never will have one, it was an awful thing. And then they built the 386, which was next (version). That was the last machine that an ordinary person could just put into something and use. After that 486s, 586s, 686s Inteliums, Infiniums. I don't know what they are.

Garner: <laughs> Isms.

Belleville: They're good for the modern world. I said I wanted to build my next generation machine, my home brew is already a raster graphics machine, I had Alto display. That big monitor on Star was incredibly expensive and hard to build because we worked really-- that was another job that I had -- to go find a monitor that can run a thousand pixels wide in that day and age can be built.

Garner: It was Ball I think.

Belleville: It was a Ball monitor. I just started building because I love to build.

Garner: You weren't trying to prove that-- well, what were your objectives in building it? I remember some of us were wondering: "Why is Bob off doing this thing?"

Belleville: "Why is Bob off doing … ?" -- well, one of the reasons Bob was doing this was because Bob had been taken off the job that Bob really wanted to do. And that was to take that machine into manufacturing. But you know, I didn't have much of a say. And I didn't get mad and leave. I just went on, 'cause it's lots of fun. My objectives were bigger screen, better answer. As a Sun guy, you know that, right? Your Sun hat, when you put your Sun hat on, you know that a lot of Sun's success came from the fact they had a big screen. A lot of those other things that people think might be a success, not including the SPARC, I think the SPARC was a big success.

Garner: Well, it had a decent operating system.

Belleville: Yeah, but where did they get that? <laughter>

Garner: From UC Berkeley, yeah.

Belleville: Yeah. I thought, big screen, keyboard, mouse. And we had this network. At that time, disks were really expensive. So the disk in the Star was a fortune! And not very big. And I just thought that with a network and a file server, you could concentrate a whole lot of RAM in a file server. Put as many disks as you want on it, because it's a shared resource. And you can swap just like you would from a disk over the network, certainly at 10 [Mbps].

Garner: I didn't realize that was your vision. That was a very prescient vision for the time.

Belleville: I thought so. And I also spent a lot of time proving that that was correct thing. I had to simulate a lot of stuff to show that that was really true. The disk bandwidths were not high. And so the network bandwidths were in the same--

Garner: Ballpark, yeah, yeah.

Belleville: Ballpark, as that.

Garner: Absolutely.

Belleville: You could put a fair bit of memory. I knew memory was on the right curve. It was going to go down (in cost). I was wrong thinking that disks would never get cheap, because it was a big, huge mechanical thing. And I thought, "Big, huge mechanical things don't get cheap."

Garner: And you have a background in mechanics, huh?

Belleville: Yeah.

Garner: And all the mechanic stuff you did was always big.

Belleville: My first-- the first disk drive that I ever had to deal with was the one that was on the CDC 6500. The hydraulic one.

Garner: Hydraulic one, yea.

Belleville: It was the size of two refrigerators. And the CDC term-- the 252 terminal is right next to it. And so there was a lot of-- shake the whole building.

Garner: Did it ever leak? That was always a nightmare.

Belleville: I didn't think this would go the way they have, you know, cheap, very cheap, very high density. I was just wrong. I just realized that mechanical engineers are really pretty good people.

Garner: But it was a good vision to imagine there might be a server based on disks, and you could pump all you needed over the network. So did you have that setup working, where you were downloading applications?

Belleville: Yep. I used the Alto over the serial line, because-- and you know, Hal Murray was always all over me about not having actually having built the Ethernet controller. It just didn't-- I just didn't get to it before the end came. I was doing my things, trying to get the MESA chip built, trying to get these next spec all finished, trying to do whatever Don Massero was thinking of. And I was trying to handle those things, and building up that Cub, and then I was demonstrating it. And I don't-- I don't remember see it-- but I would run the serial line from my office up the stairs to the conference room upstairs in that building and do demos. One of the most fun demos was when I did it for Dave House, Intel. And Dave House was not the august figure he is today, but he was an august figure even then. And he came in, and I did the rubber-banding demonstration on the Cub, I just took the mouse, and rubber-banded a line around. And Dave House says, "What graphics processor are you using for that?" And I said, "I'm using your 8086 to do that." And he looked at me square in the face and he said, "That can't be done." <laughter> He says, "My engineers tell me that can't be done." And I said, "Well, you know?"

Garner: Wow.

Belleville: "You'll just have to get some other engineers," but-- so we had some-- and so I was really frustrated by having that Cub which was--

Garner: You were a fish out of water in that environment there.

Belleville: Right. I figured the compiler could be fixed to produce--

Garner: The compiler to produce--

<overlapping conversation>

Belleville: 8086 code.

Garner: Hm?

Belleville: Absolutely.

Garner: But you liked Mesa byte codes.

Belleville: I did! But I couldn't have them, because I couldn't get that chip. I would put that chip in the Cub if I had had that chip. But his name was Mick Something, Mick Something. [John Mick]

Garner: Yeah, I don't remember.

Belleville: He and I tried really hard, but we could not convince-- you know, they have to make big commitments, I understood that. Cub is sitting working on the [desk] -- I brought Bill Duvall in as a consultant, helped me write code for the Cub.

Garner: So how did you make the famous transition to Apple on it?

Belleville: I was just sitting there working on that machine. And I picked up the phone, and it was Steve.

Garner: Oh! He called you directly?!

Belleville: Steve Jobs. He called me directly! He did that. That's what he did. And he says, and on that phone call, and it's true, and I've said this many times, he said, "I hear you're good. But everything you've done so far is crap. Come and work for me." <laughter>

Garner: He doesn't mince his words, does he?

Belleville: And I think he didn't use the word "crap." And so--

Garner: How would he have heard about you?

Belleville: He said, "Come over and talk to me."

Garner: How do you think he learned your name?

Belleville: I found out. It took me two years to find out.

Garner: Larry Tesler or something?

Belleville: No. Larry Tesler wasn't over there then.

Garner: Duvall? No.

Belleville: No, no. The guy that founded Flextronics. Tim Mott.

Garner: Oh! Hm.

Belleville: Tim Mott had been called by Steve to do the job that I got. And Tim said, "I don't want to do it. Talk to Bob Belleville."

Garner: How did Tim know you?

Belleville: Oh, he was there at PARC.

Garner: Oh, that's right! Tim Mott.

Belleville: Tim [Mott] knew me several different ways. But one thing we did there that we haven't talked about here was we did the World Show, Xerox “World Conference.” Where we took the Altos down to [Boca Raton] Florida. We did this big show. And they rigged up the first color laser printer for that show. Just, you know, overnight. Ron Rider, Bob Sproull [ph?] and Chuck [Geschke] [16]—

Garner: Gary Witherspoon [Starkweather - not Witherspoon]?

Belleville: Witherspoon?

Garner: Yeah.

Belleville: Yeah, yeah.

Garner: Something like that. Gary [Starkweather]-- <laughs>

[16] I was still on the Japanese machine with Bill English then. I was part of the team that demonstrated a Japanese word processor on the Alto.

Belleville: I should remember that, because he was the guy that actually knew how to do it. Tim was on that, because he'd been the kind of sidekick of the guy who was kind of running PARC's part of that show. I knew Tim from-- I knew lots of people.

Garner: Oh, that's right. he was involved with that. That's right, okay. Yeah.

Belleville: Yeah, so Steve called me up and he says, "Can you come over?" and I said, "How about this afternoon?" And he liked that, so I went over. And we went into--

Garner: What was your first day like-- your interview with him?

Belleville: My first interview with Steve was easy. We went into his office, which was a tiny little-- it was one of those buildings on Bandley Drive which was like a ski chalet. It was like a little house.

Garner: I remember that building, yeah.

Belleville: And Steve's office was a little cubbyhole. Chairman of the Board was (in) a little cubbyhole. That stuff didn't mean anything to him. And we went up, he talked to me. And he said, "Well, you gotta come over and see the machine." We drove over to what is (was) called Texaco Towers.[17] I think that's probably the first time that I drove in Steve's car, which was always a wonderful experience. <laughs>

Garner: Because?

Belleville: Gursharan Sidhu, the guy who did the AppleTalk Network, he says, "Every time I got out of the car with Steve, I kissed the ground." <laughter> So we went over there, and that--

Garner: What kind of car was it? Do you remember?

Belleville: Oh, Mercedes. Always a Mercedes sedan.

Garner: Okay, sedan, okay.

[17] Texaco Towers and old beatup motel or apartment building behind a Texico gas station on Stevens Creek Blvd, Cupertino, CA at N De Anza Blvd

Belleville: We got over there, went in, and that operation was just utter chaos. Just utter chaos. There wasn't anything that you'd recognize as an office! There wasn't anything you'd recognize as a laboratory. There wasn't anything you'd recognize, except like it was a college dorm party going on.

Garner: And what was being developed there?

Belleville: The Mac.

Garner: The Mac, okay.

Belleville: He very-- took me in. Andy Hertzfeld brought out the prototype, put some skins and software on it, and showed me what the Mac could do. And it was, at that time it was-- I think it was 320 or something bits wide by 256-- it was really a toy.

Garner: Small, and really tiny at that time.

Belleville: And it had the [Motorola] 68000 which was the attractive part. And I looked at that, and I said, "I can spend the rest of my life fooling around with this Cub thing, or I can come finish this!" You know? And that was as simple as that. I just decided it needed finishing, and that I'd finish it.

Garner: And you were struck by the kind of disorganized feeling of the place.

Belleville: Oh, golly, yes.

Garner: And you probably wanted to help move it in a more coherent direction?

Belleville: I did.

Garner: Yeah, yeah. But how many people were there at the time, do you think, in this college-dorm--

Belleville: I think less than 40. I'm not sure. Certainly it wasn't more than 40.

Garner: Had it already-- that's enough people where it could have already had cliques. And they didn't have an HR person probably.

Belleville: They did have an HR person.

Garner: They did have an HR person, okay. And what were you asked to do? Did Steve ask you to do something?

Belleville: Well, I was hired specifically to run software. And, somehow, I got through the interview with Andy Hertzfeld. He allowed to how I could be--

Garner: He must have thought you were not threatening or something.

Belleville: I think he was having a bad day. <laughter>

Garner: You mean, he wasn't listening to you?

Belleville: I think he thought for the next ten years that he was having a bad day. Because he could have just squashed it right there. It would never have gotten-- if he said, "No," it wouldn't have happened.

Garner: But you're what I would call a very gracious manager. You don't have a big ego. You're not out to take over the world. So he may have recognized that aspect of your personality, or--

Belleville: I don't know. I have subsequently, in the last decade, made peace with Andy Hertzfeld, which is a very good thing as far as I'm concerned.

Garner: Yeah, we'll get to that more, I guess.

Belleville: And we can just address that now. And I just took him aside-- I happened to see him at one party. And I took him aside, and I thought-- I think he thought I was going to kill him, which I had no intention of doing. I just took him and I said, "I'm really sorry! I never had any intention of throwing you out. That was not my intention. The stories that you've told, these are not my remembering of these stories. It's just not what I wanted to do. It's not how I wanted this to come out." And he just looked at me and he says, "Yeah, I'm sorry, too. I was young, and I just wasn't mature enough to understand what was going on." So Andy Hertzfeld and I are now "okay." I mean, we're never going to be the best of friends, but we're okay.

Garner: Awesome. So '82, then, you got this call and then you went to the facility and you passed the Andy test.

Belleville: Yeah, and I passed the Rod Holt test. I passed that with flying colors, I believe.

Garner: The who?

Belleville: Rod Holt was the Senior Engineer. He was the engineer for Macintosh, but he was like the third guy into Apple. Third or fourth guy (5th). And I don't know whether Markkula comes before Rod or not, but Rod was the guy who Woz and Steve had gone to his house, because they couldn't get the color burst oscillator in the Apple II to be stable. Rod knew how to do that.

Garner: This is the guy who lives in Las Vegas or something. This is--

Belleville: Rod is just one of those just super, super engineers. Engineer guy. He took me over to his favorite bar. It was that corner where Apple is now, the big building, it's an Apple, there was a feed elevator there.

Garner: Right, I remember. Yeah.

Belleville: And there was a bar, just an old bar there. And that was one of his favorite places. He took me to the bar. And he asked me some question like, "Explain the beta of a transistor." And I happened to know at that time. I showed him how I would design a simple transistor amplifier, and he says, "Okay." He told Steve that I was a systems guy, and that I was going to be just fine. But that I knew stuff, and it was going to be fine. He was running hardware and I was supposed to run software. Well, there was no running that software. It just didn't happen. I was kind of at a loss there for some months. Now Rod (Holt) was, you know had early enough Apple wealth that he didn't really need to be working there. And his health wasn't good, and he loved to sail. He sailed off to Hawaii in a race in his boat, The Sir Isaac. And he got about half-way to Hawaii, and Steve came into my office and he says, "I don't think he's coming back. He told me he wasn't coming back, but now I believe him!" He said, "So would you like to do both of those jobs?" And I said, "I certainly would! Because I'm failing here as the Software Manager of this operation." Then I took on the process of really trying to bring enough discipline to that organization to get it finished. And what I'm proud of about that is the finishing of the Mac.

Garner: So what year? It was announced in '84?

Belleville: Well, it was announced over and over again, but it actually hit the market in '84.

Garner: '84, yeah.

Belleville: 1984. The famous commercial, "1984 won't it be like 1984," was the one.

Garner: And you started in mid-'82, so—(Feb ’82)

Belleville: It took a while.

Garner: Did you feel it was, you know, 80 percent still to go when you started, or was it closer than-- and what were some of the challenges that you faced during those two years, or year-and-a-half.

Belleville: The principal challenges were that it wasn't being designed by-- those were all really good people.

Garner: Yeah, they all--

Belleville: But they were not trained engineers for the most part. The only really-- George Crow, a trained engineer. Some of his staff, trained engineers. Some of the guys like Burrell [Smith], for example, not really trained. Just naturally really talented. I mean, Burrell, tremendously talented engineer, who designed all the hardware, the digital hardware for the machine.

Garner: So maybe they weren't doing static timing analysis, for instance? Or--

Belleville: They weren't really being serious about the specifications. They weren't sure--

Garner: Was there a design document? A design spec. No? Yes/no?

Belleville: No.

Garner: No! <laughs>

Belleville: There was Burrell and Brian Howard, who kept Burrell on track, he was the adult in that game. Unfortunately, he passed away several years ago. But Brian Howard was kind of getting that done. We had some core people, like Linda Wilkin, who were gathering the engineering information and sort of forcing it into place. And I kept putting more and more discipline in that. And I kept working very, very hard with the manufacturing people. Steve wanted to build a fancy factory. Debi Coleman wanted to build a very fancy factory. She was in charge of finance, but factories and finance go together. We were always working on that factory. Spent most of our time, I think, probably on that factory. And Steve was never

happy with the person in charge of manufacturing for that project until Debi took it over. In fact, I was in charge of manufacturing for the Macintosh Division on various occasions for months at a time, while they were trying to find somebody else. We spent a lot of time on that. I signed every engineering drawing for the Macintosh personally. I forced them to bring them to me, and I would look at them. And you'd think, by that time, there wouldn't be much for me to do. But I would find mistakes.

Garner: Hm. Unconnected inputs or something?

Belleville: No, more like, "You've used five screws here when four would do."

Garner: Mechanical stuff more than electrical. More mechanical?

Belleville: This is-- all kinds of things. Stuff that just was gonna just cause a big, complicated manufacturing line to just come to a grinding halt. And so eventually, they realized that I was serious about that, and started looking at that stuff themselves, and then it all got cleaned up. Manufacturing did a spectacular job.

Garner: Did you have to ride horse over like environmental compliance testing?

Belleville: We did, yeah.

Garner: Did that go smoothly?

Belleville: No.

Garner: Never does! <laughs>

Belleville: No. There was funny story when they took it out to-- Half Moon Bay was someplace where it was radio quiet enough to do some of the tests.

Garner: Yeah, supposedly.

Belleville: And they had a truck that they took over and got in an accident. And so our FCC testing was postponed for-- that kind of stuff. It's endless. You know that.

Garner: Shake, rattle and-- oh, yeah, shake, rattle and roll tests, those probably had problems, too.

Belleville: Yeah, shake-and-bake. All that stuff.

Garner: Shake-and-bake has had problems, too.

Belleville: I forced every part of that to be done. They were good people. They wanted to do that. It just was not the sort of thing Steve thinks about.

Garner: Yeah, were there any issues with timing problems in the circuits at all?

Belleville: No, Burrell is just spectacular good!

Garner: Oh, okay, so more on the mechanical side then.

Belleville: He did it, that board was pretty good.

Garner: Did you have design reviews? Those kinds of things?

Belleville: Hm mm.

Garner: No.

Belleville: Heavens, no. <laughter> I'll tell you a story. Burrell moved. (2:05:33) He worked with a person that I know to find a different building to be in and moved without telling me.

Garner: <laughs>

Belleville: Now I didn't get in Burrell's way. I really didn't. I didn't ask him to review the design. I thought he knew how to do it. I didn't really look at it. And it wasn't that complicated. You know, the board's only about that big. Most of-- a big plunk of that's memory. And he designed all the PALs for it and so forth. He was just a genius on that stuff! But I didn't care about that. It worked, it was fine, it was going to be fine. The manufacturers, the main manufacturers, Motorola and so forth, were working with us. And those specs were good. They built a number of custom parts we had a lot of trouble with. The clock, the

keyboard interface. We had-- there was some other part that we-- it was a custom part that they were getting from somebody that wasn't really very well thought through.[18]

Garner: Now was there ever an issue-- was it the Mac or was it a different project where Steve wanted to get the disk designed by--

Belleville: No, no, no. That's a story which I will tell as quickly as I possibly can.

Garner: <laughs> Okay. Because it's painful? Or--

Belleville: No, it's 'cause it's been told a lot of times. There were five divisions in Apple. One of them made rotating storage, including a floppy disk called Twiggy. And the big feat of the Twiggy was it was double-sided, but the heads run-- opposing heads was for a while very hard. Because the two heads would not work-- the fluid dynamics of the two heads of the material would cause one of the heads to go into oscillation, or some such thing as that. So the great genius, I think Rod Holt had something to do with this. They put two heads on either end of a stick, and they had one on the top with a felt buffer, and the other one on the bottom with a felt buffer, and that was going to be great. Because they'd do a high-density, eight-inch floppy disk. And not eight-inch, but five-inch. Well, the problem was it had two holes in it. (If) you would pull it out of the drive, you put your finger on it (the magnetic media), and immediately that was the problem with it. That was not going well. Cliff Huston (Rod Holt's son-in-law) was the principal designer as I remember, and he was struggling with that design, I think.

Garner: And Sony was going to make it? Or--

Belleville: No, they were going to make it.

Garner: Huh? Who?

Belleville: We were going to make it.

Garner: Oh, Apple's going to make it.

[18] Software was using Mac prototypes with Burrell's board on a daily basis. Had those machines been failing we would have known. The board was in limited production and in use more that a year before we went into full production.

Belleville: We were right there on Orchard Drive or something like that. <laughter> And it was gonna be used in Lisa.

Garner: Right.

Belleville: And the Lisa was going to run, I don't know, a thousand units a month, or something like that. We were starting out at 20,000 units a month. So that we were not in the same manufacturing game as the Lisa was. You could do almost anything in 500 to a thousand a month. To run the factory at the speed that we trying to run it with the financial efficiency of trying to run it, couldn't do it. Wayne Rosing, was the Engineering Manager for the Lisa Division, a very competent, excellent--

Garner: Oh, I worked for him at Sun.

Belleville: Did you? Excellent.

Garner: Mm hm, mm hm.

Belleville: I thought very highly of him. Don't know if he realizes that or not. <laughs> But we had a thing called the Engineering Council, which was the five engineering managers. And we were the ones that actually ran Apple from a technical standpoint. So, the five divisions. So, he (Wayne) had a lot of eggs in the basket of that Twiggy drive. And Jerry Manock and George Crow both thought it was a piece of junk, and they both wanted to get rid of it. Sony had come up with the hard-shell three-inch drive. And they were selling a hundred a month to HP for some product that HP was making. And Jerry and George were very keen to get that into the Mac instead of what we had. And you can see, there was the problem. And then the other story that you need to know why, the other problem is, that Rod Holt had worked with Alps Electric in Japan in the construction of the original floppy for the Apple II. And so had deep ties with Alps Electric in Japan. So as soon as I had visited with Wayne Rosing one night, and I realized that we just weren't going to get enough Twiggy's, even if they could make them to make this work. And so I went back to Steve, and I said, "I'm going to finish up all the engineering we have with the Twiggy, and I'm going to go with a Sony thing." And he just took that as the biggest opportunity to attack John Bernard, who was in charge of that division. He did so to the point of nearly a fist-fight in a parking lot. And off we went! But immediately when I took Steve on his first trip to Japan, and we went to visit Sony, and we saw how they were making this floppy disk drive. They were making it up in a little room, tiny little room upstairs, no material handling. You had to carry the pallets of stuff up the stairs to make these-- it was just-- Sony didn't need to be building this. They only make a hundred a month, right? They didn't have any manufacturing committed to this thing. And Steve took one look at this whole thing and he just said, "These guys don't know how to build floppy disks!" Which they didn't! Because it was brand new, nobody knew. We went off to a trip to Alps Electric (in Sendai north of Tokyo. I was pure Japan at the time. When we got off the Shinkansen at the station, a dozen Alps shook our hands (Rod, Steve, and me) and

proceeded to grab all our luggage and usher us by car to the factory only a block away. The luggage just turned up in our rooms at the hotel.), who did know how to build floppy disks. But knew nothing about this three-and-a-half-inch technology, which they could license from Sony. And so there was a very strong relationship between Rod and Alps. They decided they would just do it from scratch. And then you could do that so fast, that even Sony, who was in production with the drive, could not catch up. George and Jerry Manock worked really hard with Sony, and I provided a position somewhat unappreciated air cover for them while they continued that work, even though I'd been told specifically by Steve, I was not to work on the Sony. And that I was to help Rod do the Alps. So I helped Rod do the Alps. And I got George to help Rod do the Alps. But, of course, it was a waste of time from Jerry's point of view. And so eventually that came true and Sony won that game in a fairly dramatic form, and Steve smiled at me and said, "Hm, good to have a good Engineering Manager." <laughter> And so that's how that went. It's caused a lot of hard feelings.

Garner: So Sony was able to just make a decision to go to high-volume manufacturing basically.

Belleville: Sure, it would just get it from them.

Garner: Yeah, okay. And that was used--

Belleville: All sorts of misunderstandings that Steve had were proven to be false. And Steve loved Sony as an idea. And we got to meet with Akio Morita, the Founder, and a very interesting fellow, and he (Steve) just-- he was interested in personal electronics. That's what he wanted to be with Sony. I mean, we've proven that now conclusively. <laughter> So, and that was in the place then.

Garner: So how often did you-- did Steve interact with you in this role?

Belleville: Every day!

Garner: Every day! <laughs>

Belleville: Every minute of every day! <laughter> Had it not been for the fact that cellphones were not yet invented--

Garner: Yeah, how did he find you? <laughs>

Belleville: I could go away. And that was the only--

Garner: So he would come visit you physically?

Belleville: Oh, yeah, absolutely.

Garner: So?

Belleville: No, Steve and I were very close. I like Steve. I mean, I don't hate Steve. I don't think he's a terrible person at all.

Garner: Did he ever--

Belleville: Attack me violently? Absolutely!

Garner: Verbally, you mean?

Belleville: Absolutely.

Garner: He would call you names?

Belleville: Yeah, absolutely!

Garner: But how can--

Belleville: How could I stand that? It hurt.

Garner: Huh?

Belleville: It hurt, it really did hurt.

Garner: It did hurt. So it wasn't something that just bounced off. It'd make you feel bad sometimes.

Belleville: No, it made me feel very bad.

Garner: Did he also say good things to lift you up?

Belleville: Not so often, but enough. And--

Garner: Hm. Would you remember an example of anything?

Belleville: Oh, I remember gobs of examples. But--

Garner: Okay, maybe one or two? <laughs>

Belleville: The thing that's true about me and Steve was we have an almost disjoint skill set. He couldn't do anything that I could do. And I couldn't do very much of what he could do. We complemented one another so well.

Garner: Like an Odd Couple, you mean?

Belleville: Yes. We were never in competition with one another because he was always far better than I would have been at anything that he did. And I always far better at anything that I--

Garner: But I got to imagine, you didn't call him names, or use emotional language.

Belleville: No, I didn't. No, I didn't.

Garner: So, did it make him feel better? Was that a way-- was it like a weird form of letting go of steam, I wonder?

Belleville: No, it was more along the lines of, "If I just encourage these people, they'll be smarter than they are." I think he really thought that.

Garner: He didn't think you were smart enough?

Belleville: He thought I could always learn. And there were things that he did tell me that were right. For example, he said, "You just don't know how to get in and get out." Which he meant managing. He says, "You just don't know how to just bop in, find out what you want to know, provide the information you want, and just leave." So, I never did learn that skill. I always spent time with people. It was--

Garner: But some people are--

Belleville: It was almost an entire year before I knew more about what was happening in engineering than he knew; that I made a transition, and I finally knew more than he did about what's happening in my own department. He was very good at bopping in and bopping out.

Garner: Yeah, he would go to each person and just sample them quickly, and go around, and he maybe thought you spent too much time, and so it would take you too long to get to know the whole picture.

Belleville: Yeah. When what I was trying to do was get the whole picture, the true picture, as opposed to just one-- somebody venting some afternoon. Because the way Apple worked is Andy would come in 10 or 11 o'clock in the morning and go to lunch. Start work, and work till three or four o'clock in the morning and go home and sleep. And that skewed all of the things that were going on. And Steve was also Chairman, so he had other things to do. So he would go in the latter part of the day, say, five or six o'clock at night. And I don't know, he was possibly looking for people to go to dinner with, or whether he just did that, because he knew everybody kind of mellowed out by about six o'clock.

Garner: It's a formative time of the day, yeah.

Belleville: It is.

<overlapping conversation>

Garner: <inaudible>

Belleville: And so he'd go, and he'd just go to the Software Group, and he'd just sit, and they'd just talk. Anything-- skipped three levels of management--

Garner: You're doomed! <laughs>

Belleville: I never had but two levels at a time. But everything skipped through, and I was always firefighting one way or another.

Garner: So he'd come back to you and say, "I heard this. So, can't you fix this problem? And why is it this problem--"

Belleville: "That guy's a bozo, why don't you fire him?" But he wouldn't have done it. But you know, that stuff. And so that was a lot of--

Garner: And you had to defend people then.

Belleville: I had to defend people. I had to coach people. I had to-- the software I never had a handle on at all. I mean, Andy just ran that the way he wanted it. It was a shame, because it wasn't the way I wanted it, and I wasn't really interested in poking around in their code and finding out what's going on.

Garner: But was it ever late? Was it ever the long pole of--

Belleville: It was always late! It was never on time.

Garner: Right. So that was the frustrating part, right?

Belleville: Absolutely.

Garner: Always more bugs.

Belleville: And you couldn't depend upon any of it. 'Cause everything-- I have a good friend that I don't know that you know-- Jerome Coonen, who wrote all the floating point mathematics for the-- he wrote the assembly code that influenced the IEEE standard now <inaudible>. He actually was part of that. That thing was known as KCS Standard before it became the IEEE thing. He is the C [in KCS]. Kahn at Berkeley was his--

Garner: Kahn, I know Kahn, yeah.

Belleville: Was his-- he's the advisor. I hired, of the two or three people I hired at Apple, I think maybe there were only two, he was one. And he did that code. He did that code in a month, two months, something like that. It was done! And I went into a staff meeting, and I said, "The floating-point code is done." And they all went, "Done?! Really?!" Yeah, he just sat down. He knew what the thing was that he was doing, and he did it! This other business was a lot of art, you know? "I have to make this beautiful, I have to do this and that."

Garner: What was it-- was it because people's impressions of what looked good were changing? Or was it because there were latent bugs, or was it kind of a combination of both?

Belleville: Oh, a lot of things. Andy was-- I don't know what he does now-- he was a very-- there are programmers who don't program with a lot of safety around their code. They assume that the other code is-- 'cause they probably wrote it-- it's going to be right. And so his code was very terse. And depended on other things around it being quite right. and that's-- he would struggle. He was enamored with Woz, certainly, and Steve certainly. And Woz had done something on the original Apple II controller board floppy disk where he'd worked all night to eliminate a via in the PC board so he could save a penny, right? And they were all taken up by that ethic of, "We've got to make this so good, so cheap, so perfect, you know? Because this is the only one we're gonna ever do, right?"

Garner: Yeah, it's assembled to the point where you can't take anything away.

Belleville: That's right.

Garner: But that's not what you wanted to do.

Belleville: And so the two or three dollars that could have-- that they possibly saved cost a year of time to market. Which all those things I knew were hurting us. I didn't want it to be expensive or overpriced or anything like that. But I didn't think this was the last computer I was gonna build.

Garner: Yeah, there would be a follow-on.

Belleville: There was going to be more.

Garner: So how did-- oh, we got to talk about AppleTalk.

Belleville: We really-- I've almost run out of time.

Garner: Yeah, we have 15 more minutes, right?

<crew talk>

Garner: Well, let's finish Apple.

Belleville: Let's see what we do as far as "come back" is concerned.

Garner: Let's finish Apple, and we got to eat lunch, too.

Belleville: We have 15 minutes or so before we actually have to go away, right, and do the other?

<crew talk>

Garner: Okay, we can always do--

Belleville: So let me talk about the AppleTalk thing. Because I basically had three jobs. I had to communicate what we were trying to do to all of my organization, which got to be fairly big. There was a time when it was 300 people, which is way too big. I had to do that. I had to do all of the outside forward product planning with Steve. So we were going to Japan all the time, trying to figure out, every time you came up with a new company we wanted to do business with, I was off to another part of the country to try to understand that technology to do things. And then I just had to do what an ordinary Engineering Manager has to do, which is everything you have to do. Fight fires of all magnitudes.

Garner: HR issues.

Belleville: HR issues was a large part of it. We had-- I had good HR help. That was never really a problem, except as it related to me. I have said, and it's almost literally true, that I come in on Monday morning, and half the people would hate me. And I'd go home on Friday afternoon, and half the people would hate me, except it be the other half.

Garner: The other half. <laughs>

Belleville: So everybody-- it was a very tense environment, people were, you know, but--

Garner: But there's-- analyze that for a second. I mean--

Belleville: Go ahead.

Garner: I mean, Steve-- the word "hate" is a very strong word, but I assume that people didn't like Steve meddling in their stuff, and in some sense, you were meddling, too. And that's why people thought-- that you were, quote, "hated." I mean, disliked you? I mean--

Belleville: You know, magically, Steve, when he was meddling always got away with it.

Garner: So somehow you--

Belleville: He would go in and he'd look at some piece of code or something, some picture that come up on the screen, and he says, "That's crap!" And the person, as opposed to saying, "No, it's not crap. It's this, that and the other thing," they would go, "Well, Steve thinks it's crap, so it must be crap." So they'd go away and get better!

Garner: Yeah, and then you would say, "Well, this could be designed better," and their reaction would be different. It would be like--

Belleville: I always tried to choose all the battles I had to make. I mean, I'll give you a specific example. Late in the project cycle, Steve said, "I don't like these DB-9 connectors on the back, let's change them."

Garner: <laughs> Okay!

Belleville: "No, Steve, we're not going to change the DB-9 connections, 'cause that could cost us a fortune! Cost us months! Gives no value whatsoever! We got everything tuned up to do this. I don't like those connectors either! We don't have time to go into a design process--"

<overlapping conversation>

Garner: What would you use instead of a DB-9?

Belleville: "To replace it with something else!"

Garner: Something smaller, huh?

Belleville: So, you know why, though, late-- the post Steve's return products, all have screwball connectors on them! And that's part of the reason. Steve was always thinking about things like connectors. But we were working very hard. Steve's not easy to work with, a lot of demands, a lot of stress in the whole deal. And I don't have the world's largest amount of physical stamina. I was never a football player. I never could stay--

Garner: More toward wrestling.

Belleville: On the court. I did wrestle.

Garner: Oh, you did wrestle?

Belleville: Yeah, I did sort of. For about five minutes in gym class in high school, I was a wrestler because I could have weight class where it made some sense. But no, no real stamina for that. And so, physically-- and I found out later why, partially, that was true. I have a medical condition. It's very simple. My thyroid gland doesn't work properly. And that was affecting me in that time. And I didn't know it. So, I would just go away. The factory-- late part of '83, we were about to give a tour to everybody in our group of the factory. They were going to go on a tour. Well, I'd spent a lot of time in the factory. I didn't need to go on a tour. I was going to go. It would have been fun. But I was just so tired. I was standing looking out my office window, which is on one of the corners of Bandley, looking across the street to the other parts of the division. The buses were loading up. And suddenly, the buses were not there anymore. I wasn't on them. I got in my truck. And I drove up to the top of Black Mountain where you get to the trail.

Garner: Go hike, yeah.

Belleville: Up the hike all the way up to Black Mountain from the Los Trancos side. And there's a power transformer up there for some of the radio equipment or transmitters or something. I sat up on it. It was nice and warm. And I sat there for a long time very, very quietly. And I sat there so quietly that the deer came all around me. You've probably had this experience. If you sit very quietly, animals will just come up to you. And I thought, "What this company needs is the AppleTalk network, a file server, and a laser printer."

Garner: You had that premonition there?

Belleville: And I came down from the thing. And I wrote those each one on a single piece of paper because I-- it was clear to me that those were the components of a serious forward-going company.

Garner: From your experience at Xerox.

Belleville: From Xerox, yeah from SRI, from everything.

Garner: Why not Ethernet?

Belleville: Well, just assumed, not Ethernet because I didn't think-- the Ethernet I knew was the [coaxial] cable television Ethernet.

Garner: Oh, okay. You're right--

Belleville: I don't know that it existed-- Ron was the one who--

Garner: Ron [Crane] co-invented or invented it, yeah.

Belleville: The twisted pair version.

Garner: Yes.

Belleville: Yeah, and so I don't think that was-- it certainly wasn't known to have existed yet.

Garner: No, it didn't exist at that time.

Belleville: All I knew was there was this enormous wire. And when we did that roll out, and IBM came and said it's a fire hazard, you remember that part of the very first day, I thought, "This is going to fail," not because it's a fire hazard because we could fix that. But it's because this is just too cumbersome. Nobody is going to be able to do this. This doesn't make any sense. The cabling plan is a failure. And had it not been for the twisted pair, it would have failed I think.

Garner: Mm-hmm. I think so, yeah.

Belleville: So, I thought of-- I had this box. I had a Macintosh. It had that high-speed UART in it. I could go at two hundred and thirty kilobits a second on that. I knew that was fast enough for the kind of stuff we were doing. It wasn't going to do voice. It wasn't going to do video. But we didn't have any of that stuff. So, we didn't have to worry about that. So, I thought I could take that existing UART, and put a transformer on it, and connect it-- transformer coupled to as many of those as I want. We'll work out some kind of a protocol. We could get all the Macs hooked together. It'll cost practically nothing. And we'll have a network. So, yes, network. And then the laser printer, Steve would come into my office around lunch time. He says, "You want to go to lunch?" And this always meant one of two things. He was going to take me out and berate me for a half an hour. Or we were going to just have a fun conversation about things we might do. And he said, we got over to the Good Earth, and he said, "What do you want to do next?" This was sometime in early '83. That was a long way from (what we would do next), but he said, "What do you want to do?" I said, "I want to build a laser printer." He said, "What's that?"

Garner: Really, he said that?

Belleville: Yeah.

Garner: I guess he didn't see a demo of a laser printer when he was at PARC that time.

Belleville: It didn't register in any event. He says, "What's that?" I said, "It's a box. It's about this big, about this wide. It's about that high, print any page you want." He says, "Well, that sounds good. Do you know how to build that?" I said, "Almost."

Garner: Did you know whether the guys at Adobe were doing theirs yet?

Belleville: About two weeks later, he came into my office. He says, "You know Adobe?" I said, "Adobe what? What's an Adobe?" He says, "Well, you know John Warnock, Chuck Geschke? You know those guys." I says, "Yeah, I know." He says, "Well, they started a company. It's Adobe. Let's go see." And so, they went over-- we went over. And they showed us PostScript coming out of some laser printer from DEC.

Garner: Oh, they hadn't started their own one at that point?

Belleville: They-- well, we hadn't-- didn't have it. But they had some commercial laser printer that DEC was selling for thirty thousand dollars or something like that. And they were outputting their prototypes. It was just the first five or six of them in some little-- one of the tilt ups around here. And so, they showed the page, one of their demonstrations was the old dental form will all teeth. It was a really complicated dental form. It's little four-point type and teeth, two sets of teeth like this on the bottom of the form. They showed him that. They showed him that picture. And they said that it had come from PostScript as well as a whole bunch of other stuff. And I knew a little bit. I knew enough about John Warnock and Chuck to know that whatever they were doing was going to be right at the leading edge.

Garner: They had perfected a lot of technology at PARC. I mean in terms of Interpress and--

Belleville: Absolutely. And it was just built into their-- because John coming all the way from--

Garner: I'll never forget walking in John's office-- John Warnock's office late on a Friday night. He was working late at night. And he said, "Xerox is never going to take my Interpress stuff and make it [public]. I'm going to leave." And the next day, he started Adobe.

Belleville: Yeah. I believe that I'm one of the first people in the whole world that ever saw the PostScript spec. They were willing to show it to me at Christmas 1983. And I took that-- so, I was scared to death because I didn't know what they'd designed. And I took that home and read that over Christmas. And I just practically cried because it was so beautiful. They'd just done that exactly right as far as I was

concerned. And they'd recognized that you can't describe pages by bits. You have to have higher level structures that you--

Garner: Mathematics, it's line curves and all that.

Belleville: All of the stuff that they've put in that thing. And of course, I was an old FORTH addict anyway. So, I knew about that kind of processor and how it would work. And I could see how that would be implementable and so forth. I immediately went to Burrell and, somehow or another, I don't know if Burrell let me talk to him or not, but somehow or another, I communicated to Burrell that he could build this super-processor with a million bytes of RAM on it. We'd stick it in this box. And then there was the matter of the engine. So, we knew-- Steve and I knew that Canon was making something for HP, again. Right? And so, Steve and I got on a plane, went to see Canon, got that trip arranged and went to see Canon. We saw the manufacturing facility for that printer, the engine, that laser head on it. It was part of their copier thing. It was not a big step up for them. But it was a big step for us. And so, we went into a kind of a negotiation with them that I'm exceedingly proud of. And that is we (Apple) had had some bad experience with offering people too much money, too many units of product. And we said, "Work with us on this one. We don't know how many of these we're going to sell. We have no idea. It could be ten. It could be thousands. I don't know. We don't know. And we need it for five hundred and fifty dollars." They said, "Yes, sir, Mr. Jobs." And so, they were going to build the whole thing. We were going to ship this board there, stick it in it. And we were going to be done. It turned out to be so hard to work with them that I-- it was one of my bad temper days. I stood up in front of the engineer, the Canon engineer. I said, "You don't really want to build this, do you?" And he said, "No, we really don't want to build this." And I said, "Okay, Debi will build it. You just forget about it. Go away." So, Debi, I went to Debi. And I said, "You've got to build this." She took a room not as big as this one that we're in here which is maybe fifty by fifty feet. She put the manufacturing together for the laser printer in about an afternoon. And she built these laser printers. And I sent Jerome Coonen over to Adobe to help them figure out how to get that code to run fast enough so it would run in that machine. He did that. We worked very closely with them. Steve and John (Warnock) fell in love. And--

Garner: Did Steve realize what a huge difference this was going to make for Apple?

Belleville: No, but I did. And--

Garner: I mean really helped, I think, push Apple into business spaces.

Belleville: I argue that it's what saved Apple from going completely out of business because had the laser printer not been there, the desktop publishing business wouldn't have evolved. And nobody would have bought those Macs in the quantities that they were bought until that desktop publishing thing happened. We did not forecast that. But--

Garner: Isn't that fascinating?

Belleville: The laser printer was the enabling technology. And I had so much trouble because very clever people like Bill Atkinson just hated PostScript.

Garner: Bill didn't like it because he thought it was too complex?

Belleville: Too complex, not direct enough, not fast enough. I mean Bill was like fast.

Garner: He's the bit tooler.

Belleville: Yeah, he's a bit tooler, a good one. And he fought me on that thing. You don't need-- Steve came to me one time. And he said, "We're not in the business of building standards. Get rid of this PostScript thing. Let Bill do it." And they had already dreamed up how they were going to do this in a different way. But had they done that, it would have failed.

Garner: Yeah, fascinating, well the fact that you didn't go on the factory tour and you sat by a transformer and had deer around you helped save Apple.

Belleville: I think so.

Garner: That's quite a story.

Belleville: I think so.

Garner: That's quite a story. I mean it made you realize that-- it got you out of the context of all that haranguing and day to day stuff and made you look at the bigger picture.

Belleville: Yeah, it also goes to show how fast you can do a product if you're in the right place at the right corporation. Yeah, it's amazing.

Garner: That truly is amazing. That's quite a-- and then the file server? We'll finish Apple.

Belleville: I don't know--

Garner: We have a few more minutes. We'll just try to cut at Apple, and then--

Belleville: Okay, we'll cut at Apple. The file server was clearly something that I knew was essential. The original Mac did not have enough disk to blow its nose. And so, I knew about file servers. I'd never designed one, but how hard is a file server, right?

<overlapping conversation>

Belleville: So, I'm not sure who did the board for that. I think it might have been Burrell, as well.

Garner: What was the protocol?

Belleville: We had to dream it up. And that's why it failed because somewhere along the line in there, the world had gotten too complicated, the Apple world had gotten too complicated. Now, we're moving in this awful period in 1985 when Steve was losing track of what was going on in the company and was considering himself a failure because he wasn't selling a hundred thousand Macintoshes a month. It was an odd-- I never saw Steve like that before. And I don't think we'll ever-- we ever saw him that way since. But he lost his confidence. And--

Garner: Was he dejected?

Belleville: He was dejected. And so, he was not paying attention. And he'd run us so ragged that we weren't paying attention either (Mac staff see photo below). John Sculley was having trouble with the board because he believed all that Steve Jobs stuff and had never learned enough-- I don't know what he would say. But-- because I don't dislike John Sculley at all. I don't think he's a bad person at all. But his skillset was such that he didn't know how to pop in and pop out either. And so, he wasn't wandering around the company in parallel with Steve trying to figure out what's going on. So, he was kind of relying on Steve just telling him how the company was going and other people who weren't really in the know. I made it my business to try to make a monthly appointment with John Sculley and visit with him and see how he thought about the world and so forth. Those were very odd meetings. So, the pressures on me personally were so great in that '85 timeframe trying to get the laser printer shipping. The AppleTalk network had a little box, Gursharan Sidhu did all the software. So, that worked. He dreamed up all the right protocols, did all the right things with no direction from me whatsoever except my rule was if you can plug them together, they should talk to one another. Steve invented the name from a collection of really bad names. And then the file server was the last piece. It was the least important at that time. And I could have used another year. If I had been there another year, we'd have easily finished it. But the software did not materialize in any form at all. And I don't really know why that was. The senior engineer on the project did not like me. I think he had reason not to like me, but we never resolved those issues. It was one of those, "I don't like you. But I'm not going to tell you I don't like you," kind of deals. So, the file s-- I

had a whole rack of them in a room that were running endurance tests to make sure they wouldn't burn up or something. And they were beautiful. They were fast. And we could put disks on them. And we could serve out to all the Macintoshes. It would have been great. But the final leg, which would have been easy enough to fix--

Garner: So, how did you end up leaving Apple?

Belleville: I got thrown out.

Garner: Huh?

Belleville: I got thrown out.

Garner: Okay, so what happened?

Belleville: When Steve got thrown out, I got thrown out.

Garner: Who did that? I mean how--

Belleville: Jean-Louis Gassée.

Garner: What?

Belleville: Jean-Louis Gassée threw me out.

Garner: So, he saw you two as a package, or what?

Belleville: It was very complicated. I'm not quite sure.

Garner: You didn't resign?

Belleville: I don't what he would say.

Garner: You didn't actually say, "Okay, I'll resign," or did you want to stay?

Belleville: I was in a mental state incapable of even taking the action of resigning. I went on leave.

Garner: When Steve resigned, you mean?

Belleville: When Steve left.

Garner: When Steve was fired.

Belleville: Steve resigned, but that was silly.

Garner: Yeah, he was fired essentially.

Belleville: Yeah, but he took that very hard.

Garner: He went off to Europe for a year.

Belleville: He did all kinds of things. But then he founded NeXT because he needed something to cohere back together. But in my case, I had been so beat up psychologically for so long. This is not fun to work with a whole bunch of engineers, half of which hate you all the time or are trying some scheme, or they're trying to get you to do something, so on, and so on, and so on. And I did all kinds of amazing things to try to correct those situations. I worked with HR, invented all kinds of things. I invented the Velcro experience where I glued an HR person to me, which they named the Velcro experience. They went everywhere there was that I went and to everything I went except the bathroom. And at the end of the day, it was a lovely woman who I don't think survived that experience, says-- I asked her, "How did I behave? Did I do anything wrong? How would you help me in all of the interactions we did during the day?" And she'd say this and this and this. And she'd say, "But really and truly, you were fine." And then--

Garner: And then Steve Jobs would come along and--

Belleville: You know, but the hurt was still all there from--

Garner: Did she see Steve and you interacting?

Belleville: Absolutely. Yeah. It was funny because Steve was the one that says, "Does she go to the bathroom with you?" Because I did it for several weeks as I remember because there was a lot of criticism that I wasn't the right kind of person. I wasn't apparently. So--

Garner: Okay, so the message got--

Belleville: Jean-Louis Gassée came in. And he looked to us (Steve's staff) -- like he was really good. We had Mike Murray running marketing. And Mike had run out of steam to a certain extent with respect to how he could think about that problem. I don't know how Mike thinks about that now. Certainly, a really good guy. But his skill, his principal skill, seemed to me to be marketing communication, at which he was a genius. But marketing, the mechanics of running a marketing operation was something he's not as good at as he needed to be. And he wasn't-- I don't think he was actually trying to fix that problem. We, as a staff, thought that that was a good thing to get Jean-Louis to say, who was running France. He'd run Apple France. And he was wanting to get a leg back into the United States. And so, he came in. He's a very charming fellow, and kind of charmed us. And then his other side came out. But he was working kind of in the backdoor with John Sculley. And then I think John Sculley probably went to the board. This is my pure supposition. Something like this happened. He went to the board. And he says: "This Steve Jobs guy, I cannot cope." And Mike Markkula and all the other guys on the board say: "You're the president of this outfit. You fix it." And I don't think they intended for him to do it the way he did it. But that's the way he did it. And I don't-- I don't think he thought that thing through. And to Mike's-- Mike Murray's everlasting credit as far as I'm concerned, we were sitting, the five of us, Mike and Debi and me and whoever else it was-- oh, Sue Barnes, who was running finance with Steve on his very last day. And we're in this meeting and just-- and Steve was a wreck. And I was tired to the point of exhaustion. And Mike said, he had a smiley face on, he says, "We can fix this." And he was right. We could have. What we should have done is we should have all gone on leave for about a month[19]—

Garner: Relax.

Belleville: Thought through this thing, gone back to John and said, "You know, you really don't want to get rid of the talent in this team no matter what you might think about Steve."

Garner: That Macintosh team, or the whole management?

Belleville: The Macintosh team. We had taken this nothing product and gone from zero to three hundred million dollars a year on a dead start. And that was a failure. That's *not* a failure.

Garner: People needed to cool their jets, basically.

Belleville: We needed to just back off and come back and get all the people together.

[19] Between the filming and this proofreading/annotation, Mike published a number of articles on his time at Apple on Facebook. In one he reported that John Sculley and Steve Jobs had told him that John was to retire soon and that Mike was to be the new CEO of Apple. This may have been what distracted him during this period.)

Garner: So, that didn't happen?

Belleville: No, that didn't happen. Steve tried to do it once. He got some of the people into his house up in Woodside, that house he had in Woodside. I don't know what happened to it. But it was huge. Mike Markkula came in. But Mike Markkula was not a fair agent in this. I don't know the way he was operating during that very short period of time. Again, I have a lot of respect for Mike. He helped me a lot. But in that particular period, he was letting John Sculley do the work, which is what he should have done and what he did do. And that caused a problem. So, at that point, I was so tired I couldn't see straight. So--

Garner: Time for change.

Belleville: There was no change. I just quit. I went on the leave. And I never came back from the leave. I finally had to call them and say, "You know I'm really not coming back. You might as well terminate me."

[**The first part of the interview with Robert Garner ends here. Chris Garcia (at the time one of the curators at CHM) interviewed Robert in front of Robert's 1970's 'homebrew' computer that is on display at the Computer History Museum. This part of the interview in the video starts at 2:44:51**.]

Garcia: You are Bob Belleville.

Belleville: I am.

Garcia: And what is this machine?

Belleville: This is a machine I built for myself in the late '70s just to have a home computer. So, this is part of the home brew tradition of computers. It's an extensive part of that tradition because many of the components of this were liberated from their homes with other organizations. So, this is an 8080 (Intel) based machine. It has 12K in static memory. The static memory is there because the logic for static memory is a lot easier than the logic for dynamic memory. So, I was able to get ahold of enough, I think they're 4K bit parts. So, there's enough to make 12K bytes of memory all hand wire-wrapped together to provide that main memory for that machine. (3 times 8 4K bit chips is 24 parts) Now, in the 8080, the way it was-- the architecture of the 8080 was such that when you pushed the reset button, it started executing the instruction in location 0 in the address space, which means that you couldn't have RAM at that place because there was no program to execute there. So, in this machine, the bottom 4K of memory is only slightly populated. But the bottom is the EPROM where it starts. So, it starts a little monitor. The monitor is called Fourteen. That was the day of the month when I started writing it. So, when you boot this machine, when you poke the go button and it starts running, you get a little arrow crosshair on this thing. And there are a very small number of commands. One of them was a go command. And you typed in a

hex address. And it would go into RAM. And so, the way things worked where you-- in fact, I don't even remember the whole process. You couldn't-- you had to have a program running in order to run the file system. So, you had the file system running. And you would execute a program perhaps from there. But mostly, the file system was to put stuff in the RAM and take stuff out of the RAM, or mainly an ordinary file system serial write thing. So, that operated-- the file system was also my design. I wouldn't say it's a great one. But it eliminated one of the problems we had at the time which was the free sector table. All these floppy disks had a record inside which was a bit-wise record of which sectors were being used and which ones weren't. And so, you get a free sector to write in. You would go to that table. And you would pick out the 0 bit. And you'd write a 1 into it. And you'd use that sector. Now, the problem was that on these early machines, these things crashed on a regular basis. And when you whacked out that sector table, you were just hosed because there was no way to figure out where the stuff was on the disk. And so, all your files were lost. And there was no hope of finding them. So, this one uses a very primitive approach where it goes through and formats the disk by writing the sectors to 0.

Garcia: <laughs> Okay.

Belleville: And so if you need one, find one that's all 0. And you won't run any risk of writing-- of wrecking the whole system by crash on the bit allocation table.

Garcia: Oh, nice. Now, when you liberated your parts, were you liberating to a plan you already had? Or were you creating your plan around what you could get your hands on?

Belleville: Mostly, created the plan based on what I can. I wanted a big enough 8080 that I could do real stuff. So, one of the things that I really wanted to do with this machine was do voice. So, you have the amplifier and the voice processing unit and the microphone and stuff like that. So, you have enough-- this is a raster display. It's a 512 by something, probably 256 because the mathematics is easier. But it might be 320, I don't know, something like that. So, 512 across for sure. And there's a separate piece of RAM, which as I remember, I swapped in and out of the address space because I always have a switch somewhere where I can write into it or I can turn and back and let the display controller use it. It's not-- we'd have to look at the drawings, which you have, to see. But I doubt if it's fully multiplexed because the timing of that is kind of hard. And none of this was at a time when anything was particularly easy. This is all low scale integration, NAND gates, flip flops, not much. So, I wanted to be able to put (voice) waveforms across the display and look at them. Then I was going to edit them in such a way that I could pick out the phonemes and do a voice synthesizer.

Garcia: Oh wow.

Belleville: And so, I had all this equipment set up to do that and was working on that. But that turns out to be a harder problem than you think because your voice slides into the phonemes and changes the

characteristics. So, it doesn't sound quite right. You have to do it a little bit differently. This machine was not up to that task. But that was one of the things that I really wanted to do with this machine was to do voice processing.

Garcia: Oh, and how much would-- I would imagine you probably never did, but how much do you think you could actually store in this machine in a voice. It would have to be less than--

Belleville: A and D converters were not particularly fast. So, I was probably not sampling-- so, if you take 3K to be the top of what a telephone can do, and if you do Nyquist stuff in 3K, that's 6K. I doubt if I was sampling that.

Garcia: Oh wow.

Belleville: So, it wasn't-- probably wasn't any faster than that. If I was sampling at ten thousand samples a second, you can see I wasn't going to go for more than about one second. So, in a machine like this, of course, you had all the memory is yours. So, many of these programs are not big. So, a little 8080 program to read an A/D converter, stick an 8-bit value into memory and move on to the next one, it was--

Garcia: Now, did you use this as sort of your everyday machine? Or was this only for experimentation?

Belleville: There was no everyday in this. In a computer, the way we have it now-- so on my home machine which I was describing just before which is a six processor AMD Phenom with 16 gigs of memory and gobs of disk and huge displays, I can do everything, all of the bills, the financial work, all my photography, all of my experimental work that I do on clocks, all the papers that write. Everything that I do is done on that machine including finding out the weather, planning trips, everything that we do on computers. You just didn't have anything that you could do here. One application that was on the machine that was popular with my daughters was the mathematics multiplication table quiz program. So, it would put up a couple of random numbers, small random numbers. And they would have to type in the product of those two numbers. And it would say yes you did a good job or try again. So, that was one of the few programs. The other thing you would do with a machine like this that people did in the home brew world was to turn it into a terminal. So, you get on. And I could get on-- I'm not sure how I did this. But I think that I could get a telephone link into Xerox. When I went to Xerox PARC, they had a machine there called a MAXC, which was really a copy of a PDP-10 that they'd designed from scratch because they weren't allowed to buy anything from DEC. That was the reason. So, they had telephone access to that machine. I had a modem of some sort, probably an acoustic modem no more than 300 baud. And so, I would get onto MAX. And I believe that the assembler for this machine was on MAX. I'd written that, an 8080 assembler that ran on MAX. And I could use the file system on MAX to store my source code, do the assembly, generate the binary code, download it, put it on the floppy disk. And then I could run programs that way. So, I was doing that in the late '80s (incorrect late '70s). Something like that

arrangement was what we were doing. This machine, I have written assemblers for this machine, this class of machine, on the machine. It's not that hard because this machine was in the era of Tiny BASIC. Tiny BASIC was something that came Dr. Dobb's Journal. It was an effort to make BASIC so small that you could run it on a machine of this class. And there were dozens of them, very, very clever people all working hard together to try to get that. So, I had several Tiny BASICs that I had fooled with and tried to rewrite and re-understand and so forth. But one thing that people don't-- haven't had to worry about for decades is I could know a thing existed because it was in Dr. Dobb's Journal, but how would I get the source code. So, more often than not, you ended up retyping the source or typing in a whole binary file of some sort by hand. So, the progress was not click-the-button, download-the-file, run-it-on-your-machine in about three point five seconds. It was a much more tedious process. And a lot of things that we did, for example, there was a point in time when Pascal became available from San Diego. And I went to a kind of a Saturday group meet where people that knew about the Pascal from San Diego came. And we brought floppy disks. And we stuck them in machines and traded off the code, took it home, and tried to get the Pascal to run on our machines. So, that was the way that world kind of worked. It was hard to get-- today, when I think about how-- I must load an application of some sort once a week from the web. Really complicated things. And in those days, firstly, your machine was not configured. Like this one has all of its memory at the 12K mark. So, hex four thousand is 0. Nobody's code was meant to run that way because all of these machines, all the commercial machines, were built so that in the boot process at some point, it copied the boot code into the RAM and then flipped the address space so that that RAM was now in location 0. And that's the way these-- all those early machines, all the CPM machines were built like that. They started booting from 0, but the ROM, the EPROM-- remember, these were UV things with a little window on them. You shine a light on, make them 0, and then write them.

Garcia: And now, one of the things I really love about this machine is the case work. And what was-- was it a conscious goal of yours to actually make it an attractive piece?

Belleville: It was.

Garcia: Oh good.

Belleville: It was indeed. When I come to the museum, I always-- I want to do this because--

Garcia: Oh <laughs>.

Belleville: When I built it, I never figured out how to fasten the top to it.

Garcia: <laughs>.

Belleville: So, I don't know if you fastened the top to it or not, but it's off.

Garcia: Yeah, we have a couple of the clamps actually that are holding it.

Belleville: So, I have been a woodworker since I was a child. And I wanted to build-- Robert Garner was talking about how it's a nineteen-inch rack. That shows my lineage. This would be a big box with stuff in it. So, I built the rack thing, and that just naturally made a cabinet that was a desk-side type of cabinet. And I'm still of the opinion that the right way to use a computer is to sit down, gather your thoughts, and type on a keyboard and use a mouse and describe what you want to do. So, you need a table that's big enough and sound enough and monitors that are big enough to see what you're doing. And so, all of these-- that's why you have it categorized as a workstation because I thought of the world as a workstation.

Garcia: Okay, and what would you say you learned from this process?

Belleville: I learned an enormous amount from building this machine. One of the things I learned which would be amusing is I don't know how to do power supplies. I'm like a write off with respect to power supplies. So, I never got-- don't turn this on because there are commercial power supplies at the back, but the power was not my strong suit. I learned an awful lot about how this machine was going to evolve. This machine, for me, is a part of an evolution that started back at Purdue. I built another kind of machine that was before this one, before microprocessors. I built a machine at SRI with some of the technology there but using a Tektronix display. I built this machine for myself. Robert Garner and our merry band of friends built a Xerox 8010 [STAR Workstation] at Xerox. I then subsequently built a thing called a Cub which was an 8086 based machine, much smaller than this one. It was a quarter of a million bytes of memory and Alto size display, which was an interesting machine. And then I was called by Steve Jobs. Then I went into Apple and built the Mac. The Mac was already there when I got there. And I was comparing it to this machine which was-- this machine is a full decade earlier than the Mac, right, and the Cub, which was five years earlier than the Mac, which in a lot of ways was just as capable a machine, a little bit more memory than on a Mac, but much better processor on a Mac.

But that progression of machines that I was building was so that-- a thing that happened in my life was when I met Doug Engelbart, the guy who is credited with inventing the mouse, who did in fact invent the mouse with Bill English. He said, "The world has come to a state where problems are too complicated to be solved by one person. We have to do teams of people to solve problems now because one person just can't get all that stuff in his head that'll take. They will need the collaborative tools to allow them to take what's in their head, make it sufficiently public so that the other members of the team can interact and see it." So, his whole thrust was to try to get our society as a whole able to solve hard problems, which, in the '70s, we already knew were there. Here we are in the second decade of the new millennium, and all those problems are way worse than they were then. And there's a whole bunch of new ones that came along. And so, this idea of being able to really use computers to get teams of people hooked together solving hard problems helping society become safer, happier, that was his mission. And I took up the part

of it which said, “You can’t do that without a terminal of some sort. You’ve got to have somewhere to put the pictures on the screen, interact with it, share that information some way.” The bulk of my career was built in trying to accomplish that. And with the Mac, I think I accomplished that, not by myself by any stretch of the imagination, but lots and lots of people. And that formed the basis of something, finally after the full network came in, that you can really solve that problem that Doug was talking about now. It can be done. It’s not being done, but it can be done.

END OF THE INTERVIEW

POST INTERVIEW ADDENDUM:

How the Wildflower got its name:

Belleville: “Butler Lampson, on the famous 7 sheets of paper, called his processor Wildflower because he believed that they would spring up everywhere like - wildflowers.

How the Dandelion (the hardware for Xerox STAR 8010 Workstation and Servers) got its name:

Belleville: “I think, came up with Dandelion because all the Xerox PARC ‘D machines’ had aggressive animal names [Dolphin and Dorado, also known as the D0 and D1] and I wanted something that would not be in the face of people like Chuck Thacker. Note however that there is a lion hidden the name and it starts with D.”

How the Cub got its name:
Belleville: “My Intel 8086-based machine, I called Cub because it was the son of a lion.”

Topic: 10-Mbps vs. 3-Mbps for Xerox STAR workstation, AppleTalk vs. Ethernet for Macintosh:

Belleville: In 1980 or 81, I happened to fly (PSA) to El Segundo with David Liddle and I made the best case I could to just start the Ethernet off at 3Mbs. I was working with AMD on a Mesa chip for Cub and AMD was pretty sure they could quickly build a single-chip 3Mbs Ethernet controller for the 8086. 10Mbs was just out of reach at that time for the silicon.

Someone could say how many chips it took in Dandelion for the controller but it was big number [~80]. I had, with Roy Ogus, added an Intel micro-controller to Dandelion to do the 'junk' IO like the floppy, serial, processor boot up and mouse control. Adding a single-chip Ethernet to Star would have been a win in my view and it was essential for Cub. Cub was 1/10 the manufacturing cost of Star and would have afforded Xerox a much-expanded next step in the office market.

By LAX, David said ‘no,’ not ‘hell no,’ but we had the 10Mbs and why change that late date. Perfectly good call in my view.

In early 1982, I left Xerox to do the Mac. There I did the AppleTalk network. (Steve gave it that name.) By 1985 or 1986 the Apple marketing person told me that there were more AppleTalk nodes in the world than Ethernet nodes.

Let's just accept that Ethernet is way better than AppleTalk. But Mac had no chance for Ethernet without a single chip controller.

The personal computer (on ethernet) had to wait for IBM, its clones and 3Com to enter the real world. Clones and Apple won the office market. How did that change history?

Photograph, LtoR, of Xerox PARC Alto workstation, Xerox STAR 8010 Workstation (Dandelion), and Bob Belleville's homebrew personal computer, on display at the CHM, Dec, 1998:

Topic: Bob Belleville's Cub prototype built at Xerox SDD:

Belleville: The Cub was a much better machine than either the Mac or Lisa and preceded my knowledge of both of those machines by about 3 years. It was meant to be a dramatically cost-reduced Star - not a personal computer - and live in a network with file servers and printers as an office solution. In the 1979-mid 80s time frame the advantage of the 68K's 32 bits was diminished by the huge cost of memory. The limited 16bit + 4 bit 8086 [memory addressing] architecture really didn't count for much 'til later in the 80s. (Then there was the even more odd 80286.) Finally, 80386 and 486 cleared things up. I didn't get a 386 until 1990 at SGI (and they (SGI's worksations) were all on MIPS processors.)

Photograph of Bob Belleville's Cub workstation prototype:

Appendix I (RLB's Obit for Steve Jobs written 11/15/2011 10 days after his passing)

Steve's passing did come as a bit of a shock for me.

For a bit more than three years 1982 to 1985 we were together a lot of the time. We made a dozen trips to Japan together. We were close. After that I only saw him a few times. I haven't seen him in many years. He was an extraordinary person in many ways and quite normal in some others.

The outpouring of feelings from people all over the world was a bit of a surprise to me at first and then it seemed natural. He was for them a combination of James Dean, Princess Diana and John Lennon and maybe Santa Claus. What is in his bag of goodies?

The iPod, iPhone, and iPad are so personal. They are warm in your hand. They sing to you when you are alone. They are caressed. They bring people nearer when far away. They hook you into groups of people you will never meet. Electronic escape and hope all rolled into one. What is not to like.

During the Great Depression the movies promised and delivered for a nickel or a dime the same sort of thing. The studios made fortunes and the stars were the magical friends we can never really have.

In those 3 years together I packed in a decade or two of experience. Steve packed a couple of centuries into his 56 years. He did everything he wanted to do and all on his terms.

Sadness now is natural, but his life was all about providing joy for a nickel or dime. It was a life well and fully lived even if it was a bit expensive for those who were close.

Appendix II (RLB's outline for the two oral history videos in 2016)

Notes for Oral History 8/22/16 RLB

goals:

to cover much more of my history with computers than just the Macintosh

to convey just how much fun it was to solve real problems in the early days in spite of the very real limitations of hardware

Sputnik Crisis: October 4, 1957
- https://en.wikipedia.org/wiki/Sputnik_crisis
- born St Louis, Mo October 1946
- just about 11 at Sputnik launch - 6th grade
- discouragement over Vanguard failures
  - which were on television
  - National Defense Education Act (NDEA)
- televised h-bomb test - saw on TV at age 6
  - seriously scared me
  - On November 1, 1952, the Teller–Ulam configuration was tested
    - at full scale in the "Ivy Mike" shot at an island in the
    - Enewetak Atoll
- https://en.wikipedia.org/wiki/Physical_Science_Study_Committee
  - pssc started 1956

so 'they' grabbed anybody nerdy by the scruff of the
neck gave us extensive extra training in math and science
as a result I had finished and had college credit for
all three semesters of calculus by the time I finished
high school

The IBM 7094 and CDC 6500: fall 1964 to spring 1969- BSME and MS
the 7094 was in a kind of shed attached to the coal
fired power plant in the very center of Purdue's
campus
it was the only digital computer there
1965 Fortran II then 7094 assembly language then
into graduate level courses 500 and 600 level
mechanical engineering looking to move beyond steam
bio-tech, cad, cam very early days
did a run to tell my Dad when the house would be paid off
started a lifelong interest in finance
CDC 252 graphics terminal masters work

Campus and summer jobs: 1965 to 1968
Inland container research lab
flat crush model of cardboard
optimization
first pendulum
Monsanto 3 summers
accounting dept IBM 360-20
labor relation scheduling
Oscar Meyer's lab IBM 1800
math library
oil blending quality control
June 6, 1968 death of Bobby Kennedy

Army service 1969 to 1971 Aberdeen Proving Ground MD
Automatic report writing using prepositions
Fuel economy reports on the IBM 360

CAD Lab Purdue 1971 to 1974
Steerable optical eye color recognition (slides)
Imlac BoDa operating system
Video terminal (slides)

Stanford Research Institute 1974 to 1977
Doug Engelbart
Graphics terminal for NLS (slides)
Selling NLS
building my homebrew

Xerox Parc then SDD 1977 to 1982
- Bill English
- Building the 8010 Star
- Building Cub (slides)

Apple 1982 to 1985
- the call
- the Mac factory
- trip to the mountain top
- Laser printer
- Apple Talk network
- File Server

Fluent 1985 to 1986 with Peter Ashkin
- Sony telephone project
- Audio interface for IBM PC

Siemens – Munich 1986 to 1987
- Telephone

3COM 1988
- met my wife
- weekly readers
- Business cards

SGI 1990 to 1998
- Forest Baskett – do what you want
- how to get your computer to do what you want
- search

1998 to present
- thyroid disease and slow recovery
- house husband
- photography and clock research
- www.thirdandlark.com

Notes for my homebrew workstation
Title: Belleville Personal Computer
Catalog Number: X2117.2001A
also plotter
Title
Homebrew printer
Catalog Number: 102620901

built starting about 1975 approximate completion 1977

8080 processor 2mhz (current desktop 6x3.2ghz) 10,000 x
7 days to do what currently would take 1 minute
12KB static ram an a small boot EPROM
12KB vs 16GB 1 million times greater
would store 5 pages of simple text vs 1 million pages
2 8in floppy disks < 1Mbyte total vs 2.5Tbyte 2.5 billion times more
Xebec Corp in payment for some consulting
512 x 256 x 1 bit display on an RS190 closed circuit monitor
current 2650 x 1440 x 30 bit 800 times more screen space
hand wire-wrapped with all custom boards and a backplane bus
much like s100
voice processor and a/d d/a (8 bit) for speech projects
keyset for single handed entry Engelbart and English
serial connection for a teletype printer
plotter and scanner

fall 60 to spring 64 high school
fall 64 to spring 60 BSME and MS
Jun 69 to Jun 71 army
fall 71 to spring 74 PhD
fall 74 to spring 77 SRI
spring 77 to Feb 82 xerox
Feb 82 to late spring 85 apple
fluent
oct 86 to oct 87 Siemens Munich
88 3com
90 to 98 SGI

other notes 2023
https://archive.org/details/TNM_Versatec_printers_and_plotters_-_Versatec_a_X_20180227_0009/page/n1/mode/2up

Appendix III Additional Photographs[20]

The Xerox 8010 hardware team in the late '70s (Dan Davies, Kaz Mass and Pitts Jarvis missing)

Left to right: Robert Garner, Bob Belleville, Nora Ogawa, Neil Hansen, Ron Crane, Roy Ogus, Jim Cucinitti, Dick Snow (from the UK on a one year assignment to the US), Don Charnley.

[20] These pictures are part of Robert's personal collection.

Steve Jobs Macintosh division staff in 1984 featured in Forbes or Fortune Magazine 1984

Left to right: Mike Murray, Debi Coleman, Bob Belleville and Susan Barnes.

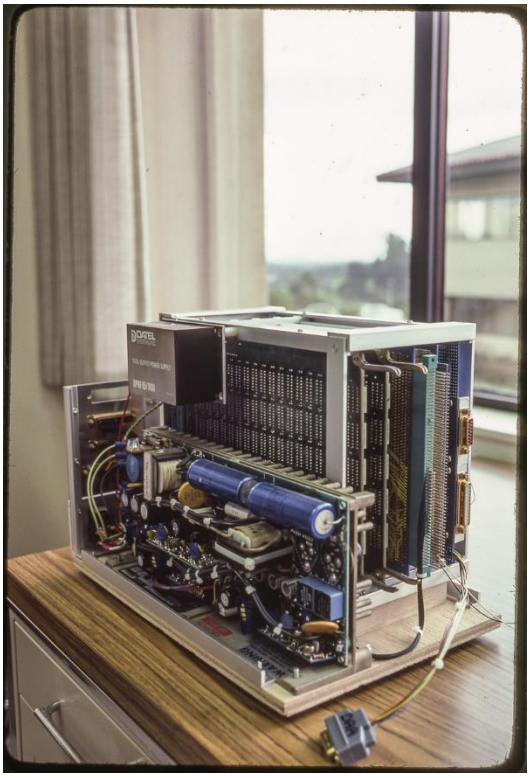
Most of the Macfintosh staff in early 1983 at an offsite meeting in Carmel California.

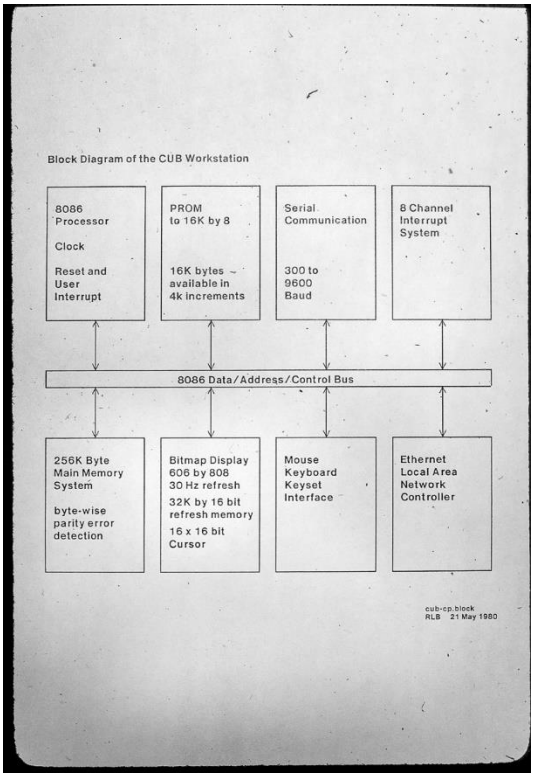
A $40,000 Bösendorfer piano *helps liven up 90-hour workweeks at Apple Computer. Chairman Steven Jobs (seated) doesn't often play.*

Photograph for an article published in Fortune Magazine, October 15, 1984. Theater of the absurd. Left to right: Bill Atkinson, Caroline Rose, (The pirate flag that once flew above the building) Chris Espinosa (barefoot) Bill Fernandez (mostly hidden) Bob Belleville, Susan Kare, John Sculley and Steve Jobs (barefoot but with bow tie). Steve doesn't play the piano.

Cub

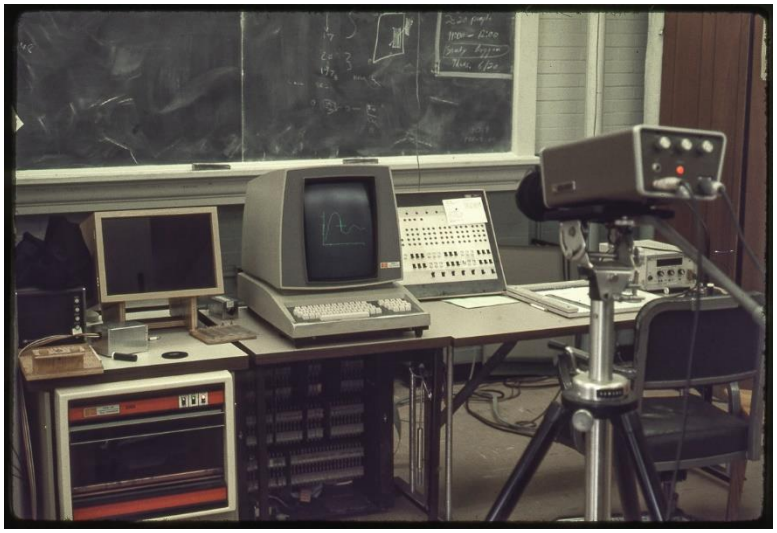
Cub's main components, LtoR audio, circuit boards, breadboards, keyset, keyboard and display and audio recorder.





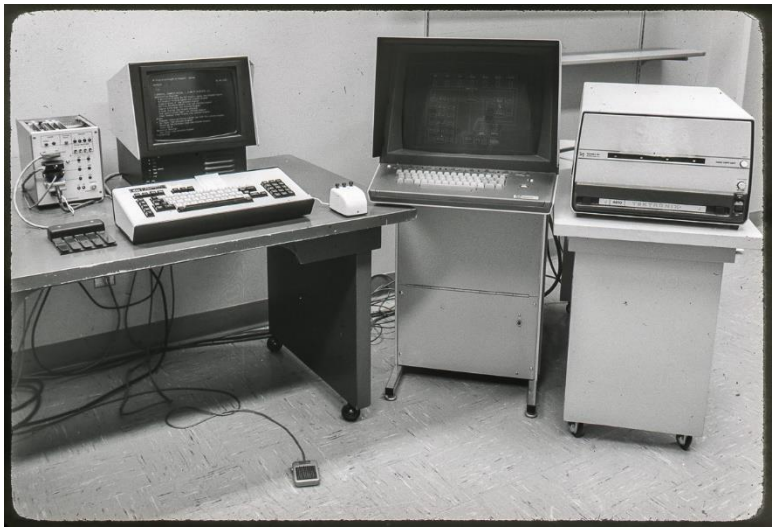
Purdue video (3 screen) video workstation.

Dick and Gladys Garrett and fellow grad student. Camera on tripod tracking the light in Gladys' right hand and left hand on the keyset.



Imlac in Dick Garrett's CAD lab about 1973 with additional devices.

SRI graphics with Tektronix display and printer.



Switch on the floor changes the mouse from the terminal on the left to the graphics display in the center.

Engineering drawing about 1975 on the Tektronix 4014 drawn within the NLS system.