Oral History of Gary Starkweather

Interviewed by:
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Gardner Hendrie: We have with us today [August 23, 2010], Gary Starkweather, who has very graciously agreed to do an oral history for the Computer History Museum. Thank you very much, Gary.

Gary Starkweather: It's my pleasure, my pleasure.

Hendrie: What I would like to start with is if you could give us some family background: where you grew-up, what was the environment like, what siblings did you have, what did your parents do—a little bit of that sort of background.

Starkweather: I was an only child. I had no brothers or sisters. My father managed a dairy, and I think his growing up in the Depression period made him want a job with great security, and there's probably nothing with more security than milking cows. They don't take vacations. They're seven days a week. They're busy, and so he enjoyed the fact that this was in the food business. It gave longevity to your job that was very hard to find in other places at that point in time. My mother was basically a housekeeper, but she had worked in business environments where she did accounting. Neither of my parents were technological at all. I think the biggest advantage for me was that in our house we had a basement, and as long as I didn't blow up the house I was allowed to do whatever I wanted down there with equipment. I lived very near a place where people would drop off old washing machines, old cars, old radios, and I could go down and bargain with the lady that owned this, and for a dollar bring home an old broken radio, and take it apart and find out how it worked. This gave me not only some education in how things functioned, it gave me some occasional electrical excitement as I would touch the wrong things inside a non-working radio. It also gave me a wonderful parts bin on which to build everything else. So allied with that was a desire to do model railroading, which I've always been involved in. Well, that involved electricity, the involved mechanics, that involved a whole bunch of things, so that pretty much occupied a lot of my time as a young person doing electronics and the sorts of things a typical budding engineer would do. This gave me a time in which I could do that. Now, as I grew up and went to college...

Hendrie: When are we talking? How old are you?

Starkweather: Okay I'm 72 so this would have been somewhere around 1945.

Hendrie: How old were you?

Starkweather: I'm 72 now.

Hendrie: But when you started doing this sort of thing.

Starkweather: Oh, I would have been probably seven or eight.

Hendrie: You started pretty early.

Starkweather: Yes, I started pretty early. I remember my grandmother, who lived nearby, knew that I just couldn't sit still very much. If I did, I got bored really easily. I still do. I always have things to do so I don't get bored. She would ask friends and so forth, anybody who had an old clock which didn't work, and if I went to somebody's house with her I took that and a little bag of tools and loved to take clocks apart. That kept me busy most of the time finding out if could I get them to work again, how they worked, what happened if you took this part out and so forth.

Hendrie: Now, was this a very big town that you grew up in?

Starkweather: No. Lansing, Michigan was the capital, but it was a pretty small town. The major industry was the General Motors Oldsmobile plant. Of course, Oldsmobile no longer exists. It's an assembly division now. But, as I say, that was back when Americans made cars. They still do, but this was the big time in the automobile business. My uncle worked in the automobile business as well. He was a CPA [Certified Public Accountant?], so he did some electric trains and we used to enjoy some of that together.

Hendrie: When do you think you got your first electric train? Do you remember?

Starkweather: Yes, I was eight years old, and I remember it very substantially because when they took it out of the box my grandfather, my uncle and my father played with it and all I could do was watch because they were having so much fun with it. I'll never forget seeing this thing running around. I could hardly wait until the next day so I could get my own hands on it.

Hendrie: Did you go to the local public schools?

Starkweather: Yes. I was in the local public school system. We had a fairly highly competent public school. One of the advantages was I grew up about two miles from Michigan State University. There was a big teaching college there. In fact, my original maternal grandfather died, but my grandmother married again and married an old boyfriend who was a teacher and a school principal in Lansing. They would bring in a lot of student teachers in from Michigan State, so there was a lot of academic things put into it. I thought it was a very rich education for being a public school. A lot of time, I mean, I remember being a college prep student in which my only elective was study hall. At the time, everyone wondered, “Why don't you take something easy and have some fun?” but I really knew I wanted to go to college. It was just something my second grandfather really, really pushed me on. He wanted to make sure that I wanted to do that. A little bit of an anecdote here. He was a graduate of the fiftieth commencement at Michigan State and I was a graduate of the hundredth commencement, so that was kind of neat.

Hendrie: Wow, that is! That's cool. What's your earliest memory of what you wanted to be or do when you grew up?

Starkweather: I wanted to be in the sciences in some form from the time I even knew what the distinction was. One of the things that helped me along that line is every year in the school they would have Christmas card sales. The kids could get something. If you went home and sold a lot of Christmas cards you could get a bike. I usually sold two boxes, one to my mother and one to my grandmother and quit so I knew sales was not in my future. The last thing I want to do is to pester somebody with something they probably didn't want. I knew sales was not it. I did enjoy music very much, but in the 1950s we had just come out of the Second World War, and there was a lot of technology going forward, V2 rockets, and it really became exciting. I was very much turned on by things that hum and buzz, and conduct electricity. I've always enjoyed music, but I never saw music as a career path. I certainly saw it as an extracurricular enjoyment. But pretty much some form of science—and I'm not sure I understood the difference between science and engineering—was my main goal. I remember in 1951 a movie came out, and occasionally they reshow it again. It's always very nostalgic for me. It was with Michael Rennie and Patricia Neal, who recently died. It was called *The Day the Earth Stood Still*, and it was about this man who landed in a spaceship and he had this robot that had this beam that came out of it that would melt things. Of course, this was ten years before the invention of the laser. I remember, after seeing the movie, running home and looking in my little parts bin and wondering, "How can I make one of these robots?" Of course, it was way beyond my skill level, but I remember many sleepless nights thinking, "Where can I get a motor to do this? How can I make it do the following functions?" I think the desire for mechanisms and for technology was just in my core.

Hendrie: You loved building things.

Starkweather: I loved building things. My paternal grandmother was from Munich, so I think there's probably some Germanic blood in me which loves to make things whistle and toot, and conduct and do all kinds of mechanical things. Every time I go to Europe and see a mechanical clock I have warm fuzzy feelings.

Hendrie: Were there any particular teachers by the time you got to high school that influenced you particularly?

Starkweather: Well, it's interesting. I had two teachers; one of them who, if he knew it, wouldn't have believed it, was very instrumental in my science background because I needed help in English, but I was a bit ahead of the curve in science. I remember two weeks into our science class in junior high school I was wiring stuff together and he said, "No, no, no. We're not supposed to know that yet." Finally one day he said to me, "I'm going to give you the final exam today," and I aced it. He said, "I think I've got something else for you to do." He recognized that I was completely bored with the stuff that he was teaching because I already knew it, and therefore he helped me in that regard. Then in high school...

Hendrie: What did he give you to do? I'm just curious.

Starkweather: Well, I actually did a number of things, wiring car horns to batteries, and making electromagnets, and doing all kinds of things like that.

Hendrie: So he was creative. He came up with things for you to do.

Starkweather: Yes, pretty much. "Here are some parts. Do what you want." I'm a big fan of giving kids piece-parts and letting them build what they want. This program construction to me is tailoring the way they think, and I don't think you should do as much of that. I think you should let them play on their own. In high school I ran into another teacher. His name was Foster Van Vliet. He was a German engineer who got tired of the industrial aspects of engineering and decided to teach math and geometry. He was a delight because he would really take you logically through, and I still fall back on many of the things he taught us on how to quickly estimate a problem. Little would he realize, but he was very instrumental in my seeing how this was a logical sequence of things that could be put together.

Hendrie: So you knew you wanted to go to college. What were your options, or what was the thinking about that?

Starkweather: First of all, my folks didn't have very much money. My father was, in effect, a laborer in this regard, so if I was going to go to college, I was going to have to figure out how to pay for it myself. My family had very little resources to do that. Now, it didn't take so much then, but they didn't even have enough to do that. Oldsmobile had an exhibit every year. It was called a youth talent exhibit, and it went all the way from about eight-years of age through high school, and they had various groups. You could enter art. You could enter music. You could enter crafts. If you built something you might get a little prize for it. Well, part of the joy of that was you begin to put yourself in competition with other people. You couldn't just be satisfied with your own accomplishments. It had to go on a shelf next to someone who was also trying to do great things. I was able to make some inroads in the youth talent exhibit and get to meet some Oldsmobile engineers. One of them was not too far away as a neighbor and used to bring some of his drawings home and show me what he was doing during the day. I thought, "Oh, this is really exciting. This is what I want to do. How do I get to do that?" Well, "You're going to have to go to college. You're going to have to take this and this and so forth." I pretty much decided out of high school I was going to go into engineering. But when I first went into engineering I remember one particular class; they were showing how a wire hangs between two power poles and that happened to be an equation for that, and that equation happened to be what was called a hyperbolic cosign. I said to the professor, "How do you know that's a hyperbolic cosign?" He said, "Well, that's just a formula someone figured out." I said, "Well, how did they figure that out?" He said, "Well, if you really want to do that you should be in physics," so the next day I switched majors and went into physics because I could always make my own handbook, but I didn't want pre-cooked stuff. I wanted to figure out how to do this myself.

Hendrie: You wanted to figure out how the world really worked.

Starkweather: Really worked, yes.

Hendrie: First principles.

Starkweather: I wanted to go down to the nuts and bolts like I did with clocks and other mechanisms that I brought home. Why is it built this way, and what happens if you change the way it's done? I went into physics and then completed my degree in physics at Michigan State.

Hendrie: Now, was Michigan State really your only option because of economics?

Starkweather: University of Michigan would have been an option, but that would have meant living away from home. My father was good enough to give me a job in the dairy on weekends so I could earn enough money to pay for my books, and the gas for my car, and tuition.

Hendrie: And you were able to live at home.

Starkweather: I was able to live at home, so I didn't have much extra. I think by the end of college I had $400 in the bank, but it was basically the only workable solution to getting a college degree. Of course, when you finish with a college degree and a bachelor's in physics it has prepared you to do virtually nothing.

Hendrie: I did the same thing.

Starkweather: You've learned a lot about a lot of things, but you haven't learned a particular skill very well. You've just learned about a lot of how stuff works. My wife was a nursing major and had about a year and a half to go.

Hendrie: Now, when did you meet her?

Starkweather: I met her in my junior year in college. We both went to the same church, and I happened to manage the youth group there and got to know her. We seemed to hit it off. When we decided to get engaged I had to promise her father that I would let her complete college. He was insistent that she complete college. I said, "Yes, I will promise that I'll make sure that happens." He didn't tell me I was going to get to pick up the bills for that. But we did that as well. We got her through college. II had to work part time as a graduate student while she was finishing up. In working as a graduate student I worked for a physics professor who was doing some work in infrared spectroscopy, which was a way of measuring certain infrared absorption bands in various chemicals. Well, I was very fascinated with the equipment. In this spectrometer were gratings, and lenses, and gears, and measuring instruments, and I got so fascinated with that I thought, "I'd really like to go into optics. It seems to me that would be fun." Electrical engineering didn't excite me. First of all, this was before the transistor so we were still in the days of vacuum tubes. While I was interested in how they worked, designing them really wasn't that hot an idea for me. So in working with this two things came out of it; a love for the optics. I had an option to go into nuclear power, but seemed to have rare foresight that this was not the field that I should go into at that point in time, and so I did not go into nuclear power. But in working with [the physics professor] not only did I learn some things about optics, but the computations were rather long and complicated. Mathematicians rely on the 5x5 matrix that has to be inverted by hand. That's a lot of work on sheets of paper, even if you had a calculator with you. Well, Michigan State happened to be on the leading edge and built a device called MISTIC, Michigan State Integral Computer; flashing lights and the whole thing. He said, "Why don't you go over and learn how to run this thing?" I went over because it was unclear what these things would be good for at this point. I mean, there was some hope, but they were as big as a house and not that fast.

Hendrie: So was this a digital computer or an analog?

Starkweather: A digital computer. This was a digital computer.

Hendrie: It was digital, okay.

Starkweather: That's right. I went over and learned how to program it.

Hendrie: What year is this?

Starkweather: This is 1960 to '61.

Hendrie: So you graduated in?

Starkweather: In 1960, and then from the fall of 1960 through the year 1961, I did this.

Hendrie: This is a, not home built, but this is a...

Starkweather: This was built by the electrical engineering department.

Hendrie: Yes, built by the electric….

Starkweather: That's right.

Hendrie: We'll call this a home-built.

Starkweather: They were desperately looking for clients, somebody who wanted to do something with this thing. Well, of course...

Hendrie: They didn't have the money to go buy a commercial machine because there were some...

Starkweather: I looked at this thing and said, "I could write a program to invert this matrix. What a deal that is." So I wrote a program to do that, and we got things done much more quickly. At that point in time, the computer looked interesting, but it was still something off in the corner. Well, upon my wife graduating we got married and I joined a company by the name of Bausch and Lomb which was one of the world-renowned optics companies through the '50s. They made all kinds of metrological instruments. They made lenses for cameras in the Second World War. It was an old German line company who made some of the best lenses in the world. They made virtually all of the optics for Hollywood. I got involved in Hollywood, taking lenses that would be put on the Mitchell cameras for the actors, and...

Hendrie: Let's back up. How come you choose Bausch and Lomb? How did you find it and why did you pick it?

Starkweather: Well, I guess by the grace of God because there were so many other places to go. I could have gone to American Optical in Massachusetts. I could have gone to a place called Thurston Optics , but I guess it was far enough away to get away from home so that we could be independent young people, and close enough that we could get back once in awhile.

Hendrie: Did they recruit on the thing, or did you...

Starkweather: Yes, they did. Yes, they recruited.

Hendrie: You went to these recruiting sessions?

Starkweather: That's right.

Hendrie: Which were common, I guess, in that era.

Starkweather: That's right.

Hendrie: Then that's how you got an offer and you decided.

Starkweather: That's right. They had college recruiting visits and so forth. I also had a job offer from Sangamo Electric in Springfield, Illinois because they made meters and things like that, but a visit to Springfield wasn't that exciting. It's Lincoln's hometown. I think he would recognize it if he came back. I thought, "Well, I'm looking for something a little more upscale than this." People have to realize that Rochester, New York, at this point in time, was the absolute world hub of imaging. There was Kodak. There was Wollensak, all these companies. If it was optics, it was in Rochester. I thought, "What better place to do that?" So I went to Bausch and Lomb, started learning about optics and lens design, found out that the optics that I'd gotten as a bachelor's degree in physics were just so infantile compared to how it really worked. I said to them, "How can I learn more about this?" They said, "Well, the University of Rochester has a graduate program in optics." In fact, at that time it was the only school in the United States that would give you a degree in optics. So I enrolled. It was expensive to go to, but I had a job now so I could afford to do that. Interestingly enough, I was also in the Army Reserve. My wife was pregnant, so we used to make, I think, one night a week we got to see each other between graduate school, and a full time job, and she was a nurse. But going to the University of Rochester I started to learn all kinds of wonderful new things, and surprisingly enough, and most people may not know this, the first real practical use of digital computers in industry was within optical design. To design lenses was a very difficult process. If in this period of time you would have gone to Kodak and watched people design lenses, there would be a room of 300 or 400 people each calculating, doing a long division, handing it to the person in front of them who would look up the sine of the angle, who would then hand it to the person in front to them who would multiply that, who would hand it to the person in front them and so forth. They would do this all day long, tracing rays through lenses. Well, the digital computer had the ability to eliminate all these people and do it in so much less time. I worked with some of the early people in the digital computer business doing optical design, and I'll never forget the first computer program to do optical design that we tested was called CAAOS. It was C-A-A-O-S, the Calculation of Apertures and Aberrations in Optical Systems. The next program which came out was called ORDR, Optical Ray-trace and Design Routine. The interesting thing is, we always took credit for bringing order out of chaos from that, so <*laughs*>. I got very fascinated with the whole optical design process. I had a chance to look at professional photographic lenses for Hollywood. About that time business got very difficult for Bausch and Lomb. I'm just a young guy. I'm there six months. My wife's pregnant. We're just starting to make ends meet a little bit. I was in a group of 16 people and they announced that fourteen of them were going to be laid off. Well, I figured, "I'm toast." But by God's good grace I was not laid off. I was one of the two who remained. I'm not sure if that was a benefit or not.

Hendrie: Now, what was the group?

Starkweather: The group was the Optical Engineering Group because the business had gone down the drain as far as any long-term effects on optical design. Bausch and Lomb did not invest in the future very much, and therefore they gradually fell behind once the government support that occurred during the war fell away. About six months later I got a call from a little company called Xerox. And they said, "Look, would you like to come over and interview?" So I said, "Sure. I will go over and—"

Hendrie: Do you know how they got your name?

Starkweather: Because eight of the 14 who got laid off went there.

Hendrie: That's easy.

Starkweather: They decided to start picking Bausch and Lomb because they knew these people. They brought me over. It took a little time for me to figure this out, but I finally decided maybe this is something I should do. So I went over to Xerox and got involved in making copy lenses and designing copier optical systems, the lights, the scanning. That's how I got to Xerox and got involved with that. So I actually went. Half the people I worked with were colleagues because I had worked with them at Bausch and Lomb. The other few went over to Kodak. Bausch and Lomb gradually got out of the optics business, went into ophthalmology where they did contact lenses, but they basically exited what I would call technical optics.

Hendrie: Yes, the high performance optics.

Starkweather: That's correct. At Xerox, of course, some of the projects I got into are what led me to the concept of the laser printer.

Hendrie: When you got to Xerox where were they in their—I don't remember what the date is when they came out with that first...

Starkweather: The first copier came out, the 914 [in 1959]...

Hendrie: Yes, the 914. I remember seeing that.

Starkweather: That's right, and of course the name came from a 9x14 sheet of paper which you could put through it.

Hendrie: I didn't know that.

Starkweather: It was followed by something called the 813 which meant an 8x13 sheet of paper could go through it. It was particularly interesting to the legal group because I remember when I was going to go to Xerox, people said to me, "People don't need copiers. I mean, there's already thermal fax," which Kodak had, and if you remember this 3M infrared stuff which was like imaging on onionskin. I said, "Yes, but it's really not very good quality." Xerox had shown me some of the stuff they were doing. About the time I got there, the 914 had been out and been a raging success. What people may not realize is the 914 is still the most profitable product ever produced in the Western world. It went from an estimate, because they told Joe Wilson who was CEO [Chief Executive Officer] of the company, "It'll never sell." I think it was to his credit that instead of selling the 5,000 that they thought he would sell he sold 350,000. In fact, he couldn't keep them in stock. Xerox took off much like Apple Computer and Microsoft did. It was a boom time in the early years.

Hendrie: And just generated tons of cash.

Starkweather: Tons of cash.

Hendrie: They invested some of it.

Starkweather: They invested it. We had clean labs. We had huge capital budgets. We could buy things. For me it was really good because Bausch and Lomb had very miniscule capital budgets. So the first six months was a little dicey learning your way around. "Have I done right thing?" I've got a wife with a child, but it was absolutely a wonderful move, a providential choice. It was just great to be there. While there, of course, I was given various projects to work on, and we were expected to spend some of our time brainstorming, not just working on assigned projects. There was a long pipeline full of new copier ideas that we had to work on, but were expected to take maybe 15 or 20 percent, say one day a week, that we could just kind of brainstorm and think about things.

Hendrie: What was your first project? Do you remember what the first project that you were assigned to when you got there?

Starkweather: That's what led to the laser printer because Xerox had a very, very advanced product which never made it very successfully, and it was because of communications technology, not the product. It was called LDX, the Long Distance Xerography. What they had done was to modify a copier by putting a cathode ray tube in it which would scan a piece of paper. You had a detector which would pick up the reflected signal, send it over a wire to another machine which had another cathode ray tube in it which would modify the light signal proportional to what was scanned, and do that on a sensitive drum. You could then print out the document at a remote location. This was basically a long distance fax machine. Now, at that time, facsimile was an interesting thing to think about, but it wasn't very prevalent. This machine was fast. You could do several pages per minute, but it required a special telephone line which made the cost of using it somewhat prohibitive. So they basically had the right idea too early. Well, typically...

Hendrie: It required a high performance modem or did it require a direct...

Starkweather: A high performance modem, yes. At that time, a 56-kilobaud line...

Hendrie: It was a 56 kilobaud?

Starkweather: Yes, which was light-speed in 1964.

Hendrie: Yes, absolutely.

Starkweather: However, one company got a bright idea and bought a whole bunch of them, and that was Southern Railway. Southern Railway put these things in, and as the bills of lading that were on the freight cars would come by, this unit would scan the bills of lading and send them to a dispatcher who could then see what cars were coming into the classification yard, and it revolutionized their business. They said to Xerox, "Can we get more of these?" Well, the design as it existed was pretty much on the way out. There really wasn't much more you could do to speed it up or make the quality better or anything like that. So the assignment I was given is, "Can you do anything to improve this?" Because of my graduate work at University of Rochester, which was going on, I was half-way through at that point in time, I was working on holography which involved lasers. Of course, people don't realize lasers in 1964 were really pretty much like a "Ham" [amateur] radio operator. I mean, to turn it on required a multiple step process. You didn't just flip a switch.

Hendrie: To get it to start the LAS [?], yes.

Starkweather: Well, part of my education in the Optics Institute was an understanding of radiometry. One of the things that a laser had was an extreme brightness that even approached the sun. Nothing else could even come close. In doing a little analysis I thought, "Boy, if we could just put a laser to scan this, we could go really fast with this thing." Oh yeah, we could then...

Hendrie: And get rid of the CRT [Cathode Ray Tube].

Starkweather: Get rid of the CRT.

Hendrie: Yes, for the scanning.

Starkweather: Then, if we could put the laser in the output unit and scan it across there and somehow turn the light on and off, and I mean somehow at that point in time because we didn't know how to do it.

Hendrie: Yes, and just focus the laser on the drum.

Starkweather: That's right.

Hendrie: And just take the CRT out and substitute a laser.

Starkweather: So replace the CRT with a laser and some type of system which would scan the beam. I took a look at that. I talked it over with my boss who thought it was about the most harebrained idea he had ever heard of. "Everyone knows these things are toys. They don't work very well. They are expensive. You need to spend your time thinking about something else." Well, I couldn't get this thing out of my head. I thought, "He's wrong. This is so good that it's got to work." I've always felt the things that look really good and have a lot of potential probably are if we can just figure out how to make it work. So I...

Hendrie: You didn't see a law of physics that was in the way?

Starkweather: No laws of physics in the way.

Hendrie: Yes. Those are really quite hard to get around.

Starkweather: That's correct. Keep Mother Nature on your side. As I looked at this I went up to my boss and I said, "Well, could I just buy a few parts that would allow me to experiment with this?" He said, "No. I'm not putting any money into this. This is a dumb idea and I'm not going to spend any money on it." So I went to the model shop and found a piece of shiny aluminum and bent it at a 45 degree angle, and drilled a hole in it, and mounted it on the end of a motor, so as it would spin around it would scan the beam. I went in the back room and mounted an inexpensive laser on a post and shined it on this little spot and let it fly around. I remember bringing an oatmeal can home and using that on a shaft to be the document drum. I pasted a sheet paper on it and would scan this laser beam back and forth, and then put a detector up there, and I was getting video signals off this thing. I thought, "This looks to me like it has potential." At that point in time we changed locations. Xerox was expanding very fast, so they built us a whole new facility in a suburb of Rochester. So we moved all our labs out there.

Hendrie: Where were you originally?

Starkweather: In Webster, New York. I was right at the main campus.

Hendrie: That's where Xerox started.

Starkweather: That's right. That's where they started. The very first buildings were right there. They took us out to a place called Henrietta, which was way out of town, but...

Hendrie: I have relatives in Rochester so I know exactly where Henrietta is.

Starkweather: Now, by California standards they were next door, but by Rochester standards it was another state away. Fifteen miles was a long ways in those days. We had some new labs there. When I got there, I had explained what I was trying to do to someone in another lab in Xerox and they said, "Well look, we've got a technician we'll loan you part time. Have him come over a couple days a week, and why don't you just, on the QT [quiet], work with him and see what you can come up with." I talked to him and I said, "How could we modulate the beam?" We looked through some books and found some special crystals that, by changing the voltage on the crystal, would rotate the plane of polarization of the light. Then, if I used a polarizer, I could get the light beam to turn on and off very fast. The problem was these cells required a thousand volts to actuate them.

Hendrie: Were these Kerr cells?

Starkweather: No. These were Pockels cells, Pockels cells. They were expensive. They were a couple of thousand dollars, but we could get one on loan, because companies who were building them were trying to figure out what they could do with them as well.

Hendrie: Yes, and you couldn't turn—the laser was so—

Starkweather: You could turn the laser on and off, but it was a very short—it shortened the lifetime a lot, and you couldn't turn them on and off very fast. What I was looking at was the ability to turn them on and off 10 or 12 million times a second. You just couldn't do that with the electrical current. This guy that came over—Bob Kowalski, dear old Bob Kowalski, what a help he was—said, "I think I can build an amplifier to turn this thing on and off at a thousand volts." He built something up, and we put it in the backroom and played with it a little bit, and sure enough we could turn the laser beam on and off. I got some optical clamps, which we had a lot of in an optical lab. I didn't have to ask my boss for anything. So as far he was concerned he had killed this project, but I had it going. I call it a behind the curtain project. We had these curtains in which he never usually wandered through the labs, and so we kept it well squirreled away. One afternoon or two afternoons a week this technician would come over and we'd work on it together. We actually built a facsimile machine which would scan on a 914 machine and make pretty crude images, but it worked. It gave pretty crude images, but it worked.

Hendrie: So you took a 914 and just started—

Starkweather: That's right, and modified it with a special drum and everything else and got that to work because most of the drums were sensitive to blue light, the lasers were only red light, but I knew some people in the photoreceptor engineering who said, "Yeah, we've got some red sensitive drums over here.

Would you like to try one," so, "Sure. So why not?" The biggest problem that I found was cost. You had to think about how to make the mirror precise enough because I had to have a mirror precision from where I was headed in design that was going to be accurate to something in the order of an arc second. Now, an arc second is about the diameter of a dime in a mile, and so a mirror to do this you could build, but it could cost about $15[000] or $20,000 apiece to build them.

Hendrie: Yes, it'd be very expensive.

Starkweather: That's right. I sat down and made a list of what I thought were the critical problems for this to become a realization. While doing that, talking with my technician and everything else, it dawned on me, "Why am I making a facsimile machine? Why not throw the input station away and let's create the image in the computer. I mean, there's no reason why I can't turn the image with software into little bits and then send the bits to the laser and print." I thought this new idea would convert my boss. So I went to him and said, "Look, I've really been kind of continuing to work on this, but I think if we take the facsimile station off we could build this printer." He said, "Now you've really done it. That's just stupid. I want you to stop right now, and if you don't stop I'm going to layoff the people working for you." Well, he had essentially thrown the gauntlet down on me. I was basically, "Okay, do I obey him, or do I think that I've got a better purpose here?" In the meantime, as I looked at the serious problems, I thought, "Okay, lasers are going to come down in cost. Electronics are going to come down in cost, but I have this huge problem with this mechanical scanner which looks like this. It's a device that's basically a disc with little mirrors on it, and how do I make something this precise, or that has this precision inexpensively?" Well, the answer is, "You can't make it that precise inexpensively." So I sat down and came up with an optical system one day scratching on the back of a pad in a meeting, and looked at the design and said, "Oh, it can't be this simple." So I finished the meeting, ran out, got on the telephone, ordered a special lens that were generally available, inexpensive ones from Edmunds Scientific with my own credit card, because I knew my boss wouldn't do it. I think it cost me $10. It came in. I could hardly wait. Had it airmailed in, got it in the next day from New Jersey, put it in the system and it worked.

Hendrie: So what's the...

Starkweather: The technique was to have a cylinder lens, a lens which has curvature in only one direction. When the beam would be divergent due to the improper manufacturing of a face this lens would redirect it back to the focus, and hence the rays which would take divergent paths off each facet were brought back to the same scan line. By putting together what I called an anamorphic optical system, which was an outgrowth of the work I'd done in Cinemascope at Bausch and Lomb, I knew what an anamorphic system was like, I was able to make this whole system work, and it worked so well I couldn't believe. It's as close as any inventor ever comes to a Eureka-moment, that a device that costs $10 fixes a $15,000 problem.

Hendrie: Exactly.

Starkweather: It's interesting to note that the lens in the scanners, which at this point in time even an inexpensive one—one with fairly loose tolerances—would still have cost in the neighborhood of a $100 or $200 and the lens was $10 or $15. Today in production, on personal laser printers, the lens and the scanner cost $3. This was, as far as I'm concerned, a real breakthrough. I immediately filed patents on this, took the design to some friends and they said, yes this looks rock solid to me. I don't see a problem—

Hendrie: Yes, they looked at it and said, "Yes, you're right."

Starkweather: I said, "Well I tested it, I just want to make sure I wasn't in a dream or something here", because it worked so well I couldn't believe it. As I had said before, I had this issue with my boss. He was good but his basic problem was—and I found that I ran into this many times in the remainder of my career. There are a lot of people who are very skilled at what they do but they have no imagination. I'll never forget Einstein's quote that "Imagination is more important than knowledge." I think that it's interesting because many of the failures <*noise interference*> I later saw in Xerox, and even other companies, was a failure of imagination, not a failure of knowledge or anything like that. I did have this problem with my boss and I thought, what am I going to do about this, because this thing's going to work. He doesn't want me to work at it. So do I go to another group? That was always a possibility. I thought, "He's a fairly powerful guy and he could make life rough. He may say you can have him but you're going to hold him down or anything like that". He had big strong connections in the company. At least that was a fear. Whether he'd do it or not I'll never know—

Hendrie: What sort of level was he?

Starkweather: He was what we would call a department manager. He sat quite high. He would report to the vice president or in some cases even senior vice president. He had a lot of experience in the town. Let's say you say, "I'm going to leave Xerox and I'm going to go to Kodak," he could do as much damage there as anywhere else, if he wanted to. If he wanted to. I was agonizing over this and I used to share some of it with my wife but we had two small children at this point. She's got her hands full. She could care less about whether I got a rotating mirror that's working or not <*laughs*>. We had a house now. We were starting to be solvent as young couples if—

<*Voice overlap*>

Starkweather: I happen to pick up the company newspaper one day and it said, "Xerox announces plan to form a research center in Palo Alto, California." My wife was not particularly enthralled with Rochester anyway. The kids were always sick. It seemed perpetually cold. Yes, you did have a summer albeit a short one. I picked up the phone and called her and I said, "Xerox is going to open a research center in California. If I could get a spot out there, would you go?" And she said, "I'll have the furniture in the street by the time you get home."

<*Laughter*>

Hendrie: That's a great line. I love it.

Starkweather: She said "I'm starting to pack now." I said, "Well now look—"

Starkweather: "I have a little more work to do to figure out whether I can really make this happen."

Hendrie: She was a native of Michigan, too?

Starkweather: She was a native of Michigan, too. She was from Detroit. She was a registered nurse and so what I had to do was figure out, "Is there any way I can do this?" I called a fellow who I knew was going out there. His name was listed as one of the original people, one of the original six or seven going out there. I called him and said, "John is there any chance I could get—what're the opportunities for coming out to Palo Alto?" He said, "Well I don't know we're pretty young." He said "We certainly would love to bring a talent like yours out here." But he said, "I don't think we have the power to do that. What is it you should like to work on?" I said, "Would you buy me a plane ticket through your department, fly me out and I'll give you a presentation on what I'm thinking about."

Hendrie: Now what was his name? John?

Starkweather: John Erbach.

Hendrie: Erbach.

Starkweather: John's father worked at Kodak. John was a lifetime Rochester resident who was very happy to get out of Rochester as well. He and his wife moved to Portola Valley in California and John was very helpful in getting me out. I went out, made a presentation and told him about my idea for a laser printer. They were more than excited and I didn't realize exactly why, because at that time, they had put out offers for people who had accepted to people like Chuck Thacker, to people like Alan Kay.

Hendrie: Oh wow.

Starkweather: To people like Bob Taylor.

Hendrie: How did they ever identify these people? I figure that somebody was really sharp.

Starkweather: Jack Goldman. Jack Goldman was the brains from Xerox behind the Palo Alto Research Center.

Hendrie: He went out there.

Starkweather: That's right.

Hendrie: And then ran it. He could spot talent.

Starkweather: He knew that there was—he wanted to make a research center that was outside of Rochester, because he said if we keep the research centers in New York, they'll all be making copiers and we ought to not just make copiers. We need to expand beyond that. There were choices in Boston, but they didn't feel that the weather would be conducive to getting California students out and all the electronics and computer revolution at that time were all West Coast operations. Los Angeles was a little too complicated for people—hard to get around, big. The natural choice seemed near a major university and in a very beautiful area. They chose Palo Alto because Stanford University was nearby. Everyone wanted to come to PARC [Palo Alto Research Center]. What I didn't realize is, they were thinking of making a personal computer which used a screen which was bit-mapped. You'd paint the characters on the screen using bits, not just character matrixes as would normally be done on say IBM [International Business Machines, Inc.] consoles at the time.

Hendrie: Yes, right.

Starkweather: Their biggest problem was, "We're going to have to print this stuff somehow. How on earth can we print a bit-mapped image?" When I showed them a laser printer, they said "That's it, okay. That would do it." They said "We'd love to have you out. We will make a spot for you. But the politics as they are, we cannot offer to have you move here. You've got to make that action yourself." I went back and I had no sooner landed and got in when the next morning, my boss called me and said, "I don't know what you're thinking but you're not going to Palo Alto." I said, "I think that's a little premature to say that." He said, "No it's not premature. You're not going." So I had enough foresight—

Hendrie: He was a control freak, wasn't he?

Starkweather: I had enough foresight; I took the company personnel manual with me on the trip. On the way back I read that at Xerox, it was always a big-time goal to match an employee's skills with the corporate needs. I said to him, "You're in violation of company policy." "What do you mean?" I said, "It's the goal of the company to match skills with the company's need." He said "Well, I'll decide that." I said "Fine. Thank you very much." I went out, picked up the phone and called the senior vice president by the name of George White and said, "George, I have to meet with you as soon as possible."

Hendrie: George is in Rochester?

Starkweather: George is in Rochester.

Hendrie: How did he know who you were?

Starkweather: We had met before. He certainly was aware through other connections that I was doing something on a laser printer. Little did I realize George was fully in favor of this whole idea, because he had come from a high tech industry. He had been part of and supervised an operation called Electro Optical Systems in Pasadena, which did a lot of government contract work. The government was aware of using lasers for basically profiling on the ground. They would scan a beam from an airplane and look at profiles on the ground. Now of course, everything they built was *beaucoup* [very] expensive. They didn't worry about costs because this was tax money.

Hendrie: It just had to work.

Starkweather: Yes, tax money. It just had to work. I went over and talked to him and I said "Look, I want to go to Palo Alto." He said "Well, I understand." He said "You've got to do something for me." He said "This is a procedural issue. I'm going to make you three alternative offers and I want you to look at them for a week and come back and give me your decision." One of them was to be a management liaison. I was going to be on an airplane most of my life flying to Pasadena, flying to Palo Alto, looking at projects, becoming like an overseer. Last thing on earth I wanted to do. One of them had to be working in a different group on different projects. I think the third one had to do with another liaison project. I came back in a week and I said "George, it's not what I want to do." I said, "Either I'm going to take this laser printer project to Palo Alto or I'm going to take it to a company that cares about it." Now that was a big bet on my part. This was the Nixon Administration. The economy was in the pits. I had two little kids and what was I going to do for a job? George looked at me really hard and he picked up the phone and he said, "You can go." He said "the problem I've got to deal with is your boss. But you can go." So I called my wife. I left his office and said "Pack up." She was thrilled. When I got back, my boss was livid.

Hendrie: He got the call from George White.

Starkweather: He was steamed to no end. I've never seen him so angry. He said, "Well you tried to pull it off." I said "I did pull it off, John. I just asked you. I'm only trying to do what I think is right for the company. I'm not trying to hurt you." "Well, I don't like it one bit and I think it's a mistake." I said, "Fine, I understand." He said "You can go. So I went out to my office, started to get things wrapped up because I knew this—probably this was in an October time frame.

Hendrie: Of what year?

Starkweather: January of 1970.

Hendrie: Nineteen seventy.

Starkweather: By January '71 I wanted to be gone. About a day later I got a call from him. He said "I've got a memo written up. I want you to read it." I said "Okay." I came in his office and the memo said that he was going to promote me to a section manager which was a two level jump, almost unheard of, that I was going to inherit all these people and I was going to have a big management position. I said "John I don't want this. I want to go to Palo Alto and build a laser printer." He said "Well that's what this was all about, wasn't it?" It's interesting. In his mind, everything I was doing was a political move. I had never seen that as part of how he was thinking. He thought this was nothing but a power play on my part. Not that I wanted to go build a laser printer.

Hendrie: He couldn't conceive of wanting to do something as your objective.

Starkweather: That's correct. I said, "No. Tear that up. I'm going to Palo Alto." Things just stayed icy between us. I got things set up. Went out. Did some house hunting. We picked a house, changed my mind on the plane. Went back again, picked another house. We started construction building a house. In January of '71, I put my wife and my kids on a plane. Told my kids "Don't look back. You may turn into a pillar of salt."

<*Laughter*>

Starkweather: The reason I moved at the first of the year was New York had very complex taxes. California had complex taxes. If I moved right at the end of the year, one state was one year and the next state was the next year. I didn't have to play these little games between the tax forms. Probably not all that complicated, but I had enough going on in my life that this was not an additional complexity I needed. We landed in January, moved into a townhouse rental for six weeks and I remember every morning, this was even in February, my son would raise the curtains and he'd say, "It's sunny again."

Hendrie: How old were your kids at this time?

Starkweather: My kids were four and seven. They were thrilled. They could run out and play—

Hendrie: It's a good time to move kids.

Starkweather: Absolutely. They hadn't established any long term prospects. Years later when I had a chance for us to relocate, I never would do it until they graduated from high school, because I didn't want to break that up for them. I had had the privilege of having lifelong friends when I grew up. I didn't like change that much. This was a big deal for me. I'd let them develop their long time friends. So I started at Palo Alto. We had nothing. I mean they said, "Here is your lab." I had a desk and some papers and pencils and everything else was up to me. They had a big budget so you could buy what you wanted. When I looked at my lab—and of course it was an old Encyclopedia Britannica behavioral lab so I don't know what they had in there before me—the windows were about a foot off the floor. I don't know if they had monkeys in there or what.

Hendrie: Oh my goodness.

Starkweather: You had to get on your knees to look into the next room. They said "This is your lab. It's nice lab." But all there was, was a power plug. That was the entire contraption. I had to go get some catalogs and start ordering power cords and screw drivers and milling machines and whatever it took to start building my device. That took a while but within three or four months, I had some equipment. I had ordered a Xerox special copier and at this point, I'm going to take a little of divergence because this was a miracle in this particular case. Prior to departing Rochester, I had had a fellow that I knew in manufacturing come to me. He said, "There's a new machine we're coming out with that is going to do multiple reductions." This was one of those things in which you could put a big sheet of paper like computer output on the surface and reduce it down to 8 1/2 x 11 [inches]. The company marketing people said there's no market for this. Of course, most of us looked at each other and said "You've got to be kidding me. What do you mean there's no market for this?" "Well, we checked and there just won't be very many sold." Well, somebody said, "I don't care, you're going to build it." Some managers said, "This is going through." In the process of engineering it, they had made a huge design mistake and it was such that when you would change magnification, the crosses on Ts would disappear. The vertical strokes on a K would be gone. It would look like a greater than or a less than sign or something.

Hendrie: Oh my goodness.

Starkweather: This as a huge problem. He showed it to me and I said, "Who designed this thing?" He said, "Well the engineering group over there." I said, "Well, let's go over. You know the guy. Let's go over. I want to see a demonstration of this thing in their lab." So I went over. The guy showed me and the image looked good. I said, "Okay, change magnification now." He pushed a button and then he started to fiddle with it. I said, "What are you doing?" He said, "Well, I've got to adjust some things." I said, "Is the customer going to do that?" "No, no no." I said, "Then leave it alone." Sure enough his machine produced the same problems. The technician said, "Oh my gosh." They went and called the senior engineering manager in and he took at look at it and he said, "This is a horror story. We've got 30,000 parts ordered. None of this is going to work." I said to him, "Give me a week to think about this. Let's see what we can do. I know what the problem is. Let's see if there's another solution." Well, I got back—

Hendrie: You knew what the problem was? Did they know?

Starkweather: They knew what the problem was, but they had no idea how to fix it.

Hendrie: They didn't know how to fix it.

Starkweather: The problem was—

Hendrie: What's the problem?

Starkweather: The scan slit was so big that the image blurred when it went to the side. It washed out because of the improper way they built the machine. The light beam wasn't coming in vertical to the drum.

Hendrie: Yes. Aah.

Starkweather: There [were] two ways to fix that. One is, replace all the optics—and there was a more technically complicated way but I won't go into the details of that—or you could just reduce the size of the exposure slit down. The trouble is that required six times as much light. We already had 12 bulbs in this thing. We can't put 72 bulbs in it. I said, "You know, do you have a more sens—"

Hendrie: Are these fluorescent bulbs?

Starkweather: These are fluorescent bulbs. That's right. The drum that was in there was blue sensitive. My laser printer was going to be built on a red sensitive drum. But to some extent, that was actually a detriment because that meant the laser printer would require a special photoconductor which was two strikes against it at Xerox. It didn't follow a major product line. That was going to require more capital investment just to make—

<*Voice overlap*>

Hendrie: Yes, you couldn't just take the things running down one production line—

Starkweather: No. Rip the optics out—

Hendrie: —and some of them over there and just change the optics.

Starkweather: That's right. I said to them, "There is an experimental photoconductor that uses arsenic in the photoconductor that is six times more sensitive." We got a special drum and it worked. The program was rescued. My boss called me in—

Hendrie: Made the slit narrower and changed the photo…

Starkweather: My boss called me in, the same one that wouldn't let me move and said, "Well, you've really made us look bad now." "It's not that I made you look bad." He said, "Well the optics don't work." I said "We had nothing to do with the optics. Someone else did." "Well, they won't know that." I mean it was just a constant sort of harangue on the whole thing. The beautiful part out of this, this miracle created a laser printer with a red drum in production that I could build my laser printer on. Had that not been the case, I wouldn't have had a platform on which to build it that was a production system. In Palo Alto I ordered two of these, brought them in—I'm going to give you a picture of the first unit—mounted on one of those printers in the lab in late 1971 that actually produced the first marks on paper that showed this would actually work. We still had to worry about the digital system which drove it because this is a machine which laid down 35 million points a second. We had to figure out—

Hendrie: Why was your objective to go so fast?

Starkweather: Well, first of all, we didn't have a slower machine.

<*Laughter*>

Hendrie: That's probably—that's enough of an answer isn't it?

Starkweather: I mean you could cut it down by a factor or two but that's still 20 million points a second.

Hendrie: Yes, exactly.

Starkweather: The other thing was that Xerox was in the high volume computer copier business. That's where all the money was perceived to be. Therefore, they had these little small machines—

Hendrie: They were not in the office copier.

Starkweather: —but the small machines were considered Pee Wee profits compared to the big devices. In calculating the performance we needed, we had to design it to go 500 spots per inch in both directions and at a page a second, which made 35 million points per second the requirement on the printer. I told one of the bosses, a fellow by the name of Bill Gunning. I don't know if Bill's still around or not. What a gem of a person he was. He said, "Let's keep these design things in place, because if we can make it work at 500, the product may only require 300 and then it's just a matter of easing everything down to a product rather than trying to increase the pressure to make it work as a product." He was absolutely right. We built this first machine and it actually proved its worth. Then we came into the battles of everyone else. By this point in time in the company had discovered that laser printers could be a hot item. There were two other—

Hendrie: Oh, so how did this happen?

Starkweather: Once I went to Palo Alto and started talking about a laser printer, I had to give presentations to management. Management would take it back to their people and say, "Why didn't you think of this?" Those people—

Hendrie: And of course was there a battle?

Starkweather: Oh yes.

Hendrie: Was there a psychological war between Research and Engineering?

Starkweather: Absolutely.

Hendrie: It's our job to make products, those guys are just supposed to play.

Starkweather: Absolutely. Who was going to get to saddle the winning horse?

Hendrie: Yes, okay. Got it.

Starkweather: There were two other projects that started up. One of them was called Allegro, which was a program that had a special cathode ray tube come back to haunt us again, that used a stroke writing in which the characters were painted on the screen. The thing is, it would then paint these characters, image them with a lens and make these pages. Well, yes that worked. But the characters weren't very fancy. They were pretty much what we would call a non-serif character. They weren't something you'd—you certainly wouldn't—bankers wouldn't use this thing. Data reports might use them. There was another one which was even more complicated, which I won't take the time to talk about which was really a monstrosity. But they were basically two competing technologies. Jack Goldman, who was the head of research, was so much in favor of mine, he brought the senior executives out, called me one day and he said "Can you have all this running tomorrow?" He said, "I got three senior executive coming out on the corporate jet tomorrow to see your project." Of course, at this point in time I'd gone from nobody cares and wants to fire me to all of a sudden I'm getting to show this to the king.

Hendrie: Yes, that's pretty good.

Starkweather: I wasn't looking for this quite any faster on acceleration ramp. I guess that's what we were going to do. They came out and everything ran just fine and they saw it. On the plane back, they had to discuss, "How do we pick one?" So they got back to Greenwich, Connecticut because Xerox had its headquarters back in Stanford, Connecticut now.

Hendrie: That's right. They moved from Rochester to Stanford, right.

Starkweather: They called me and they said, "How do you think we can make a technical decision on this?" I said, "Well, first of all, you've got to decide what you want this machine to do." I said to them, "I'm trying to build a machine that prints everything. Nothing you can't print. Pictures, graphs, charts, texts all that kind of stuff." I said "I think we should come up with a document set of originals which basically represents what we should be able to print." That's a great idea. "Suggest a set." I came up with five documents: a graph, a chart, graph paper, multiple sizes of text, some with serifs some not with serifs and so forth. I said, "Let's use this proposed document set and have all of the three projects who want to build printers reproduce this set and let's see who does the best job." I knew the big monstrosity program was in deep trouble. No way could they print these documents. I knew that the people doing the cathode ray tube program were going to have a huge problem with graph paper, because theirs was a stroke CRT using magnets to steer the electric beam. Doing graph paper means having to cut corners. You're going to have to make right angles. Electrons don't like to make right angles. The magnet power would have been so high it was a real problem. When everybody reproduced the documents, the laser printer won hands down. It couldn't be beat.

Hendrie: Wasn't there sort of—I mean there's something wrong with you proposing documents [that] are going to check all this.

Starkweather: First of all, I felt I was being intellectually honest in suggesting that if such a printer was to have market success, it should do all kinds of documents.

Hendrie: Absolutely, if you can.

Starkweather: That's right. If you can.

Hendrie: If nobody can—

Starkweather: That's right. It's different thing.

Hendrie: —then maybe there's a market for one that can.

<*Voice overlap*>

Starkweather: That's right; a niche market in some areas—

Hendrie: Yes, yes a smaller market, but—

Starkweather: At this point in time, no one thought of electronic printing in the classic sense. They thought, "We're going to get into the computer printing business. We'll do fancier computer printers." The net result of all this was that it had the secondary advantage that this test document set, which was everything you could print, printed on my printer and I knew that.

<*Laughter*>

Starkweather: That's what I'd been after the whole time. I said, "You guys have to shoot a target I know I can kill."

<*Laughter*>

Starkweather: The test came out and then the decision was that we need to move this project forward. A lot more money was put into it and a fellow by the name of Ron Rider—I don't know if you've talked to Ron or not.

Hendrie: No.

Starkweather: Ron was tasked with building something called a character generator. This was to be an electronic device with memory in which you would feed a character stream and it would generate bit mapped characters that could be printed on this laser printer that I'd built. The characters could be rotated within the text line. They could be printed upside down. They could be printed at different sizes. He was given this task to print this.

Hendrie: To produce it.

Starkweather: Yes to produce it. Meanwhile, in the intervening time, I was building better and better versions of the laser printer, getting it to where, rather than having it run in my lab, it could run in anybody's room. At PARC, we used to call these technology levels. Level four means it's occasionally operable by the inventor.

Hendrie: With a screwdriver in hand at all times.

Starkweather: Right. Level three is all is operable by the inventor, occasionally operable by someone else. Level two is always operable by someone else but occasionally operable by people who don't know how it works. And level one is, always works for anybody. We decided I wanted to bring this machine to a level one status, something that could be produced. Ron finished his character generator in 1973. We married the two machines and it was called the Electronic Array Raster Scanner, called EARS, the EARS printer. This machine was put in place at PARC, hooked into the system and over the next year and a half printed four million copies and everyone connected the network to it. We were doing network printing from our own computers, the Alto computers which had come along at that point in time, and it was a raging success.

Hendrie: Yes, so you had a computer room printer that anybody could—

Starkweather: That the secretaries were printing stuff on.

Hendrie: Yes, and they'd just have to go pick it up.

Starkweather: They'd just go pick it up. In fact, we even had the bins set so that they were alphabetized. If S was in your last name, you could go to the S bin and your output would likely be there and not in the A bin. We'd even modified the source—

Hendrie: Was that even automatic? I mean you—

Starkweather: We modified the sorters to do that.

Hendrie: Okay, so this was mechanically done. It wasn't done by people looking at it.

Starkweather: That's correct. There were a number of features that had been put in. The business people got hold of this and said, "There just might be a market here for something like this. But it's still too big and still too complicated." So we redesigned this—

Hendrie: Did you know how much it cost at this point?

Starkweather: Yes, at that point in time we were still looking at probably, I'm going to guess, $30,000 for a device like this. Interestingly enough the government was starting to look at this. They brought us in some test files to print and someone said we need to make a better version of this. We took the same copier base that had been used with the red drum, and hired another technician and we stripped out all the old electronics and put brand new digital electronics in this machine. I miniaturized the laser scanner so that it fit in. It was a small machine with just a grey top. It looked like any other product. We had painted covers and so forth that went on it and it was called Dover because one of the guys who was chief in helping us along on this, by the name of Roger Ellenby—John Ellenby excuse me, John Ellenby was a British guy and he wanted it to be the White Cliffs of Dover. That's why we were getting this nice, clean paper out of this thing.

Hendrie: Oh okay, it was because the paper was so clean.

Starkweather: That's right. The problem was, we couldn't build a character generator for each machine. It was too complicated and too expensive.

Hendrie: I'm not following you.

Starkweather: There was so much memory. It was emitter coupled logic. It was a lot of circuit boards. If you did this, the cost of the printer would be higher than we thought it ought to be. "Is there a better way to do it," was the question.

Hendrie: There wasn't any reason you couldn't do it. It was just money and it didn't seem like it was a very clever way to do this.

Starkweather: There ought to be a better way.

Hendrie: It was there ought to be a better way.

Starkweather: Ought to be a better way. There was an idea that we could try and let the little Alto computer generate the images. But when we did that, did it through software, we found out that it took about ten times longer than it need to.

Hendrie: Well then, the printer, the mechanism could run ten times faster than the Alto could feed it.

Starkweather: If we can just suck the Alto dry—

Hendrie: We'd just slow everything down.

Starkweather: Probably one of the brightest guys I'll ever meet, Bob Sproull, who was the son of the chancellor at the University of Rochester, worked with us. Bob said, "Let's take a look at this." He did an instruction analysis on the Alto; finding out what was taking the time to make this image. Bob is just brilliant on the way he approaches these things. He found out that 90 percent of the time the Alto was just taking pieces of image and OR-ing the bits together one plus one is one, zero and one—

Hendrie: Yes, I understand.

Starkweather: Just an OR gate. He said, "I think we could build an interface board which does this in the hardware." He designed an interface board in hardware, brought it into my lab and hooked it up to the first of these machines which were reproducible. I remember him to this day, in there with a wire wrap tool, unwrapping wires and wrapping wires and watching the images on the screen. Sure enough, this particular board could keep up with the printers and it was called the Orbit Card okay, because it OR-ed the bits <*laughs*>.

Hendrie: I love the names engineers give their—

Starkweather: But the card wasn't that expensive and so we know—

Hendrie: Yes, with IC [integrated circuits]. Integrated circuits were in by that time.

Starkweather: That's right.

Hendrie: Just a few ICs yeah, you're in the '70s—

Starkweather: The decision was to build five of these printers and we could put them in various locations in the building so each department could have its own printer. We built these. Somebody who was in connection with the Lawrence Livermore Laboratory got wind of these things and said, "Could we come over and take a look at it." [We] said, "Sure, we'll give you a non-disclosure agreement and you can take a look at this." They came over and they said, "Are you ready to sell them?" [We] said, "Well, not our decision. We are a research center." "Well, we'd like to buy some. We'll pay you $100,000 a piece for them." That currently was probably ten times what they were going to cost or six times what they were going to cost. We called the Xerox executives and they said, "No, we're not going to go into, we're not going to make special machines for these people." We said, "It might not be just for these people. There might be some use for that." Also, this base copier that we had been using was basically nearing end of life. So there were 25,000 that were coming off lease being stored in the warehouse in Los Angeles.

Hendrie: With the red drums.

Starkweather: With the red drums. I said, "Let's take these machines. We can have them refurbished for $700. They're built like bronze statues. These things run forever, big castings and bearings and so forth in them. We'll modify them. We'll custom build the laser heads for them and productize the circuitry and so forth and we can lease maybe 35, 40 or 50 of these things and see what they do." "Well, you can do that but we're not going to turn it into a product because there's a new machine coming along which will be even better." Interestingly enough that new machine was a disaster, never worked well. It was just awful. But we did end up making 35 or 40 of these Dover machines.

Hendrie: Because of the—they were planning the engine—

Starkweather: The Orbit card—

Hendrie: They were really cheap engines.

Starkweather: That's right, because of the Orbit card. We farmed off the production of the laser heads and so forth to Electrical Optical Systems because we didn't have the machine shop facilities to make 35 or 40 units. It was not really our charter to be in the limited production—

Hendrie: Yes, right.

Starkweather: —of these things. We did make these machines. I test engineered them very carefully. We built two spare laser heads just in case something went down on a customer site, we could run out and quickly replace the head and put them back on the air. We didn't service them out there. We just replaced the laser head and sent it back to me for service. Interestingly enough, we never had to do it.

Hendrie: Now were these—had you sort of made the laser head—

Starkweather: We had designed it—

Hendrie: —designed it so literally it bolted right in.

Starkweather: Yes. Bolted right into the system—

Hendrie: So you could build it up—

Starkweather: That's right.

Hendrie: —and then to modify a copy, bolt it in.

Starkweather: Couple little fixtures would hold it right down in there. In fact, this is the scanner that came out of one of those printers.

Hendrie: Oh wow, okay.

Starkweather: This is the mirror that's inside there. This was a Dover mirror and none of these machines ever required a laser head replacement.

Hendrie: Wow.

Starkweather: The last time I heard, one is running in Brazil someplace but I don't have any direct knowledge of that. The Computer Museum, I believe, has a Dover.

Hendrie: Yes, I believe they do.

Starkweather: I don't know what number it is but these machines basically proved to everyone that this can be a product.

Hendrie: Because they worked and they worked reliably.

Starkweather: They worked. In the meantime, a man was brought on board and I don't remember where he came from. It could have been Control Data [Control Data Corporation] but I'm not absolutely sure, by the name of Jack Lewis. Jack was a fabulous businessman who had imagination. Jack decided to come up with a computer printer project and they were going to build it in our Dallas, Texas operation. They were going to double the speed of my machine, but they were going to cut the resolution down so that the effective band width and performance of the laser system didn't have to be changed very much. They did have to use an Argon laser. That's another story. Nevertheless, this machine became the Xerox 9700 which was the first commercial cut sheet laser printer, ever. It was a blockbuster machine. The biggest concerns that the marketing people had were, people won't use them enough, that it won't pay, and the copy volume or the print volume just won't be there. Interesting to note, most copiers always underperform their market projections. If they say this is going to be a 30,000 print a month machine, it's 20. If it's going to be a thin 10, it's 6. They said this thing's go to do 250,000 a month or it won't make any money.

Hendrie: Now is this what, because of the pricing model that they had? Were these on lease? There was a third copy—

Starkweather: Well they were expensive to build?

Hendrie: Yes, so how did Xerox sell these?

Starkweather: They had a special division that they were going to sell. That's what Jack Lewis did. In fact, Jack Lewis was a neighbor of mine, in Saratoga, California. His son went to the same high school my son went to and we used to sit near each other in the stadium at the football games. We could short circuit the Xerox food chain and talk about this thing. When it came out, the machine had an interesting, brilliant business model that Jack put around it. For $10,000 a month, rental on this machine, you could print a million pages for free. In other words, so you paid $10,000. That would be the equivalent of a million pages. There was a very small page charge but a million pages. If you didn't print a million pages, let's say you printed 900,000, 100,000 would go in a print bank so that if next month you printed 1.1 million, same thing. He put this on the market. It was a runaway success. People—I have a memo somewhere—I couldn't locate it. I tried to locate it for you—that said you'll never sell more than 300 of these. 25,000 were sold.

Hendrie: Really?

Starkweather: Yes. The minimum copy volume wasn't 250,000; it was one and a half million. We had one place that did two and a half million. Bank of America had 14 of them running 24 hours a day in Los Angeles doing bank statements. They had a crew of five Xerox people on site that did nothing but oil, grease and fill and feed these machines so they could stay running 24 hours a day.

Hendrie: Oh my goodness.

Starkweather: Caterpillar Tractor bought one to produce service manuals, because they could make a digital change in the file and produce an up-to-date service manual right now, because it printed collated paper. Unlike other laser printers which the cut sheet thing, for example, would come out all page ones and then all page twos and then it would have to be fan folded, bursted as they did, tear the edges off, big problem. It all looked like computer printout. It didn't look like real documents. These things came out like books. The other thing you could do was, it had two paper trays in the 9700 which was based on the Xerox 9200 copier. Each tray had 2,000 sheets of paper capability. So that meant this machine could run for almost an hour off each tray. So you would fill up one tray and fill up the other tray and its running. Then there was a 500 sheet overflow tray. You could put 500 sheets of paper. Should both trays run out, it could run off the overflow tray for three minutes without stopping while you were filling the other trays okay.

Hendrie: Oh my goodness.

Starkweather: This machine could essentially be run as long as it held up, as long as it didn't require toner or a cooling off period. This became a runaway success. The quality was so much better than any competition that people were producing memos and other documents on it and it really broke into the market big time. This was just a marvelous success. It was a great opportunity to see what you had always dreamed about actually operating.

Hendrie: Yes. It was really running.

Starkweather: It was really running. Now at that point in time, we were looking at how to make small laser printers. Once the big laser printer got launched, the 9700—

Hendrie: What year was that?

Starkweather: Nineteen seventy-seven, July of 1977 it was announced.

Hendrie: Okay.

Starkweather: A few weeks earlier than that, IBM had announced something called the 3800 which was a laser printer. But the 3800 printed on fanfold paper and it was a much lower resolution. It was not what I would call office document quality. It was line printer quality.

Hendrie: Their focus was to make a non-contact line printer.

Starkweather: That's correct. They basically went in the direction which I personally perceived—and I think I was right in the long run—was a doomed direction, because computer printing moved out of the computer room and into the office. Therefore, they'd built a machine which was in the wrong environment. It was big and heavy and required a whole lot of stuff to do. Of course, IBM eventually got into the laser printer business, did okay at it, finally sold it off, which is now Lexmark, which does very well in Kentucky. But we tried to get Xerox into the small laser printer business.

Hendrie: Oh, I want to ask you a little bit more.

Starkweather: Okay.

Hendrie: While you're discussing competitors, what else did you know was going on while you were working it?

Starkweather: Well, part of the intensity—

Hendrie: Did you feel any—

Starkweather: —working. Sure.

Hendrie: —competitive pressures? What was—talk to me a little bit about that before we get to the small ones.

Starkweather: No problem. We conceived of a lot of competitive pressures because we knew IBM was working at it. We could watch the patent literature. You could go to technical conferences and people were always talking about, "I got a laser that does this and you could use a laser to print that." We knew that people, especially the Japanese, would be working in this and we didn't know how deeply they were into it. Canon was very heavily into it, but Canon was working down the personal printer side. They were not working on the big fast computer printer side. Xerox, of course, was natural because all laser printers for a long time were built upon boxes which had been copiers. Therefore the laser printer got a free engineering ride because the copier investment had already been made. All we had to do was to rip out the standard optics and put in the regular stuff. I had also made some experiments which were not, again, received very well, in which we were trying to [put?] an electronic scanner back in the copier to make an electronic copier. In other words, “Let’s get rid of the physical optics that scan back and forth in the machine and scan it electronically.” You might say, “Why would you replace such a simple optical system with all this electronics?” “Well guess what? I can scan from your copier and print on mine.” Therefore, I could in the future of networks, which we saw fairly clearly when we’re looking towards this at PARC, why does the image have to stay close to its point? In fact the real key to copying was coming back to stare at us again. People always ask, “Where was the charm in copying? You had wasted copy things before Xerox came along.” The reason is that copying is made at the point of receipt of information, not at the point of origin. Therefore, you don't copy things at the newspaper plant, you copy it from the newspaper you have in your hand. That is the big, huge breakthrough in making copying practical. Our logic was, scan at the point [of] the information and print at the point of receipt. Therefore, let’s just run that model again. Of course today, that’s what you do have. You have discs in the copiers. Nobody has a light lens copier anymore. It’s all done with electronics because it’s so cheap and it can be stored. It can be processed. They can do all this kind of stuff. You can optical character recognize off the platen. There’s remarkable stuff that you can do. The biggest problem with this was that in scanning you had to store images on a disk, because if you had a ten page document you wanted to scan all ten. When you played it back they could play it back in collated fashion, not all page one, all page two. You want to get rid of the sorter bin for example. How much storage does it take on disk? Well, it might take 50 megabytes. Oh, that’s a big disc, because the first big disk I ever bought in 1971 had two megabytes and it was a fast disc, capable of actually moving data to the laser printer, but cost $17,000 for a two megabyte disk. Of course, no one said, “Disks are never going to be that cheap.” Of course, they’re wrong.

Hendrie: Yes. They were wrong.

Starkweather: I go down to Costco and buy a terabyte—

Hendrie: Exactly.

Starkweather: I can buy a million megabytes for one hundred and fifty bucks.

Hendrie: Yes, it’s amazing isn’t it?

Starkweather: And so interesting on how people’s minds get frozen because of what they think today’s capabilities are. When you shoot squirrels you lead the squirrel, you don't shoot it where he was. The trouble is, most businesses shoot where the squirrel was, not where he’s going to be. Long story short, Xerox had no interest in electronic copiers at that point. We had to suppress that a little bit because it was something which was basically poo-pooed. Every time we’d put the sheet up, everyone would bring up all the negatives. That was the same reason they didn’t like the laser printers because I had to have a page storage for the image, because once a laser scanner starts, you can't stop it. That’s a whirling wheel and it’s going to keep going.

Hendrie: Yes, right.

Starkweather: You have to store a full page of document. That's in some of these printers; maybe it might be as much as two megabytes in the earlier ones. Two megabytes was $30,000 worth of memory in those days. Today it's a penny. No one worries about it. But a lot of us at PARC could not convince these people that transistors were going to get smaller and smaller and smaller. We used to bring up Bill Gates favorite quote "Waste transistors. They don't cost very much."

Hendrie: Yes, and Moore's Law was not well understood at Xerox.

Starkweather: Absolutely and no one would have dreamed that it would continue the way it has continued. I know when Gordon Moore first announced it, they said, "That would mean that in 15 years things are going to be 32,000 times cheaper." He was a pessimist. It was 50,000 times cheaper. That was hard for the non-technologist to get their mind around. Of course, who would have thought disks would be as cheap as they were. I had a friend of mine who worked in semiconductor memory. He said, "I have to get out of this business because the other morning I woke up and realized that the ultimate goal on my job is to make an infinite amount of memory for nothing." <*Laughs*> Interestingly enough, he's almost there.

<*Laughter*>

Starkweather: Nevertheless, the small copier became something of interest. Most of us couldn't understand why we wouldn't each want a laser printer on our desk.

Hendrie: That's right.

Starkweather: Then I wouldn't have to run down the hall. I wouldn't have to get in line with the guy who just decided to print 250 pages. I would have to sit there for two minutes waiting for it to finish and on and on. Xerox didn't make very many good, small machines. They were kind of big, big machines and you might find one that did fifteen pages per minute which was the size of a paper shredder. But nothing really small. Every year I would go to a trade show in Germany called the Hanover Fair. Sure enough at the Hanover Fair, was Canon and Fujitsu and all these other people showing these little, teeny-weeny copiers that weren't quite there yet. We said, "Man I could put a real inexpensive laser on those." At this point in time, laser scanners were still in the neighborhood of $2,000 or $3,000, even in large volume production for the scanner system. Why would you buy a $200 copier and put a $2000 laser scanner on top of it?

Hendrie: Were the lasers still—

Starkweather: Still a gas laser.

Hendrie: That's what I was going to say. They're still gas lasers.

Starkweather: That's correct.

Hendrie: So nobody has figured out how to—

Starkweather: The semiconductors were just starting to come along and people were looking at it. Semiconductor lasers were all infrared. Think I had trouble getting a red photoconductor? Now how am I going to get an infrared photoconductor? Those existed in the lab and they were in some of these lab books but they weren't by any means in production. Surprisingly enough, that didn't seem to bother the Japanese. In 1984—1981, actually—Canon introduced something called an LBP8, Laser Beam Printer #8, which had a little semiconductor laser in it and ran at eight pages per minute [and] could make nice clean pages. The other difference was—and this is a key difference—Xerox machines were what we called positive copying machines. White paper down, white paper up. A lot of machines did what they called negative copying where you would want the spot to appear, you would put light and then only the spot where the light appeared would be developed. This, in a sense, reduced the amount of light you needed so it was a more efficient way to go. But in terms of electronic printers, IBM used what was called a negative to positive copying system. Xerox didn't have a single machine that ran negative to positive, not even in the labs.

Hendrie: Was this a philosophical reason?

Starkweather: They perceived no need for it. We're going to copy stuff. Why do we need to copy negative things? Somebody said, "If we do microfilm, that would be nice because then we can project negatives of microfilm." It's a niche market. There was a little bit that went on. But by and large, they had no good negative to positive systems even in the labs. When Canon came out with this, first of all, they thought it wouldn't work very well. Part of the reason was any defect in the photoconductor would show up as a black spot. Where any defect in the positive photoconductor showed up as a non printing area. A spot that doesn't show any toner wasn't nearly as objectionable as a spot where the toner is where it shouldn't be. We used to call it pepper spots. They said, "I just don't think we can ever get the kind of purity we need to make that go away," till Canon introduced theirs. They didn't have any pepper spots. They managed to make them so inconspicuous that it worked just fine. Xerox tried to get into the business but never did and of course 1981, Canon shows the laser beam printer. They didn't have the electronics expertise. In 1984, Hewlett-Packard got a hold of it and called it the Laser Jet and put a little semiconductor memory in there so they could do canned characters. You could do fixed sizes, 10 point, 12 point, 13 point and so forth. What Xerox wanted to do was to make a page which was completely graphically free. Any sized character, any angle, any orientation—

Hendrie: Same bit-map scheme.

Starkweather: That's right. Same bit-map scheme but with basically unencumbered [?]. We could do that software in-house. At this point in time—and this was about 1981—the people who had been working on this, some fellows, one by the name of [Charles] Chuck Geschke, which you may know about. He was one of the co-founders of Adobe, worked in an office right next to me. The next office down from him was John Warnock.

Hendrie: Okay.

Starkweather: John Warnock worked with another fellow, Martin Newell. Martin was an English guy and they together had worked in the flight simulator stuff. In the flight simulators, they had used the language called Forth. Forth was a very interesting language. I said, “It’s the only language you would ever use to program a computer in which the creator cannot understand what he wrote.” <*Laughs*> Because it was so, it’s a wonderful language and extremely compact. It’s like writing in encoded form directly. They had this language they wrote, which they called John and Martin or JAM. And JAM was running on our computers and we were running test machines inside the company on which we could do text in a circle and text on a path and one overlay on another one with text showing through in the middle. I mean gorgeous stuff that was everything you could ever do in a typesetting house. HP couldn’t even come close to this. But it required a fully bit-mapped memory and it required this language JAM. Chuck and John went to Xerox management who had by this time, solidified yet again, and said to them—

Hendrie: Yes, the imagination factor had been replaced by—

Starkweather: —gone again. They said, “Look what we can do.” They said, “Our customers don't need that. They just produce memos and stuff. They don't want to do all this fancy graphics. That’s not there.” They said, “Yes, but this is—you could do all that stuff, too.” They said, “If you think it’s so hot, go form your own company.” They did. It’s called Adobe Systems. They gave away yet another gift to the technology industry in the form of Postscript. Of course, Steve Jobs got wind of these little printers, knew of Adobe and said, we could put Postscript in one of these little printers. The laser writer was born. I remember one day getting a call from Stanford University; one of the electrical engineering professors there [called] and said “Gary, they’re going to have a show and tell today and you’ve got to see this.” I went over to Stanford and there sat a Macintosh; the first one I’d ever seen. There sat a laser writer and they were running Postscript and they were printing beautiful pages at 300 dots per inch in every degree of complexity you can imagine. I said, “The world is here. The only problem is it’s not ours.”

Hendrie: It’s not a Xerox.

Starkweather: That’s right and that was 1985. At that point in time, I developed some additional things with printers like color, which again Xerox said has no purpose. Color is a non-useful market. It has no potential. One of the fellows who had actually started color computer imaging at PARC, by the name of [Richard G.] Dick Shoup, actually started a company called—oh I wish I could remember it. Anyway, if you ever watched the news with the characters popping out at the weather, that’s all his work.

Hendrie: Really?

Starkweather: Yes.

Hendrie: Okay.

Starkweather: He was trying to do that at Xerox but management said, “That’s a dumb idea. You don't belong here.” He left the company. Of course, color printing was of no use either because they tried it once; what was indeed a crummy color copier. But I did make a color laser copier and I’ve given you a sheet that you can take to the museum. I show some color work done. A little prior to this, [in] 1977, PARC, in its desire to sell this whole global imaging office printing concept, had rented out a resort in Boca Raton, Florida and we decided to have something called a World Conference. There we showed the Dover Printers, printing at a page a second. We showed some smaller printers printing at slower page rates and we showed a color printer, printing in color. We showed Altos doing all of this with a color Alto that you could do color composition on. We brought 200 executives and their wives out to the site to show them the world of the future. None of it stuck. Everybody came back home and was very disillusioned. At that point, PARC started to come apart.

Hendrie: Really?

Starkweather: Chuck and John left and went to Adobe. Bob Metcalfe went and started 3Com [Computers, Corporation and Compatibility]. Several other people left and went to other places. Some of the computer science people left—like Bob Taylor and Chuck Thacker—and went to the DEC [Digital Equipment Corporation] Western Research Labs with Gordon Bell. I stayed there a little longer and one day I came in and said to myself, “If I knew in 1978 what I know in 1988, would I still be here? And the answer is no.” Apple Computer made me an offer to come and work in printing for them and I went over to Apple and left Xerox.

Hendrie: Really.

Starkweather: I remember walking out the door saying, “One more year and I would have been here 25 years.” They have really—it’s gone away. The charm is gone. The glory has departed.

Hendrie: What happened?

Starkweather: I went off to Apple at that point. The company at this point in time, in 1977, got so hurt by small Japanese copiers that they, unbeknownst to most people, almost went out of business. The company, who was basically as big as can be and strong as can be five years earlier, nearly came close to going out of existence because the Japanese just literally tore them apart with this stuff. Xerox thought that their way of doing it was the only way to do it. They had a document called Phase Program Planning for example, which was a way to bring a product to market in seven years. The only trouble is, the Japanese could do it in two. That meant that you were always five years behind the power curve on this thing.

Hendrie: Especially if you were aiming where the squirrel is.

Starkweather: That’s right. The way to hit that squirrel was not use slower bullets.

<*Laughter*>

Starkweather: Unfortunately, and it's too bad because Xerox should receive a lot of credit for producing probably the most productive research center ever on the face of the earth. If you look at all that's come out of it, it far out-shadows American Telephone and Telegraph. It far out-shadows all the IBM research centers, all the things that came out. I think the estimate today is probably $100 billion worth of businesses came out of the PARC research. Unfortunately, very little of it ever came to their pocket, because they basically sent it all packing and sent it away.

Hendrie: They couldn't figure out, they just didn't have a way.

Starkweather: They just couldn't figure it out—

Hendrie: They didn't have a culture to move it from research into engineering and into product.

Starkweather: That's right. The two last serious things I was involved in was a high resolution laser printer which basically made images on photo paper that you could then take to a copy house and they could make production copies of stuff that looked like it had been typeset. It had more quality than any laser printer by far. It was superb quality. I tried to get a business started to do this and they had no interest in doing that. So I just shut that down. Then we bought a company by the name of Versa Tech which did large format plotting. We hooked Versatec, Inc., up to the imaging system that Xerox was working with at that time, called Interpress. It was a postscript technology. We were producing large posters. We could do clones of *Time Magazine* covers with an executive's picture on it and all this kind of stuff and begged Xerox to give us $500 to open an office front in Palo Alto to see if we could sell these things. They said, "What would you have to charge?" We said, "Oh, probably forty, fifty bucks for a big poster." "Nobody is going to do that." Well, go look up the revenue on large format printing today and see what it is. People routinely will get together, collect two bucks from everybody in the office and print a large format poster of the guy who is getting married and take him out to lunch. And the money is not in the poster. The money is in the ink, in the consumables. That's another thing that Xerox was very late to understand. They thought the money was in the printer and it was the old Kodak rule of give them the camera, sell them the film. Don't make the money off the camera. So I think with that result then, I basically was disillusioned enough. I pulled aside the guy who was the founder of Versatec, Inc., Renn Zaphiropoulos and I said to him, "Renn, what's the problem with this place?" He said, "The problem is that we have very competent people who have no imagination." At that point in time I knew that was a much more difficult problem to fix. I had to make a decision at that point, I think, "This is enough." That's when I went over to Apple, spent ten years there—

Hendrie: What did you do at Apple? You can tell us about that?

Starkweather: I got into the printing business at Apple and worked there for a year and a half and then had some ideas in color which, again, were not liked, even at Apple Computer. People might not imagine that, but black and white imaging was perceived to be the only way to go because you might have to pay $600 for a color display instead of 200 for a black and white display. Of course, what they didn't realize is the minute the color display came out, you couldn't give away black and white displays. Use them as paperweights. In pushing that, I left the peripherals group, which did printing and made a lot of money for Apple doing printing and went over to the advanced technology group before I became an Apple Fellow.

People say, "What's an Apple Fellow?" It's basically an individual who's chewed through his leash so many times they stop tying you up.

<*Laughter*>

Starkweather: So there I was, responsible, and I worked with Alan Kay. He looked at education and I looked at publishing. We had people like Gursharan Sidhu who looked at networking. We basically had an open ticket to come and see the CEO any time we wanted. The advantage was they didn't have to listen to us, but we couldn't be shot for saying what we felt. It was basically a diplomatic immunity post for a technologist which was kind of fun.

Hendrie: That's pretty good.

Starkweather: Of course, Apple then began to get into trouble as well, prior to the return of Steve Jobs.

Hendrie: Oh, yes. Has what's his name gone yet as the king of Pepsi?

Starkweather: Oh, that's right, John Sculley. John Sculley left and was then was replaced by Michael Spindler who just seemed to struggle with the company. Michael Spindler left and Gil Amelio came to run the company, and Gil was a guy that tried hard but he [was] just the wrong guy. He brought a knife to a gunfight. It just really wasn't the right thing for him to do. I could see the company either going seriously downhill or out of business. At that point in time, I was deciding, "What should I do?" I got a call from a fellow at Microsoft; he said, "Would you like to come up here and interview?" I said, "Well, it rains a lot up there out in California."

Hendrie: Who was that?

Starkweather: A fellow by the name of David O'Hara. I'd worked with David and he was very much into color as well and we used to you know, roust about how it would all be so great if we could just get people to accept the whole thing. Dave went to Microsoft, called me. To make a long story short, I went up and interviewed and they offered me a job and I left Apple and went up to Microsoft where I worked in the Windows group for a year and a half and then transferred to research and spent the rest of my time in research working on large displays, large combinations of displays, wrap-around displays and so forth, because from a printer perspective, a lot about what was happening in printing was sharpening the knife, not revolutionizing the business. I'd always been someone who wanted to change the way things worked, not just hone it a little sharper. I stayed in displays there until I retired in 2005. I still consult for them from time to time. I've had a lot of fun doing that and I think one of the things is I wear an iPhone and it's kind of fascinating because Steve Jobs shows you what imagination can do for a company. Businessmen are important. I always told people, I always considered people in three categories in a company. There's what I call bureaucrats, which keep the trains running on time. There's engineers which make sure the bridges are strong and the trains can go across them. Then there are commandos looking for new things to do. You better decide which one you are because the worse thing is a commando who has to be a bureaucrat or a bureaucrat who has to be a commando. They don't like the work and all three are important. They have to be in their particular categories. To me, one of the beauties of Apple was that it had a lot of this capability but it needed a spark. When Steve Jobs returned, I remember looking at it and saying, the stock is down to $11 a share. I don't know how much longer they can last. This morning, it was $246, okay. The net worth of the company, the capitalization of Apple is now greater than Microsoft. What I've always thought was: I loved Einstein's quote, "Imagination is more important than knowledge." I used to put [that] on John Sculley's desk for him and I had one at my office at Microsoft that was a quote from the founder of IBM, [Thomas J.] Tom Watson. He said, "You want to increase your successes? Try doubling your failures." The trouble is, we've grown into a society in a lot of cases that thinks it can compute or plan out failure. Failure is the result of trying hard. Failure is not the result of doing things wrong, not always. I've always told people, companies [that] are unwilling to fail are not going to succeed. I think Steve Jobs took big risks in things. I knew Mac, I knew iPhone and iPad and someone said, "Well, that's not really the right thing." Wrong again.

Hendrie: Yes, that's right.

Starkweather: From my perspective, I've had the great good fortune of God's blessing in allowing me to have more joy and more thrills than I ever thought I could expect to have.

Hendrie: Very good.

Starkweather: Thank you.

Hendrie: Good. Thank you. Let's take a pause.

Starkweather: Okay.

Hendrie: I think I have some more specific questions.

Starkweather: Okay, great.

Hendrie: We're just going to continue with some of your random thoughts.

Starkweather: That's fine.

Hendrie: Let's record them, rather than not recording them.

Starkweather: That's fine. One of the interesting things in the early laser printer era was that our subsidiary in Japan, Fuji Xerox, which was part of the Rank Organization, had heard about it. They were excited to come over and see this because they realized they could print Japanese characters with this. Of course, people don't realize that if you think typewriting in English is hard, you ought to see what typewriting in Japanese is like. You have little tweezers. You have to put pieces of characters in and then click and then remove those pieces and I mean it's a very painstaking process. You can print in Kanji a little easier with a Japanese typewriter. But Kanji is an everyday language. You would never send information to an executive or to an important client in Kanji. You would have to send it in some other Japanese character. I think it's Hiragana or something like that which is much more detailed and elegant. They realized that this printer could actually print all those fonts. They were excited to come over and see it. They came over and they said, "We brought you some sample characters that are digital. Would you print those for us and send us the samples?" I said, "Sure." We printed them. We were very excited. We thought they looked good. I left you some samples you can put in the Museum if you want. I left you a memo that would be interesting to go in there with; they took photos of the prints I sent and analyzed them. They said, "Well it's very nice but you know— <*phone rings*> —it's very nice but do you know that there's a piece of this character missing?" "Yes." "Well, this makes it mean something different." I looked at it and I thought, it's just a couple of toner spots. I don't see any big deal there. They said "Oh no, no, in Japanese, that's very important." So we had to learn to tune the system that worked for Roman characters wasn't necessarily going to work for idiographic characters.

Hendrie: Really?

Starkweather: Yes, so that was very beneficial early feedback in the early 1970s that we couldn't get sloppy about image quality in any form. Just because it would print Roman characters and work in most of the Western world, didn't mean it would work in the Eastern world. I wanted it to work anywhere. When we fixed that and there are some sample prints you'll have, shows their concerns about what doesn't work and what does and we were able to re-engineer some piece of the machine to make it a little finer imaging and fix those problems. That was a very valuable, early piece of the problem that worked. I think the other thing which is a complete aside in a sense, but one thing that I think is very important and I just never want to forget this: A fellow came out to work with me early at PARC, by the name of Tibor Fisli. Tibor was a Hungarian refugee, who, as a teenager, escaped across the border under gunfire out of Hungary and became a man running a machine shop in Ohio. We hired him away and he came and set up a machine shop at PARC for us and worked for me for a long time. Tibor had a lot of value and he actually designed some of his own laser printers later on. I want to give Tibor credit for that because he is no longer with us. He was a great guy. I'll never forget one thing he did for me once. I used to rough out these mechanical drawings and give [them] to him that said "I need this part made." I would just make it real easy with a right angle. He'd say, "You can actually chamfer the edge of this and round that edge a little bit and it will be much nicer." I said, "Yes, but that takes more of the machinist time." He said, "Ah, you don't understand. Then they take pride in their work." That to me was very beneficial. Design things so that the person making it appreciates what he's doing. He said, "You know, they like to think they do good things, too." That was one of the most productive insights I ever had.

Hendrie: Wow, isn't that interesting.

Starkweather: I'll always be thankful to him for that insight.

Hendrie: That's very interesting.

Starkweather: He was able to do mechanical engineering and do things for me and then we had lots of good interactions and just to work with these. One of the neat things was [that] PARC was a very eclectic environment. We had people all the way from optics, to fundamental physics, to machinists, to hole drillers, to wiring people. A resource you needed was always around. You could always find somebody. All you had to do was to convince their boss, [you] need[ed] this done and they were assigned to it. There was no, what I would call, corporate insurrections that went on, which said, "I don't want to work on this." If it was considered valuable by management, it got support and that was a very nice thing. The most pleasant thing for me when I came to PARC, they said, "Fine. What do you need to build your printer?" I said, "This could cost fifty or one hundred thousand dollars." "Oh, no. Problem. Start ordering it. Let's get it going." The freedom of that was so great when prior to that, I couldn't get my boss to buy a one hundred dollar optical part for me.

Hendrie: Yes, no politics and no stifling bureaucracy. Obviously you need organization.

Starkweather: Right but we had overarching architecture which was to produce an information future in which things were electronically created and electronically reproduced. If your project was involved in that, you go support [it], okay? Projects which didn't support that were wondered [at], "Why not? That's what we're here for." There were a few that went that way. But for the most part, it was a very, very beneficial organization.

Hendrie: Good.

Starkweather: See, we've talked about color. Color was always one of the fascinating things to me. I can remember people saying, "Do you know that for a color image it's going to take three bytes and it's already expensive with one byte for black and white?" You never hear anyone asking that question today.

Hendrie: Yes. Exactly.

Starkweather: Now I have four bytes because I have an alpha layer that I can do things for and all that kind of stuff. It's interesting what problems have gone away due to memory. I remember fighting that role in Apple because many printers that were in design, were designed to minimize memory because memory was expensive. It was so hard to convince them. By the time your printer comes out, the memory you're worried about will be half the price than it is today. Sure enough, they'd come out and find out that, "Oh boy, we should have put more memory into this thing because now the images could be more complex." For a while, it was a real wild chase to get there. Of course now, I have a terabyte disc on my desk. Who worries about that stuff anymore? I keep telling people who call me and ask, "What should I throw away?" I say, "Don't. Go buy another disk. It's not worth your time."

Hendrie: Wow. Let me put you on pause for a second.

Starkweather: I built the first printer and got it going at PARC and that was on what's called 3180 Porter Drive. It was the old Encyclopedia Britannica building. PARC began to grow rapidly. It was the hot place to be. In fact, Jack Goldman, who was ahead of Research, said that business travel to Rochester in the wintertime was unlimited because they knew you had to be going there on business.

<*Laughter*>

Starkweather: But Xerox decided it needed to expand. It was going to build a new building. But they hadn't decided quite where to put it. It's the current PARC, of course, out there. They bought a building from Friden/Singer and that building happened to be a half mile away and across a freeway. I said, "Great, what are we going?" He said, "Well, you can't go till the new building is up because we don't have the room. Only computer people can be in that building." I said, "Great guys, how am I supposed to print for a year and a half?" "I don't know, couldn't you just develop the machine?" This was before it turned hot. This was 1972. I said, "This is a problem. I don't have any data sources here." "Well we could just—" I said, "I'm all done with the little stuff. We're on to the bigger things. I don't need just little test patterns anymore. We're past that point." "What can you figure out?" What I figured out is [this]; I went up on the roof of the building at Porter Drive and found that I could see the other roof of the other building. We couldn't put microwave up because it didn't have enough bandwidth. I have to send 35 million pixels per second through the system. I couldn't lay a cable under the freeway. I sat down and did some back-of-the-envelope calculations, submitted a plan to my boss and he said, "Go for it." I bought four astronomical telescopes and I put two on one building and two on the other building and in one astronomical telescope on each building, I put a laser with a modulator. On the other telescope, I put a receiver with a special detector in it. Then what I would do is—

Hendrie: With a photomultiplier tube?

Starkweather: Photomultiplier tube. That's correct. Then, I put narrow band filters on them so that all I could see was the laser light and that way they would run in the daytime. I could shield them. Then, when the starter scan signal came out of the laser printer to say, "I need the data now," it would send it up to the laser. The laser would pulse down to the other end. The other end would trigger the computer down at the other end which would then send me a data stream back, receive it and print it on the printer. The only problem was, I was one inch over because it took six microseconds for the light to make the round trip <*laughs*> and the scanner hadn't stopped.

Hendrie: Oh my goodness.

Starkweather: We didn't have enough buffer memory to delay it so I could preload two scan lines. So for a year and a half we had a one inch shift on the page to print all these things <*laughs*>. But the interesting story is, this thing ran flawlessly for a year and a half and they used it. When I wasn't using the laser printer, it was a TV transmitter. Of course, generally invisible, it was only down one day in the year and a half due to fog. Rain didn't stop it; in fact, because of the Bay Area pollution, rain actually cleared the air. I measured the transmission channel everyday and actually the transmission went up on rainy days, because the red light went through the rain very nicely and it also washed the dirt out of the air. We had one complaint by the Stanford police that some lady had driven into the ice plant because she saw this red beam in the sky <*laughs*>.

Hendrie: Oh no.

Starkweather: They said, “Can you turn the intensity down?” So I turned the intensity down and we got around that problem.

Hendrie: But it was still okay.

Starkweather: It was still okay.

Hendrie: It was still bright enough.

Starkweather: That’s right. So this year-and-a-half hiatus never occurred because we were press—we were sure IBM was going to be doing something. I said, “I can’t wait a year and a half to work on the perfection of this.” Indeed, it was a valuable year and a half. It was really fascinating that we had this pipeline going through.

Hendrie: That’s how you solved that problem.

Starkweather: That’s right. Occasionally, when it would rain, these flat roofs would sag and the lasers would go out of alignment. So we bought two walkie-talkies. This friend of mine, Bob Kowalski, who was an inestimable help; I’d put him up on the other roof. We call, “Do you see it yet?” “Do you see it yet?” “Ohhh!! I see it now!” Because it was so bright <*laughs*>. You keep tuning the stand. You’d crank the laser beam back into the other aperture, the other unit. Then, you could go until—then, of course, the rain would evaporate off. Then we’d have to go back and readjust them again. Fortunately, it didn’t rain that much in California. Pretty much from April to November you didn’t have to adjust anything.

Hendrie: Oh, wow.

Starkweather: We’d go up with our umbrellas and our walkie-talkies and put the lasers back in alignment.

Hendrie: Yes, just literally adjust the leveling.

Starkweather: You could see this red beam moving around out in space, and you had to steer it down into the other unit.

Hendrie: But you could see it?

Starkweather: Oh, you sure could.

Hendrie: Yes, because it was bright enough. And it was collimated enough?

Starkweather: You were enough in line that the backscatter was sufficient to see it, yes, because these were eight-inch telescopes. I would send it in. We had this eight-inch red beam going down to the other roof. Now, of course, it expanded a little due to diffraction. If the roof sagged a little bit, it could steer that beam off several feet. We had to crank it back into position.

Hendrie: Then, of course, it wouldn't hit the other telescope at all.

Starkweather: That's right. That's right.

Hendrie: But you didn't have to have it directly…

Starkweather: No, no, no.

Hendrie: …absolutely centered.

Starkweather: That's correct. That's correct.

Hendrie: Wow.

Starkweather: That's one anecdote that probably, to me, was one of the more fascinating outcomes: that we had an optical communication channel running at 35 megahertz in 1972 <*laughs*>.

Hendrie: Homemade…

Starkweather: Homemade.

Hendrie: …but it was working.

Starkweather: It worked, and it never was down. Absolutely was never down.

Hendrie: Wow, wow, that's great.

Starkweather: The guy who invented sticky notes at 3M sang in a church choir. When they would both practice or have a church service, he had these little slips of paper where the hymns were going to be. Of course, inevitably, he might open up, one would fly out and he'd have to put it back. He thought, "Man, if I could just make this thing stick in here a little, then I could just peel it off without damaging the hymn book and it would give me a way to either reuse them or at least wouldn't be falling out on me." So he went to the engineers at 3M and said, "Look, I'm making some little pieces of paper. I want a glue on it that's not so good, just doesn't stick all that well." They said, "Well, you need to know at 3M we make good glues. We don't make glues that aren't any good." He said, "No, no, you misunderstand." "Look, don't bother us with this, okay? We make good glue here." He thought, "What am I going to do?" He went to some friends and mixed up some of his own. He spread some on paper and made a little stack of them. Then he thought, "I'm going to suggest this to the marketing people." They said, "This is of no use. Why waste your time on this?" He had a bright idea. He made up several pads of these things, took them to the executive secretaries and said, "Here's what they're for if you want to put it on a memo. If you need more, give me a call." Pretty soon he got a phone call back from the CEO's secretary who said, "This is terrific. I got to have some more of these." He said, "Would you talk to your boss? Here's the result I've had, and here's the memos of people who don't like these things." Well, guess what? The CEO called him and said, "This is a great idea." That became born as sticky notes. Market today is worth a billion dollars a year for sticky notes. He had the ability to try it out. To me, that's so key: just give people the chance to fail. Alan Kay used to say, "Most creativity is driven out of people by the tenth grade." Here's what we're going to learn and here's what we're going to paint and here's what we're going to do. I had a second grade teacher whose name I cannot remember, and she wanted us to paint boats. I could've cared less about boats. I didn't want to paint boats. I loved trains, couldn't get enough of trains. I kept telling her, "I want to do a train." I came in one morning—it was [my] fifth grade teacher, excuse me. She said, "Here's a roll of paper." I said, "What's that for?" She said, "I want you to put it up all the way around the room. Your whole job this semester, when we have art time, is to work on a train." The whole year I painted a freight train all the way around the room. She got her artwork done for me, got me to participate in the project. But she gave me something I was interested in. Today, they want to pigeonhole. "We're going to build Cape Cod sandcastles today." "I don't want to build a Cape Cod sand castle." "That's okay. That's what we're doing." Build a sandcastle. Build whichever one you want. Build one in a dome. You want to build a Victorian one? Who cares? To some extent, I think I owe it to a number of people in my life who gave me the ability to continue to think out of the box. I will always be thankful to them that they didn't shut it down. I think we have to be careful when people say, "I want to build it this way." Go ahead, okay? Don't want to hurt yourself. But for the most part, that's not the issue. The issue is, and I fight a lot of computer games, that they're pre-doctored. Here's what you can do with it. No, I love Legos. You can build a stairway, or you can build a rocket. To me, that's the sort of thing that has always been—and PARC was a place that had a lot of Legos <*laughs*>.

Hendrie: <laughs> That's very good. That's very good.

Starkweather: I just wanted to share that.

Hendrie: Yes, that's a great one. One question I wanted to ask was about patents. Tell me about the patents in this area. What things did you end up patenting? How important were patents in the business world?

Starkweather: First of all, I consider patents extremely important. Xerox was very, very disciplined on protecting themselves. To that, I give them great credit. Part of that was because Chester Carlson, who was the inventor of xerography, was very much key in the patents on his process and had not been for those other people that have chimed in on it. He had good control of that. When Battelle bought those rights and sold them to Xerox, the secret of Xerox's success was the uniqueness of this whole thing.

Hendrie: It had some protection from competition for a while.

Starkweather: That's correct. Yes, at least you get 17 years that they can't step on you. When I did the laser printer stuff, when I came up with the correction lens for the scanner, I called the patent department that afternoon and did up a patent IP [Intellectual Property]. I filled out my lab book which had how I did it in there, pictures of the mechanism. I had somebody witness it, and I took care of it right away. Within five hours, I had an authentic copy of something that could be used in patent. I ended up with probably about 40 patents in that particular technology. Covered everything we thought could possibly be there. Let me tell you another way that patents are interesting. In my high-resolution laser printer, it's pretty hard to get more than about 6 or 700 pixels per inch across a page using this technology. There are a number of optical reasons for that. I wanted one that would have 5,000 per inch so that I could do maybe even lithographic quality things. You can put a prism on the end of a stick or a motor and spin it around. If the motor axis wobbles, the spot moves around. Of course, the smaller the spot the greater the tolerance requirements. The bearings would have to be extremely precise. There goes the cost again. I sat down and went through my old optics books. There's a prism called a *pentaprism* in which the light goes in, reflects off two walls and comes out the front. The interesting thing about a pentaprism is it's insensitive to rotational motion. If I twist the prism, the output light beam will go up and down but parallel to the other one. The interesting thing is the lens could care less which zone the light's passing through. The light still goes back to the focus.

Hendrie: That's what lenses do <*laughs*>.

Starkweather: That's correct. I filed two patents on this. I got a call from the patent department. "This is already covered." I said, "Really. Could I get the copy of the patents?" They sent me a copy of the patents. I took a look at them, read through all 19 claims and said, "It's not here." I said, "They did not claim this particular feature." I went back to the patent examiner and they said, "You're right. You get a patent." I got two patents. Xerox never made use of this. But several years later, I was at a graphics conference in Germany. These people were showing a high-quality page maker. I said to them, "That's very neat. Boy, that's pretty compact. How'd you get that to work?" He said, "Let me show you. We got this pentaprism inside." I said, "Oh, you do." <*Laughs*>

Hendrie: <*laughs*>

Starkweather: I said, "That's very interesting. I have a patent on that." The guy just about turned white. "Well, I don't think so. This is a special deal." I went to the phone, called Xerox, who I didn't work for anymore. I called a patent attorney I knew and I said, "I think you ought to check into this." Sure enough, he did. It did cross their patents. I got called in on a dispute on the patent from a German company; none other than Heidelberg, which was a big printing company. Their attorney came over from Germany and he said, "Well, this is so obvious that anyone in the art could see it, that's how to make it work." I said, "Then, why didn't you invent it?" He couldn't answer that <*laughs*>, "So obvious, how come you didn't invent it?" They lost and they had to pay Xerox some money for that.

Hendrie: Ohhhhh.

Starkweather: Even though I never got a nickel for it, I value patents because I consider intellectual property of extreme value. It's your idea. It's so easy. I don't know if you ever saw the one about the windshield wiper movie, where the guy actually had the—for the intermittent wiper, you should see this movie. I can't remember what the name of it is. I think Russell Crowe's in it, and it's good. He patented an intermittent wiper and Ford stole it from him. He noticed it when it came out at an auto show. There's the Mustang with the new intermittent wipers. He said, "That's my patent." He took them to court and he won $20 million on that patent. It protects the individual. It protects my idea against all onslaughts for at least 17 years. Interestingly enough when I thought my 40 patents had pretty much covered the ground, today there are about 4,000 patents in laser scanner technology.

Hendrie: Really.

Starkweather: There's always a new way to skin the goose. Today, the big concern about patent infringement is that if you're going to file a patent, you have to file it in every country that you hope to be protected. Now, that costs about, maybe $1,500, the last I knew, to file it in every country. You're going to file 100 countries, ooh, boy, that's a lot of money, so $150,000. A lot of companies won't put that in their patent budget. The trouble is that that means someone in a foreign country can steal your idea and make a product that's not sold here. That's the first problem. The next part of the problem is people are stealing your intellectual property left and right as it is. They don't even care. To some extent, the concern over patents, to me, is reducing the value of intellectual property. I am not sure that, if the laser printer or some of these other things would've been invented today, that you could actually protect them or that companies would put the money behind to actually protect their interest. Because you might be able to sell laser printers exclusively in America. Everything in other parts of the world, you wouldn't be able to protect it if you didn't file there. The costs of doing that have gone up. My attitude on patents is they're absolutely critical. It's much easier on a mechanical patent, where shaft A goes through gear B, which turns lever C. It's much harder in software. It was up until barely ten years ago that there was even a patent attorney in the patent office with a computer science degree. That has changed now. That's getting much stronger. I'm part of the National Academy of Engineering and we're always talking about intellectual property protection because theft of someone's idea is wrong, just plain wrong.

Hendrie: One of the curators wanted to know whether you were surprised by Canon's introduction of the semiconductor laser.

Starkweather: No. Part of the reason for that is we had a fellow who worked at PARC. His name was Robert Burnham, and Bob's main interest was in semiconductor emitters. He and I worked very closely together on looking at semiconductors. He made some of his own. In fact, the first version of my telescope transmission system had a nitrogen-cooled LED [Light-emitting Diode] in it. I didn't think it would work based on calculations, but I was willing to try it for him. I remember putting it in there, and it was just a dim glow. As soon as it came to liquid nitrogen temperatures, this thing glowed like the sun down there because of the improvement due to the cold temperature. Bob said, "Look, it's red today. It'll be green tomorrow. It'll be blue the next day." Xerox had no interest in supporting semiconductor lasers of any sort. Bob went off and worked at the University of Chicago, in Urbana, for a while. I don't know what he's done now, but he was very much a pioneer in semiconductor emitters in that regard. What people need to realize is that, from the first laser-printing engine in which the laser costs $3,000, the scanner costs $2,000, the electronics cost $5,000 and all the other parts, today the mirror and the lenses cost $3. The laser costs a dollar. The entire laser assembly and a personal printer is $25. I don't think even those of us who were aficionados of this would've estimated it could come that low. You can go down to Costco today and buy a color laser printer for $300. I think it's amazing how it has come down, and so sometimes even the inventors don't have enough imagination <*laughs*>.

Hendrie: <*laughs*>

<*crew talk*>

Hendrie: What do you think is the next big challenge for the technology industry?

Starkweather: There's, of course, a lot of them. To me, there're two things. In fact, to some extent, I should give credit where credit is due. When I was at the 25th anniversary of the personal computer, in San Jose, Gordon Moore spoke and so did a couple people from Intel. They were asked what they [thought was] the single biggest concern on letting technology move forward. Their comment was the network. I was talking with somebody yesterday. I teach at a church near here, and they wanted a copy of my presentation. I said, "It's 20 megabytes. It will not transit in most e-mail systems. They won't let you get at it." We need a network system that says, "I don't care what your material is, it can pass through the system." Because it's no good if the system blocks the transmission of the information any more than I couldn't do graphs on a printer sort of thing. If I can't send anything anytime, then it's really not the network I'm looking for. So first of all, I think the network is a big problem.

The other thing is I think we've got to come up with much higher security because people are now talking about computing in the cloud. "I'll just store my data out there in space somewhere." "Don't worry about it on your own machine. Log into our website. We'll put the stuff on your disk in our system. Any time you need it, it's there." My attitude is has anyone ever thought of putting their money in the cloud? You say, "No, I like my money where I can get at it." Wouldn't you like your data in the same place? My feeling is [that] computing in the cloud is a good idea, but it's no better than it is secure. To some extent, that is an issue that needs to be seriously considered. The other thing is there's been a lot of debates about the display versus paper. While paper has become less important, in some ways, people ought to realize that, last analysis, 40 percent of the companies who install e-mail systems increase their printing. It's not something which tends to go away with electronic mail. It's something which tends to come. The way I have tended to answer this is the following. Sure, in fact, the iPad may be a significant improvement there. But the way I answer this is the following. Let's, for a moment, do a thought experiment and say, "What would the ideal display look like?" It would permit color. It would permit seeing it in virtually any lighting conditions, in the sun or in the room. It wouldn't be so expensive that if I lost it it'd be the end of the world. You can go on. It should be readable. It should be reproducible. I say to people, when we talk about these things, "Haven't you just described a sheet of paper?" To some extent, I think you have to be careful that you may be trying to replace the wrong thing. It's the storage of paper that's costly, not its production. Since most paper can be easily recycled, I'm not going to go and expect the same experience of a 100-page document on an electronic device that I can thumb through and look, oh, that graph is interesting. I can't look through electronic materials with the same facility that I can look through a paper document. Not only that. I can hand it to you, and you can look at it. Didn't have to have any protocols. Bandwidth transfer was instantaneous. I didn't have to worry about if it did come through okay. I think a lot of these things and issues will go away. But when they're as convenient as a sheet of paper, which is still there, it's important. I love to scare librarians and tell them, "Do you have most of your stuff backed up on CDs?" "Oh, absolutely." I said, "How long will your CDs last?" "Uh…I don't know." I said, "You're using aluminum CDs?" "Yes." I said, "Try 10 or 15 years," "Really?! It's going to be gone?!" I said, "Well, it can develop defects. You can't read it anymore. You need to go to gold. Those may be good for 200 [years] as far as we know." "How good are cuneiform tablets good for?" "Ooh, least 3,000 years, aren't they?" We have to realize I can go read the Declaration of Independence without any software. Make sure the information I get—if you had all your data on floppy disk, what would you do with it now? Nothing around. To some extent, DVDs are going to go the way of better DVDs. CDs are virtually walking out of the system. We need to be sure that we have a backtrackable system that makes sure the information I've stored on something is not lost to me as I make this rapid lurch into the future. To me, that's a big concern. I want data I can get my hands on, and right now a sheet of paper is data you and I can read. I don't require any software. I don't require an operating system. And, therefore, to store my passwords in some ether that could go away is a frightening thought to me. Meanwhile I'm just going to copy them <*laughs*>.

Hendrie: <*laughs*> Good.

Starkweather: I'm sure I could get some arguments on that, but I think I've got a point I haven't heard anyone properly answer.

Hendrie: Yes, I do, too. What problems do you think the technology industry can solve for society in the future?

Starkweather: I think one of the things is making us more productive. The other thing is allowing people to have more time to themselves. We talk about productivity, but I've watched people go from 40-hour weeks to 60-hour weeks. The story we used to have at Microsoft is we work flextime, any 80 hours of the week you want. <*laughs*>

Hendrie: <*laughs*>

Starkweather: We find that technology may have become at least as much a burden as a helper and may actually become a master more than a slave. I watch people now sitting. Instead of talking to each other on a bench, they're texting each other. Be careful we don't lose some of the humanity in this whole process. We should try and make sure that the technology always stays our assistant and doesn't become our master in this regard. I think there are some real dangers to that. I first saw that when I took a sabbatical from Apple. Every five years, you could get six weeks off at Apple. I took my first sabbatical. Week one I was tempted to call my secretary and say, "Anything happening down there, how are things going, getting interesting e-mails?" And my wife said, "Look, you're off for six weeks. Just be off for six weeks." The second week, I thought about it a couple times. By the third week, I didn't care what was on my e-mail at work. Then, I got back after the six weeks. It took me a full month to get back in the groove. I was thinking, "Gosh, I could go out to lunch right now, go a little early, well, no, this is work, I got to be here." E-mail became somewhat of a taskmaster. Who's training and who's being trained here? A big question about the future of information technology is, "Do I get to stay human in the process?"

Hendrie: How do you think the computer industry will change in the future?

Starkweather: That's interesting, because, first of all, computers are going in everywhere. My guess is—I would like to go—and I used to push this idea of what I called the smart peripheral in which—what do I really need to bring with me? A keyboard and a display, some pointer device. I don't need to bring the CPU [Central Processing Unit]. I don't need to bring the disk. I don't need to bring all that stuff. Therefore, couldn't I come up with an architecture in which I've got a computer in the closet and it talks to a tower and goes through my cell phone so I have access to my computer from wherever I am but I don't have to carry it with me? Therefore, computing today is marked on, "I'm selling you a box and then I sell you an operating system and then I sell you a better operating system and then I sell you an application, then I sell you a better application." I mean, Word now has so many features. Most of us use probably less than five percent of them and can't figure how to get at half of them. Now, it's not because they haven't tried hard. It's not a matter of weakness in the technologists, but they've become so complex that maybe they do too much. I would think that they could think more towards adaptive systems. Ted Taylor, who was a wonderful software guy, wrote a book called *Watch What I Do*. His thesis was, "Why can't the computer watch me and say, 'Every morning he gets up about 8:30, goes in and pulls his e-mails, he always looks at this one from "Jack and Jill" and this one from CNBC and the one from "zupidooey" he doesn't pay much attention to. Tomorrow morning I'm going to have those all pulled for him and say, "Here's the ones that you like to see," I'm going to be a help to him.'" Today, the most powerful personal machine remembers one mouse click. It doesn't remember what I did yesterday. I can't go back and look through my calendar. It puts the productivity burden on me. It enhances my features, but it doesn't do much to help me get faster.

My feeling is [that] they need to think more about making the technology adaptive rather than, "How do I sell the next box?" Because if you make it useful to me, I will always need it. The ideal case, of course, is the phone company, which doesn't try to sell you the phone anymore. They sell you service. I would like to see the computer industry head more towards a service model in which—for example, I don't buy applications anymore. When I log in, I rent the system. It says, "Oh, by the way, a new version came on last night. We've downloaded it for you. You can now use that." I don't have to go to the PBX [Private Branch Exchange] and load a disk so that my phone works on the new phone software. They take care of that for me. Yes, they charge me for that. But guess what. I don't have to do it. I think today we're in a strange transition between the old model of, "Look at my big computer and all the stuff I got on it and the little computer that I haul around, which weighs so much I don't really want to carry it around," and the fact that maybe they could just make this a transparent technology for me. Telephones, cell phones are pretty much a transparent technology. I think they've got to figure out how their business models can cope with selling a different form of silicon and a different form of software that satisfies me better. Because the first person that solves that problem's going to put them out of business. I remember when copying came in place. You see any more thermal fax machines? No. Carbon paper, who wants it? Because the better idea was there. I can remember carbon paper being the argument against having a copier, because it's already there. I used to ask people, "How do you copy pictures with carbon paper?" "Nobody needs to copy pictures."

Hendrie: *<laughs>*

Starkweather: I mean, silly stuff.*<laughs>*

Hendrie: What advice would you give to a young person just starting out in their career and who is interested in science and technology?

Starkweather: I think there would be two areas that would be extremely interesting. One is software. I have to believe that there's going to be an insatiable appetite for software. I think, in Butler Lampson's words, software is still an art form. It's not yet a science. We call it computer science, but still it takes—it's very hard for one user to read another user's source code. If that's the case, it still is art, not a science. The other thing is robotics, because we now have Roombas which run around and vacuum your house. Our cars are getting increasingly robotic. I've got an automatic parking system in my car. Who knows what they're going to have? They have lane-change protection now in some of these things, automatic brakes. If the car in front of you starts to stop and you don't notice it, it applies the brakes for you. Going into robotic technology and then probably putting all that, if you could take something really far out, and moving it into biomedicine. Because now putting robotic devices that, for example, are noninvasive medicine. You swallow a camera and it takes pictures, travels through your gut. They put it in a box, and it downloads the video. Here's what your gut looks like. No colonoscopies. I can swallow it as many times as I want. It passes through in 24 hours. I know there's some work going on in what I call min[i] circuitry, these little miniature mechanical things, in which, today, if I take some medicine, I swallow it. It's in a capsule. Eventually the capsule dissolves and the medicine's dumped into my system. Really not the ideal way to do it. You don't take a scoop of fertilizer and dump it directly on the plants. You sprinkle it around. It goes on proportionally. This stuff usually doesn't work that way in most cases. They try to have slow release and so forth. Interestingly enough many times the release should be based upon, say, the pH of the body. You can have pumps, miniature pumps, people have been designing these, that you'd swallow with a pill. The pump itself will pass through you. But in passing through, it reads the status of your gut and will dispense medicine based upon what it needs, not upon the fact that I got to dump it all as I go through. Therefore, applying that, having readouts, having the ability to see all this—the iPhone supposedly has an application coming out, not from Apple but from medicine people in which they will plug a Holter monitor into the phone. It then fits under your shirt, and you walk around. If you're a heart patient and you're having problems, the model would be that if something unhealthy shows up, the phone calls your doctor, sends him the chart, he calls you and says, "I want you to come in right now," or, "Stop where you are. I'm going to send an ambulance," or something of that nature. To me, those things are so astounding as to their abilities to protect health and to benefit life that I would say going into software and robotics and medicine probably has to be the most fruitful enterprise you could. That's not saying that automobiles, electric cars aren't interesting. But believe it or not, those will probably all be managed computer-wise as well.

Hendrie: I think that sort of wraps up the questions that I had.

Starkweather: Well, I thank you for your time.

Hendrie: I thank you for your time.

Starkweather: Thank you for taking the effort to come all the way down here.

Hendrie: That's wonderful.

Starkweather: It's a pleasure.

Hendrie: Thank you very much.

Starkweather: It's interesting. I never would've imagined. I remember walking into my lab at PARC the first day, and it was a vacant room, nothing but concrete block walls and these funny windows down on the floor, which means they must've had animals or something in here at one point in time, and looking at everything without a screwdriver in the place and saying, "What have I done?" <*laughs*>

Hendrie: <*laughs*>

Starkweather: Then saying, "You've done it, you better get going." <*laughs*>

Hendrie: <*laughs*> You'd better go figure it out.

Starkweather: <*laughs*> That's right, yes, yes. Not the right question <*laughs*>.

Hendrie: Well, thank you.

Starkweather: Sure, you bet.

<*crew talk*>

Hendrie: Tell us what the picture is of.

Starkweather: This particular picture is the first laser printer prototype that was built. This is built on the base of a Xerox 7000 copier. The top of the machine was removed, which was just basically window dressing. A metal plate was placed on top with all kinds of optical components. This little unit here is the modulator, which was the one that turns the laser beam on and off. Behind here, this big grey box is the laser itself and it's a very powerful laser. This laser produced almost half a watt. Now, calculations would indicate that we only needed one-hundredth of that. People didn't believe that this would work. Because the pulses were so short, they thought that the semiconductor would not respond in a linear fashion to that light.

Hendrie: This is the selenium drum.

Starkweather: This is the selenium drum. Therefore, they suggested that I have a powerful laser. Because they thought for sure I was going to need the extra power. Part of the reason for that is that in exposure issues, there's something called reciprocity failure. Reciprocity failure says that a bright light will work better for a fast time than a dim light will work for a long time. It's not a direct product. Since I was going to be exposing about a million times faster than had ever been done on selenium, they were sure this would be a huge problem on the photoconductor. Interestingly enough, I started imaging and didn't get an image. I kept putting in more filters and more filters and more filters. I finally put in enough filters where it was down to the calculated level and images started forming. The whole result is that selenium photoconductors and, in fact, many photoconductors are linear over ten log orders. That's over a factor of ten billion exposure range and unlike anything photographic in that ability. All these parts on here have the spinner motor. You can see this little mirror above the laser. These are all little mirrors to turn the optical beams. These were all adjustable like an optical bench. We could tune all this up and make it work and it helped us understand what parts needed to be built and how. This was the first unit from which all the others came about, and this was the one to prove that it all came together and would work as we had envisioned.

END OF INTERVIEW

