Oral History of Robert Proebsting

Interviewed by:
Gardner Hendrie

Recorded: September 14, 2005
Sonora, California

CHM Reference number: X3274.2006

Gardner Hendrie: …Bob Proebsting, who has graciously agreed to do an oral history for the Computer History Museum's Oral History Program. I think where I'd like to start Bob, maybe you could give me a little bit of your family background, where you grew up, what your father and mother did; a little bit about your very early life.

Robert Proebsting: I was born in Chicago in 1937; grew up in the Chicago area until I was in 6th grade and we moved to the suburbs, Park Ridge, when I was in the 6th grade. And I lived in Park Ridge with my folks until I went off to college.

Hendrie: Now, did you have any brothers and sisters?

Proebsting: Two brothers—an older brother, two and a half years older than me, John, now deceased; and a younger brother, Dave, who happens to be visiting with me as we speak.

Hendrie: Very good.

Proebsting: Two and a half years younger.

Hendrie: Okay. What did your parents do?

Proebsting: My dad was in advertising, had his own advertising company and had done that for many years. Earlier in his life, he had been an artist. And my mom was a housewife for the full duration that I knew her.

Hendrie: Stay at home mom--

Proebsting: Stay at home mom

Hendrie: --while the kids were growing up. Good. Okay. When you were in school, what do you remember about your earliest thoughts about what you might want to do when you grew up?

Proebsting: Oh boy. Before we moved, I don't know what grade I was in, but before we moved in 6th grade, I got ahold of an old radio that a neighbor was throwing away and wanted to see what made it tick. And I was interested in that and had the radio unplugged and found out the hard way that an unplugged radio can still zap the living tar out of you. There was obviously a capacitor. Years later, I went back and measured that radio that I still had and the plate voltage was 280 volts and I have no idea how much of it had discharged when I got across it, but it hadn't discharged all the way. It was still at a nippy high voltage and I learned the hard way that even an unplugged radio that didn't have a battery could somehow--

Hendrie: Could give you a zap, yes.

Proebsting: But I was already interested in electronics at that point in time. Electronics was a hobby throughout high school and college and I went to college, Knox College, in Galesburg, Illinois on a full scholarship from having won a physics exam that the college gave. First place on that exam was a full-tuition scholarship. Second place was a half tuition.

Hendrie: That's wonderful.

Proebsting: And I actually tied for second place in the math exam that they had. It didn't take a whole lot of time to decide I wanted the physics scholarship at full tuition instead of the math scholarship at half tuition.

Hendrie: Very good. Now you really liked the sciences and math when you were in high school?

Proebsting: Absolutely.

Hendrie: Those were your favorite subjects?

Proebsting: In high school and college, I did not need to work in math or in physics. I can skip reading the text and get A's.

Hendrie: Okay, it just came to you.

Proebsting: In German, I could study my little tail off and get C's.

Hendrie: That's very interesting. Well, we don't need to put this on the record, but I had the same experience, where I was very good in math and physics in high school and I could study my tail off in German and I could not-- It was incredibly hard. Were there any particular projects in high school besides the little radio story, things that you decided to go and build or got interested or went and helped somebody who was working in the electronics field? Any stories you remember about things you did that were ways you got fulfillment for your interest in electronics.

Proebsting: My brothers and I built push carts that had steering with a rope around the pole that we rigged up different ways without knowing the "standard" way to do it. We figured out how we could make a car steer and we rigged up a slingshot that shot things out into the lake at a lake house where my parents spent all summer, every summer. The slingshot was basically a fork in a tree with inner tubes, truck inner tubes, as the rubber bands and the block and tackle to pull it back and then shoot something as far as we could out into the lake. And we had a lot of fun doing that until one day when somehow the sling got caught the other way and this heavy rock went in our direction; it didn't hit us but this was the very last time we ever tried shooting that slingshot. It had not occurred to us that that was a possibility and it didn't immediately occur that it's something we didn't want to have happen again and go the wrong way.

Hendrie: Why did you choose this particular college? Why did you decide to take the tests to see whether you got a scholarship?

Proebsting: My older brother had gone to this college so it was high on my list. I wanted to concentrate on studies, but I was a very good swimmer. I wanted a college that had a swimming team but I didn't want to take an athletic scholarship because then you're at the mercy of the coach. He says "You're going to work out today; practice and swim forward until six as well as from 7:00 AM 'til 9:00 AM; you're going to be there." I wanted no "I've got a test that I'm taking or a term paper or a whatever." I wanted the flexibility to let my academics come first. So I chose the scholarship that had no strings attached, instead of perhaps an athletic scholarship that would have had a lot of strings attached.

Hendrie: When you went to college, did you think you knew what you wanted to do when you got out of college? Did you have any ideas?

Proebsting: I was sure I was going to be a physicist.

Hendrie: So you knew you were going to major in physics.

Proebsting: Oh, no question about it. I actually had a double major, physics and math. At Knox there were six physics majors in my graduating class. Four of them went on to get a PhD in physics; one a Master's degree in physics; and I got a PhD in electrical engineering. So out of six physics majors, five ended up with PhDs, one with a Master's degree. These were some good students. The first quarter, there were 640 possible points; the final was 200 points, each big test was 100 points, quizzes were 20 points, lab reports were 10 points—640. Second place in the class had 540; I had 638 and I didn't study it much. It was natural. It was absolutely natural. And I knew I was going to continue on, get a Master's and PhD in physics and enjoy a career in physics. I finished my Bachelor's degree with honors in physics, Phi Beta Kappa—and went on to the University of Wisconsin where I got a Master's degree in physics.

Hendrie: What area of physics? By this time you'd sort of focused on looking at solid state or nuclear?

Proebsting: I didn't really know. As an undergraduate, you do everything. You really have no clue.

Hendrie: That's why I was saying, when you got to the Master's level, you might have started--

Proebsting: When I got to the Master's level, it became clear to me that I'd break physics up into two areas. One, the physics of everyday life. I push this rock this way and it moves this way. The other, the physics beyond everyday life; relativity, quantum mechanics. I could turn the crank. In fact, at the University of Wisconsin, the qualifying exam to continue on for a PhD, you needed some grade for a Master's and some higher grade to continue on for a PhD. I was second out of eighty-some candidates. I could turn the crank and get the right answer on relativity problems or on quantum mechanics problems but I didn't know why. I understood that if you use this equation, you get the right answer. But I didn't have a clue why that equation really worked.

Hendrie: What was fundamentally behind that equation.

Proebsting: What was behind it? Why does an electron behave as a particle and as a wave? Not a clue why it behaved-- I understand that it behaves that way. There's certain experiments--

Hendrie: And you understand the correct equations to use when you analyze it.

Proebsting: But that bothered me something fierce; not understanding why. And I talked to the professors; frankly, they didn't understand why either. It just didn't happen to bother them. I was always intrigued by electronics and I thought well, with electronics, I charge up a capacitor and I know what I'm doing; I know why I'm doing it; I know what the result is of doing it. That's what I want to work with. So I decided to switch from physics to electrical engineering. Although I had qualified to continue in physics, I decided that I'd be much happier as an electrical engineer and have never regretted it at all.

Hendrie: Now were there a lot of courses or coursework you needed to do that would backfill your electrical engineering knowledge so you could go get a PhD? Did they let you, give you a PhD?

Proebsting: There were probably more than I took that I should have taken. Over the years, I periodically noted a lack of knowing how to something that all the engineers knew how to do. But on the other hand, when we were working with something fresh, something new, I was much sharper than my colleagues at understanding what this was and how to do it because I wasn't working with it from a canned equation that this is the way to get the answer. I was working at it from the fundamental physical principles.

Hendrie: You started with the laws of physics to try to understand it.

Proebsting: Yes, exactly. So there were things where my colleagues all knew of course the answer is something. Why? Okay. But there were other things where all my colleagues had not a clue and I did, and once they explained why something was the case, I could understand it. But yes, there were things missing that would've been helpful to know but overall, if I had it to do over again, I'd take exactly the same path, the physics up through the Master's degree and the PhD in electrical engineering. I would not do it all in engineering because the physics I think gave me a much broader knowledge base to do new things.

Hendrie: Yes. I have to say I have made exactly the same observation in my life. I also, my training was in physics and it served me very well for exactly that reason. It helps you think about and figure stuff out from inspiration from first principals.

Proebsting: You'd figure it out, not substitute into an equation and if the answer is wrong--

Hendrie: You may not know it's wrong.

Proebsting: Yes.

Hendrie: Did you have to go back and study Laplace transforms and some of those things, classic electrical engineering? Did you pick up on circuit theory?

Proebsting: You picked up on one, probably my biggest deficiency. I never had anything on Laplace transforms and my colleagues would say "Oh, this is stable because the third pole is north of the second pole."

Hendrie: The north pole is north of the south pole.

Proebsting: Yes. And I'd have to ask them to try to explain in terms that I could understand, which sometimes they could do and sometimes they couldn't do and I'm not sure that that was their fault, not mine. That was the big one in my mind as I was saying, things that I was deficient in. Now, I was deficient in knowing how electric motors and generators work. That caused me no grief at all other than in my own workshop, but some things that were relevant. Now, I had never had a course in logic and I took a brusher-upper course, a one-week-teach-everything-you-need-to-know-about-logic-in-one-week by RCA Institutes. I was in that class and the lecturer, teacher, said any combinatorial logic function can be expressed as an and/or function—A and B and C, or D and E, or A and C and E. Any can be expressed as a two-level combinatorial function. Right then and there, I had invented the programmable logic array. Okay, I know what a read-only memory is. It's a first AND gate, a NAND gate followed by a second NAND gate; only it was fully programmed. Every input, the first term was addressed 0 and 1 and 2 and 3 and 4 and 5, et cetera. The next one, not 1 and 2 and 3 and 4 and 5. Okay, just minterms. But it didn't need to be. Right then and there, within seconds, I had formulated what turned out to be an exceedingly important invention—the programmable logic array that most CMOS textbooks have a whole chapter on the subject. And I heard that anything can be and/or—hey, we can do that in MOS real easy.

Hendrie: Now when did you take this course? I'm very interested. It was later in your career.

Proebsting: No, no, no. This was sometime in the first year after my PhD.

Hendrie: Oh, wow. Okay. Can we roll back and you're finishing your PhD. Now what are you thinking about?

Proebsting: Okay. I made a disastrous mistake in choosing a PhD topic. I worked with the wavelength stability of gallium arsenide laser diodes. I hated it. I hated every second of it. It was something my dissertation advisor thought was a good project and I was too lazy to find a real interesting, good project. I paid dearly in years of servitude. I talked to two researchers at RCA who tried to do what I originally tried to do. They were unsuccessful; PhD researchers at RCA who had full laboratory ability with them and they failed just as I failed.

Hendrie: Now what did you try to do? Were you studying something or were you actually trying to build something?

Proebsting: I was trying to measure the wavelength stability of the gallium arsenide laser using fringes and it never worked. It never worked. Finally they let me get through with a lesser project. They were kind to me. The process said “think hard about what you're going to do professionally; don't take the first thing that comes along unless it's the best.” And bipolar integrated circuits amounted to-- I loved circuit design. This was my thing. I wished that there were PhD dissertations in circuit design.

Hendrie: And you would have picked one, yes.

Proebsting: I would have picked one.

Hendrie: Now, do you know why you love circuit design? Have you ever thought about what it was--

Proebsting: It came naturally to me. I could do it well. I knew right from early on.

Hendrie: When your first problems that you had--

Proebsting: I could make a circuit that would do something. The circuit design, bipolar integrated circuits had been around for some time. They accounted for over 99% of all integrated circuit sales and I thought MOS was really the right way to do it. MOS made more fundamental sense than bipolar.

Hendrie: Can I just roll back quickly; what year are we talking about?

Proebsting: I finished my PhD in 1967. I decided that I wanted to get into MOS integrated circuits and now MOS integrated circuits I'm sure are more than 99% instead of less than 1%. The popular wisdom was that they were never going to amount to anything but I looked at the physics of what they had and why they worked and how they worked. I said this is a better way to do it. So I decided I wanted to get into MOS integrated circuits and chose Texas Instruments in Dallas, actually Richardson, Texas as the place to go.

Hendrie: So did you look at other companies?

Proebsting: Oh, yeah.

Hendrie: What were some of the other ones you looked at and rejected?

Proebsting: RCA, which was my second choice. In hindsight, it probably would've been a better choice.

Hendrie: They also were doing MOS work, weren't they?

Proebsting: They were doing MOS work and they were doing a lot of CMOS MOS work, which TI was not.

Hendrie: Any other?

Proebsting: Oh, there were a few. I went to a couple different divisions of General Electric and others but I'm not even recalling who they were. RCA was the only one that I was really having a debate at the end, who do I want to choose. With what they did over the years compared to what TI did over the years, RCA probably would've been a better choice. And so I went to TI.

Hendrie: Were you married or anything at this point?

Proebsting: Yes, married. I had two children.

Hendrie: When did you get married?

Proebsting: I got married to my first wife in 1961.

Hendrie: Where did you meet her?

Proebsting: At the University of Wisconsin.

Hendrie: When you went to Wisconsin to do your Master's.

Proebsting: And we had two children—Todd who was born in '62 and Lynn, my daughter, who was born in '64. Todd now has a PhD in computer science and works for Microsoft. Lynn has a Master's degree in accounting and does some consulting work but is mostly is a housewife. My career at TI--

Hendrie: Now who did you work for when you first got there and what did they ask you to work on?

Proebsting: Bob Crawford was my first boss. He wrote a textbook on MOS and he was quite a good teacher of how this stuff worked and why. I think I gained a lot from working with him. Jack Mies [ph?]

was another engineer who desperately tried to get me to build a radio on a chip. Well, they finally succeeded in doing that about 20 years later but a lot had to happen in those 20 years. There was no way that the technology we had at that time was compatible with putting a radio on a chip. But that was his dream. I spent a little time trying to do it.

Hendrie: This was work on MOS. Was this in a product development group, a research group, an advanced development group—how would you characterize the group you were in?

Proebsting: The product development group that had a goal of selling the product. I went to a customer, Microswitch, a division of Honeywell, who made a keyboard, computer keyboard and it used the Hall Effect. As you typed down, you're pressing a magnet down and the magnet comes close to a Hall sensor and the Hall sensor kicked out what it turns out was a four-pin package this Hall sensor, power supply, ground and two outputs, both of which independently went high when the key was depressed. And they wanted a code changer so that their huge diode array that converted the key depression into an ASCII code—they wanted a code changer that could take that ASCII code and convert it into a EBCDIC or a—I don't even remember what all the codes are—but into other codes. And I thought about the problem and came back to them and said “I can do that with no diodes.” You can have an array that has no diodes whatsoever and still have a reasonable number of pins on the package and output the ASCII, the EBCDIC code and all the others and got a patent on the technique. All it was was you OR together in pairs, pins. Pin 1 goes to inputs 1 and 2 on the chip. Pin 2 goes to 1 and 3. Pin 3 goes to 1 and 4, 1 and 5, 1 and 6, 1 and 7; 2 and 3, 2 and 4, 2 and 5, 2 and 6, 2 and 7. And with 13 pins, you can get—I think it was 13 pins—all 80 keys on a keyboard. So when you press a key, the decoder is looking for a given decoder; you're press in key number X, looking for pin 7 and 11 and not 1 and not 2 and not 3 and not 4 and 5 and not 6 and not 8 and not 9, et cetera. So I saved them a tremendous amount of money. They were very, very happy with this circuit. I also at that time did what I believe was the first 256-bit memory, semiconductor memory. As something for the audience to ponder, if automobiles had come down in price the way semiconductor memory has come down in price between the time I did my first semiconductor memory and today, what would an automobile cost? You're guessing too high. You're still guessing too high. You're still way too high. Well the answer is not how many dollars a car would cost or how many dimes or how many pennies, but how many cars would you get for a penny? How many full-fledged complete automobiles would you get for a penny? Our integrated circuit memories have typically been about $10. My first one had 256 bits. Then one kilobit. Then four kilobits. Then 16. Then 64; 256. A megabit. Four megabits; 16; 64; 256. A gigabit. And that's about where we are today. Well that, from a quarter kilobit—256 bits—to a gigabit, that's a factor of four million. So if a car cost $10,000 in '67—and I think that's about right—that's a hundred thousand dimes, a million pennies. It cost a million pennies and it's gone down by a factor of four million. You get four cars for a penny now. That is how much the technology has changed. I mean, it's been incredible. Now, almost all of that is from process development that I had virtually no part of. But the technology has moved dramatically over these years and my contribution has been in the circuit design arena, particularly in DRAMS.

Hendrie: You talked about this decoder that you did for Honeywell. Did TI then go and make it?

Proebsting: TI manufactured it; Honeywell bought it and put them in their keyboards. Absolutely. It was a very successful product.

Hendrie: Now what about this 256-bit RAM memory? Was that used in any product or was it just an idea you came up with at that time? Tell me about that.

Proebsting: It was, in its day, very awkward to use and incredibly fast. For its day, it was awkward but incredibly fast.

Hendrie: Did TI make a product of it?

Proebsting: Oh yes, and some people bought it. But the market was limited to people who needed a very fast memory because they had to put all kinds of periphery around it to make it work.

Hendrie: How fast is very fast?

Proebsting: I think I had one customer who had about a 50 nanosecond access time and this was in '67 or '68. So way ahead of its time in speed but awkward as all hell. The signal you got out was a differential current, just a little differential current that you had to have a hell of a sense amp--

Hendrie: To go and figure out.

Proebsting: So, instead of my doing the awkward work of sensing it—it's slow with my PMOS MOS technology. Instead of doing it with my slow PMOS, I left it to the user to do it and he could do it much faster but at much greater awkwardness for him.

Hendrie: How did you store it? Did you store the data basically in flip-flops?

Proebsting: Of flip-flop; PMOS only. So PMOS driver device, PMOS load device, PMOS access transistor. The chip had 256 bits, a 16 by 16 array. There were 16 column select lines. You selected one of them low for the turn on to PMOS transistor—the others are high—and you have to select it with the levels of the day: I think minus 12 volts.

Hendrie: Oh my goodness. I see what you mean. There's a lot of stuff around it.

Proebsting: Sixteen pins. You had to pick one of them and make it go low. Sixteen rows. You had to pick one of them and make it go low. And then the single pair of outputs, differential, you had to drive them rail to rail, differentially if you were writing; and if you're reading, you had to sense the small current difference. So all of the work was left to the user but the user had a core with which he could work to make a very, very fast memory for its day.

Hendrie: What was the part number of this? Do you happen to remember?

Proebsting: No, not a clue.

Hendrie: Okay, that's fine.

Proebsting: It was a PMOS 256 bit static RAM.

Hendrie: So those are two of the first things you worked on when you first got to TI and did?

Proebsting: Yes.

Hendrie: Any other things that you worked on?

Proebsting: Yes, I did at least one shift register; at least one read-only memory. I was involved in a few circuits but I don't remember the others.

Hendrie: Okay, that's good. Why don't we change the tape now before we get into the MOS Tech story.

Hendrie: Ready.

Proebsting: Yes.

Hendrie: Good. Well, you just designed some-- telling us about the circuit you designed at TI. What happened next in your story?

Proebsting: Well, TI was absolutely enamored with a technology called discretionary wiring. It was a technology in which you used the first layer or two of metal and fabricated a whole bunch of individual circuit pieces on a wafer. And then you tested and found out which ones worked and which ones didn't work and for each wafer made another pair of wiring circuits to wire up the working circuits leaving out the nonfunctional circuits to make a large-scale function. So, each wafer had its own-- two masks made for two layers of wire to achieve large-scale integration.

Hendrie: Now was this is development of Jack Kilby?

Proebsting: Yes. Yes. That's…

Hendrie: I remember discretionary wiring.

Proebsting: This was a development of Jack Kilby and he was a strong proponent of it. TI's budget, I believe, was over a hundred times as much for discretionary wiring as it was for MOS. And we in the MOS group thought that MOS was the future.

Hendrie: And this was discretionary wiring-- these were of course, bipolar wafers with-- do you remember how many gates, you know, how many circuits there were?

Proebsting: No. No.

Hendrie: That's all right. Continue.

Proebsting: And we were very frustrated that we didn't get a larger budget to develop this technology that we really believed in.

Hendrie: Mm-Hmm.

Proebsting: Faster.

Hendrie: Yes.

Proebsting: And we were frustrated and my then boss L. J. Sevin [ph?] went out to form his own company, which ultimately became Mostek, and wanted some of us to join him. And...

Hendrie: Oh he was frustrated too?

Proebsting: Oh he was frustrated. <Overtalk>.

Hendrie: Yes.

Proebsting: We both wanted to make a buck, but I think it was more frustration than anything else that our company didn't really believe in what we were doing. They were kind of funding us going along the way but not really funding us the way a technology that is going to eventually dominate the industry should be funded. So he was out looking for funding, for money, for starting up a MOS company. And TI was aware that this was happening. And one Friday afternoon, Friday the 13th, 13th of June 1969, I was called into the executive vice president's office and asked to make a decision. Texas Instruments or Mostek.

Hendrie: Now who was the vice president at this point?

Proebsting: Fred Busey [ph?].

Hendrie: Fred Busey. Okay.

Proebsting: And who was later president.

Hendrie: Okay.

Proebsting: And I didn't know if Mostek would ever get its funding or if they did if it could be of such a limited amount that perhaps they'd have to make me a lowball offer or what might by the case. I really didn't know.

Hendrie: But L. J. Sevin had talked to you about joining.

Proebsting: Oh I had talked to L. J. Sevin about joining and told him if he's got this money and he wants me, I'm there. I'm there. Yep. And so Fred Busey said, "I need to know." "Can I call L. J. Sevin and see if I have a job offer?" "No." "Can I call my wife?" "Yes." So I called my wife and told her what was going on. Sharp lady. And she then carries on the conversation where our conversation my half consists of yes, yes, no, yes, no, no as she's asking various questions. And, because Fred Busey's the right across the table from me hearing 100 percent of my side of the conversation, and we decide we'll chance going with Mostek. Now we had just bought our first house and refrigerator and washer and drier and ladder and etc., lawn mower. All the things you need to go with a house. In debt way beyond where a human being should be in debt. And now quitting my job for an unknown period of time, maybe forever.

Hendrie: Yes.

Proebsting: And-- but we decided…

Hendrie: And you have a family.

Proebsting: I've got a family. But we decided together go with Mostek. Not--with no clue if and when Mostek would ever get its funding and if not move somewhere and get another job.

Hendrie: Right.

Proebsting: Okay. So, at that point I tell Fred Busey my decision to go to Mostek. That it was not a decision I was planning to make at this time or perhaps ever but under the circumstances that's my decision. He said they'd prepared to double your salary if you stay at TI. And my response was at my last design review I begged for more. I thought I deserved it. I had done some really good things. Inventing the PLA, coming up with this Honeywell circuit that was exceededly profitable. That I had done enough to deserve more and they showed me this chart with a bachelor's degree, a master's degree, and a PhD, how much money you can make over time. And I'm right at the top of what a PhD with one year's experience can make. Right at the top. But people in our group who were contributing nothing, who had been there forever were making much more than me. And I thought you should be rewarded not by your years of service but by your contribution. And they would have nothing to do with it. And so I said to Fred Busey, "If I'm worth that much I should have gotten it at my review. And if I'm not worth that much I don't want to get that much and then stay level until I'm… "

Hendrie: Till you retire.

Proebsting: Until I retire. Or meet that curve again.

Hendrie: Yes. Exactly.

Proebsting: And he somehow wasn't happy with that comment and shuffled me next door where Mel Sharp, the head of their legal department, was waiting for me with termination papers. I'm sure he also had a contract. Well it turns out my wife called L. J. Sevin after we got off the line. Told him what my conversation with Fred Busey was. And he tried to call all the other folks who were gonna be a part of Mostek. Well, these other folks were in different offices at the same time. So, L. J. Sevin couldn't get anybody in his office. Well he figured out what was happening. Each of us was independently in an office with a high-level vice president being asked to make this decision.

Hendrie: And being offered twice their current salary.

Proebsting: Oh I don't know that that happened with the others.

Hendrie: But…

Proebsting: I know it happened with me. I never discussed it whether it happened with the others or not. It may or may not have happened with the others. But-- so L. J. Sevin couldn't get anybody. Called their wives. Told them exactly what had gone on with me and furthermore that they got their funding today. And there's gonna be a big party at his house tonight for everybody who leaves and we start work on Monday. So now all my colleagues, all of whom, 100 percent of whom, say, "Well under the circumstances I'll take Mostek."

Hendrie: Yes. I'll take my chances.

Proebsting: I'll take my chances. Yeah. With that, he called all their wives and told them, "Party at my house tonight. Mostek has its money. We start on Monday. If your husband has…"

Hendrie: "Has said yes. I'll go with Mostek."

Proebsting: "Has said yes."

Hendrie: And of course he had no way of knowing.

Proebsting: All of them said yes.

Hendrie: Okay.

Proebsting: Now my colleagues in the meantime are wondering, "How do I go home and tell my wife I'm without a job? How do I do this?" When the wife knows that they've got the job they want waiting for them on Monday.

Hendrie: Yes.

Proebsting: But they have no clue.

Hendrie: That's wonderful. That's wonderful.

Proebsting: They have no clue that the wife knows this.

Hendrie: Right. Okay.

Proebsting: And so we started and we were following, I believe that the following is correct. I have not, I've heard it many times. I've never checked it personally. Our financial results-- we started just about a year after Intel. And our financial results were virtually identical to what Intels had been a year earlier.

Hendrie: Okay.

Proebsting: Through the time that we were acquired.

Hendrie: Okay.

Proebsting: And through a couple of years beyond that when the products that were coming to market already in the pipeline coming to market, ran their course. But when those products died, we didn't have anything to replace them with because the new owners said, "You will only do circuits that are guaranteed to be profitable. You will not take any risks." We'll talk about risks that we took and the results of those risks as we continue this interview.

Hendrie: Okay. Yes. All right.

Proebsting: But we got to where we were by taking risks. Calculated smart risks, but nevertheless, risks.

Hendrie: Yes.

Proebsting: And occasionally we lost money but we made up for it for other circuits that made a ton of money.

Hendrie: Exactly.

Proebsting: Well we had then decided we would not do any circuit. Our new management, none of whom, none of whom, zero of whom, had any experience in the semiconductor industry.

Hendrie: The classic formula for an acquisition.

Proebsting: Yes. And we…

Hendrie: You know what? Why don't we postpone talking about that till we get to the acquisition?

Proebsting: Okay.

Hendrie: Yeah. Let's do that.

Proebsting: That's fine.

Hendrie: That would be good. So let's get back to, you know, it's Monday morning. Have you had discussions beforehand as to what Mostek is going to do?

Proebsting: No.

Hendrie: And what's the plan? So what happens?

Proebsting: We all show up at the offices of the head financial guy, the head guy who worked on financing.

Hendrie: Yes. Okay. What was his name?

Proebsting: Dick Petrus [ph?].

Hendrie: Dick Petrus. Okay.

Proebsting: And he was a technical guy who had been in MOS some years earlier.

Hendrie: Okay.

Proebsting: But he was now a financial company putter togetherer and he was in fact our first president.

Hendrie: Oh. All right. And do you remember where L. J. raised the money? Where, well Dick Petrus and L. J. raised the money from?

Proebsting: Most of it came from Sprague Electric.

Hendrie: Okay.

Proebsting: And they were by far the biggest single contributor and we used their fab lines initially, until we had our own. And we didn't have our own place of business, probably a year maybe two after we were founded did we go to our Carrolton sight where we built our first fab.

Hendrie: Okay.

Proebsting: So, up until then, we were making our circuits in the Sprague Electric line up in Worcester, Massachusetts.

Hendrie: Right. And you had-- but you had some-- you rented some office space?

Proebsting: We rented some office space. We initially, for a week or two whatever it was, we initially-- remember it was just the previous Friday…

Hendrie: I understand. There's no lead-time with this all at.

Proebsting: No lead-time. The previous Friday that we found out that this was happening.

Hendrie: Yes. I know. I think this is wonderful. You start immediately.

Proebsting: And so we were in Dick Petrus's office area…

Hendrie: Yes. Okay.

Proebsting: Crowded to say the least for, I don't know, two or three weeks. And then we were in rented office space in downtown Dallas. And as quickly as possible got our site in Carrollton, Texas that had a fab line but for the first probably two years at least of our existence, maybe more, our circuits came from being fabricated…

Hendrie: Up in Worcester…

Proebsting: Up in Worcester.

Hendrie: From one of your investors.

Proebsting: Yes.

Hendrie: Okay. So you're coming to this company and you're starting work and have all of you come from TI? Do you all know each other beforehand?

Proebsting: No. Most of us came directly or indirectly from TI.

Hendrie: Okay.

Proebsting: Some of us-- I came directly from TI. I'd say-- there were 13 of us that started it. I would say probably 9 or so of the 13 came directly from TI and probably two others came indirectly from TI. Had been at TI, was known from being at TI, but had moved on somewhere else. And our secretary, one of the 13, had not been at TI or ever I think. And I think there was one other person who had not been at TI.

Hendrie: Were all of the original 13 engineers? Well obviously Dick Petrus was, may have been once upon a time.

<Overtalk>.

Hendrie: He was the manager but he was an engineer too.

Proebsting: He had once been an engineer. Two of the people, Bob Palmer and Luway Shareef [ph?] were process engineers.

Hendrie: Oh. Okay. So Bob Palmer was one of the 13?

Proebsting: Bob Palmer was one of the 13. And he and Luway Shareef went to Worcester and set up the process line for MOS.

Hendrie: Okay.

Proebsting: In the otherwise facility that had some work close to MOS along with a lot of bipolar work. So it wasn't quite like converting from purely bipolar to MOS. It was half way between bipolar and MOS that they had to convert from to MOS.

Hendrie: And they apparently had a line at Sprague that was not fully, you know, not fully utilized in space.

<Overtalk>.

Proebsting: They had space available. I don't know how much they suffered at giving up this space, if any. But they made space available.

Hendrie: All right. Okay. That's really cool way to start. Yes.

Proebsting: And they were doing work with ion implantation of structures. I don't know what the structures were for on the integrated circuit.

Hendrie: Okay.

Proebsting: And Bob Palmer gave me a call one day and he had already talked with several of the other engineers that they could make depletion transistors on the same wafer with enhancement transistors, any benefit?

Hendrie: By using this ion?

Proebsting: By using the ion implantation.

Hendrie: Ahh. So that was, yes. Rather than just dope-- some doping technique.

Proebsting: Yes.

Hendrie: Okay.

Proebsting: They could selectively implant some transistors.

Hendrie: Okay.

Proebsting: And the others had said, “No. There’s no advantage to that at all.”

Hendrie: Did you-- were depletion load transistors used at all at MOS?

Proebsting: Of course not.

Hendrie: Yeah.

Proebsting: No.

Hendrie: I mean what do they do? Yes. Exactly.

Proebsting: No they were not used at all.

Hendrie: Yes.

Proebsting: And I said, “Oh good lord yes. That’s a fantastic thing to have. We could tie the gate to the source of the depletion transistor and have a current source for a load and it’ll go all the way up to VDD instead of going up to VDD minus VT.

Hendrie: Yes.

Proebsting: Yes a tremendous advantage. The circuits will go faster, they’ll use less power. Absolutely it’s great.

Hendrie: And nothing like a current source load.

Proebsting: And right then and there I basically thought that I had invented the depletion load. Filed for a patent on it. And the examiner found a very relevant single statement in the "RCA Technical Journal" from back in '65 I think.

Hendrie: Oh my goodness.

Proebsting: One sentence that's, what they figure of the depletion load with the gate ties it back to the source…

Hendrie: Yes.

Proebsting: One sentence saying it would be very nice to have this depletion load because it would go all the way up to VDD but you can't fabricate depletion and enhancement on the same chip, period, new paragraph, new subject.

Hendrie: Oh my goodness.

Proebsting: And so clearly that caused that part of the patent not to…

Hendrie: Yeah.

Proebsting: Be…

Hendrie: So they thought of the idea. They did not have a method for…

Proebsting: That's correct.

Hendrie: Actually implementing it. If they'd had a method…

Proebsting: That is…

Hendrie: They would have built circuits that way cause they really did get it.

Proebsting: They realized the benefit, to my knowledge, when I filed for the patent I was the first to realize the benefits.

Hendrie: Yeah. Well how many people had asked the question of anybody, of a good circuit engineer?

Proebsting: Yeah. And-- but I did get a push-pull version of it. Two stage. A first simple inverter stage whose output drives the gate of the depletion second stage and it outperforms a simple depletion load tremendously. It's more complex.

Hendrie: Yes.

Proebsting: But very high-end performance.

Hendrie: Okay.

Proebsting: And I did get claims on the push-pull circuit that turned out to be very valuable for Mostek even though all the claims were rightfully denied on simply a depletion transistor with the gate tied to the source as a load element.

Hendrie: Okay.

Proebsting: Any claim like that was correctly denied.

Hendrie: Yes.

Proebsting: I had no clue about this technical article in the "RCA Journal."

Hendrie: You weren't reading technical articles five years old.

Proebsting: But that, unlike many times when I've applied for a patent where a examiner has sited an army tank against my airplane patent…

Hendrie: Yes. This was a good examiner.

Proebsting: This was a valid…

Hendrie: Right.

Proebsting: And I didn't try to get around it and say no no you're misreading it. This was clear. Somebody did it before me.

Hendrie: Yeah. Okay.

Proebsting: I lose.

Hendrie: Anyway.

Proebsting: But so Sprague's work with ion implantation that Bob Palmer recognized he could make a depletion transistor and then that I recognized that depletion transistor has value…

Hendrie: Could make a really-- yes. Could make an integrated circuit I guess.

Proebsting: And between the time of that invention and the development of CMOS, depletion load was the way to go.

Hendrie: Yeah.

Proebsting: I mean it was a better circuit than an enhancement load.

Hendrie: Yes. Okay.

Proebsting: And most circuits were that until CMOS, which is a yet better way to do it…

Hendrie: Right.

Proebsting: Took over and made depletion loads totally obsolete.

Hendrie: Right. You didn't need it. You had an active device pulling it up.

Proebsting: Yes. Turn it off when you want it off. Turn it on when you want it on.

Hendrie: Turn it on when you want it off. You don't need a passive load even if it is a current source. Yeah. Okay.

Proebsting: So…

Hendrie: Well, so very good. So now when would you say how long, you know, after Mostek started did this sort of eureka that "We have a really good idea for making faster, better potentially maybe you don't need to go to a high voltage now because you have a current source. You might even make TTL compatible parts."

Proebsting: I'm gonna-- we did.

Hendrie: Well I'm just saying…

Proebsting: I'm guessing that it was somewhere between six months and a year after we started.

Hendrie: Okay. Okay. So when you're-- let's role back to when you're really just starting.

Proebsting: Now that's a guess.

Hendrie: What do you think, you know, do you remember what some of the conversations were about what in the world you're going to build? You know you gotta build a product. What are you gonna, you know, what are you gonna do?

Proebsting: Oh we…

Hendrie: Or are you gonna go out and talk to customers and do some custom products? What are you gonna do?

Proebsting: We talked mostly to customers about custom products.

Hendrie: Okay.

Proebsting: And a customer who was using a fair amount, or was going to be using a fair amount, of MOS for a display. Burroughs had a self-scan neon display that had a whole bunch of dots. It's a neon sign with data scrolling across the sign. And you get from the MOS circuit the left, I don't know which way it scrolls, but one column of the letter "A," then the next column, and this column, through the gasseous conduction the lights that are on whether you turn on this one, if this is on, this goes on.

Hendrie: Oh. Okay.

Proebsting: And if this is on, this goes on. Then you turn this off.

Hendrie: Yes.

Proebsting: Then you turn this one on. Three-phase. One, two, three. One, two, three. And all the ones, then the twos, then the threes. So it's self scans but you need a circuit to provide the font of the letter "A," and "B," and "C," and what have you.

Hendrie: Yes. Exactly.

Proebsting: And we had done some work at TI for Burroughs and knew that they used MOS and we went to see them.

Hendrie: And you knew-- yes. So somebody knew one, the customer and so you…

Proebsting: And we went to see them and here's the deal that we got. They had already funded two companies to develop this product.

Hendrie: Okay. Two companies. Do you remember who they were?

Proebsting: I'm not gonna say. Yes I do.

Hendrie: Yes you do. The correct answer to that is yes you do and that's all I'm gonna say.

Proebsting: Yeah. The correct answer is yes I do.

Hendrie: Okay.

Proebsting: And they-- we went to see if we could be a third source. And the phenomenal deal that we got was as follows:

Hendrie: Okay.

Proebsting: They're under no obligation to buy circuits from us. They're under no obligation to fund any of our developments. But if they want some of our circuits, because they're better or whatever than the competitive circuits, they will pay us twice as much as they're paying the competitors for the circuits until the development that the competitors received, the development money, the upfront money, we get twice the going rate as long as they're buying circuits from us until we have received the development money that the others have received plus the cost of the circuits. So if the other guys fail, we get the development money. If they come through, we don't get anything.

Hendrie: Right. Because why are they going to pay twice the amount for the circuits for a while. And if they can get them from somebody else…

Proebsting: They're already six months into development.

Hendrie: Oh all right. Yep.

Proebsting: Okay. So this is the phenomenal deal we were able to negotiate.

Hendrie: Yes. Not very good but okay.

Proebsting: Okay. So I was assigned the circuit.

Hendrie: Okay.

Proebsting: And to make a long story short we saved Burroughs' tail.

Hendrie: Really?

Proebsting: We delivered product a little over a year ahead of company number two.

Hendrie: Oh my goodness.

Proebsting: We delivered product two months after recept of contract.

Hendrie: How would you do that?

Proebsting: Working hard quickly.

Hendrie: Yes. Okay. Was a complicated circuit, you know? Did it have lots of transistors on it?

Proebsting: Well it was lots of transistors but it was a read-only memory. It's very straightforward.

Hendrie: Oh of course. Yeah. Exactly. All right.

Proebsting: I mean it…

Hendrie: Yes. That's the basis for it.

Proebsting: That's the basis for it was a read-only memory.

Hendrie: Yeah. It didn't have to have programmable fonts for example?

Proebsting: No. No. You…

Hendrie: Fixed font.

Proebsting: Fixed font. You hard-programmed the font. And so we were not able to negotiate a very favorable deal but we got all of our fund-- all of the original up-front money that the other companies got because during the first year of shipments the other companies didn't have it, didn't have anything and if they wanted product, they needed to get it from us and they wanted…

Hendrie: And so they paid you the double price until…

Proebsting: And they paid us the double price so they took-- but we saved their program.

Hendrie: And I'll bet the development money was pure profit for you because if you did in two months, you couldn't have spent that much developing it.

Proebsting: That is a fair observation.

Hendrie: Right. Very good.

Proebsting: So…

Hendrie: No that's great. That's a great story.

Proebsting: That is in a start up especially when you're going in against known entities…

Hendrie: Yes.

Proebsting: And you're going in late…

Hendrie: Right.

Proebsting: A program that's already in progress but we had confidence that we could do it and make things happen, even though we were starting six months late.

Hendrie: Very good.

Proebsting: We were-- had a big enough ego and whatever.

Hendrie: Right. And you-- yeah.

Proebsting: Well we can do that.

Hendrie: We can do that. That's very good. So, when did you get that contract? How long did it take after, you know, you started the company? Was that six months or…

Proebsting: I'd say six months.

Hendrie: Yeah.

Proebsting: Give or take. I really…

Hendrie: Yeah. You don't remember exactly. All right. It was pretty early.

Proebsting: It was-- yeah. Quite early.

Hendrie: Very early.

Proebsting: Quite early.

Hendrie: Quite early.

Proebsting: And that product L. J. Sevin had on his wall the first check we ever received for product…

Hendrie: Was for that product.

Proebsting: Was for that product.

Hendrie: Very…

Proebsting: So it was pretty early.

Hendrie: That was very early. Yeah.

Proebsting: Yeah.

Hendrie: Okay. Well of course I'm-- my problem is to figure out who the other people are but, you know.

Proebsting: Well…

Hendrie: I'm-- I assume-- what I'm not sure it's a PMOS product?

Proebsting: Yes.

Hendrie: Yeah a PMOS. PMOS metal gate. Right?

Proebsting: Yes.

Hendrie: So it probably was RCA and Intel.

Proebsting: It may have been.

Hendrie: It may have been. I don't expect you to say. All right?

Proebsting: Okay.

Hendrie: We'll-- let's continue.

Proebsting: Good.

Hendrie: So what happened next? What did you work-- was that the first circuit that you designed or was that the first successful one that you were able to sell and get some volume on.

Proebsting: In the first two or three years at Mostek, I designed at least half a dozen circuits. Some read-only memories. Some shift registers. Mostly they were very simple circuits. A read only-memory is really-- there's not a lot to it.

Hendrie: Yes.

Proebsting: And you can design it quickly. But there were no calculators at that time. You designed with a slide rule and a pad of paper.

Hendrie: Okay.

Proebsting: I mean certainly no circuit simulation.

Hendrie: Right. And so what would you do? You'd design it? You'd draw out a schematic of the transistors. And you'd name-- label all the widths and lengths of all the transistors…

Proebsting: And perhaps I would lay out the circuit.

Hendrie: Okay.

Proebsting: And perhaps I would make the tester to test the circuit.

Hendrie: Which it never cut the Rubylith.

Proebsting: And perhaps I would cut the Rubylith.

Hendrie: Oh okay. It just depended.

Proebsting: I'm not sure if I ever cut the Rubylith. I peeled it.

Hendrie: Yes.

Proebsting: I'm not sure if I ever cut it. I don't think I…

Hendrie: I don't think that's a good thing-- a good use engineer's time.

Proebsting: I don't think I ever cut it but I did peel it.

Hendrie: Yeah. Okay.

Proebsting: We wore many many hats.

Hendrie: It's what start ups do is the…

Proebsting: From engineering the circuit to laying it out to the Rubylith, to the testing, test-- how you test it, to making the tester to do the testing, to marketing, to writing the data sheet, and many many hats.

Hendrie: Yes. Okay.

Proebsting: So in the first few years I did a bunch of circuits. The catalog circuits were not as successful as the custom circuits.

Hendrie: Okay.

Proebsting: The custom circuits had a buyer who was interested. Again the buyer might be like Burroughs where they're interested only if they don't have a another source.

Hendrie: Yeah. Only if you can get there faster than…

Proebsting: If you can get there faster but we were willing to start a little bit behind the starting line and see what we could do. The catalog circuits we did not guess very well on what people would want.

Hendrie: Okay. You did not have a product-- what I call a product marking genius who just has this ability to see into the future as to what people are gonna want.

Proebsting: I don't want to by that critical of our marketing.

Hendrie: Okay.

Proebsting: I think it was tough in general to figure out. You know, we were trying to do two things. Combine what particular skills we had with what kinds of circuit utilized those skills.

Hendrie: Right.

Proebsting: For example, I'm very weak in logic. And for me to make a chip that's mostly logic would have been a ludicrous thing to do.

Hendrie: Yeah.

Proebsting: Even if mark-- if I was the only designer, which I wasn't, but if marketing came up with, "You gotta make this logic chip." It just didn't match our skill.

Hendrie: Yes. Okay. I understand.

Proebsting: At least my…

Hendrie: At least your skills.

Proebsting: Skill. So it was a combination of trying to find circuits that used our skills that were of interest to people.

Hendrie: Okay.

Proebsting: And if we came out with a circuit three months after somebody else came out with it and anybody who needed that circuit designed in the competitive part, we're out of luck. And our competitors aren't gonna share with us what circuits they're doing. So I don't think it was so much our marketing, lack of marketing skills…

Hendrie: It was just a-- at that point it was very young MOS applications industry and their weren't any. It was very hard to figure out.

Proebsting: There's no conventional wisdom really.

Hendrie: Yes. Okay. 'Cause there isn't enough track record to develop even.

Proebsting: Yeah. Yep.

Hendrie: Okay. Good.

Hendrie: We were talking about the early products and that most of the work, the volume that Mostek was getting was from custom circuits, can you continue the story of what's going on with you and what you're doing and what Mostek is doing?

Proebsting: Okay. Mostek developed a 1 kilobit dynamic RAM, 3 transistor. It had some advantages over the competitive part, the Intel part, but Intel's marketing, they could sell refrigerators to Eskimos and they out-marketed us something fierce, and their product really became the standard, even though it didn't really work. If you changed the addresses slowly, data would change. As you turn off one address and turn it on, if the address is moving slowly, the new address would turn on before the old address was turning off, so the read condition on the first column would be there to do a write to the second column. Fortunately for them, typically the driver transistors, the TTL that drove it, switched quickly but that, I'd never put my name on a circuit that did that. Intel's circuit absolutely did that and we pointed this out to customers but it didn't, they really won the game.

Hendrie: I should send you the transcript of the Karp and Regitz transcripts because I've interviewed both of them about how the terrible problems they had with the 1103 and getting it and customers being able to use because it was just so, I mean it was very difficult to get it right. There were other problems with it. But if you didn't do it, and you wouldn't necessarily know what to do.

Proebsting: And ours was a very solid circuit.

Hendrie: Who designed it?

Proebsting: Vern McKinney was the primary designer. And that circuit in my view, was the best 1K dynamic RAM out there, three transistor but Intel clearly won at the marketplace.

Hendrie: About what time is this in Mostek's career when you get to the point of offering those, certainly that's a standard product?

Proebsting: Probably about '71, maybe '72, I think '71.

Hendrie: So three years into it, maybe four, between three and four years into it.

Proebsting: Something like that, yes.

Hendrie: Do you remember how big, how fast Mostek grew, how big Mostek was after three or four years?

Proebsting: **Oh,** Golly.

Hendrie: I'm sure I could find that somewhere, I just thought if you happened to have it sticking there in one of your memory cells you could dump it for me.

Proebsting: Thirty plus years ago we grew from little tiny to quite big and where we were at what point, I don't recall.

Hendrie: While Vern is designing this, you're still doing some custom circuits of some sort, you can't remember exactly.

Proebsting: I don't recall.

Hendrie: Why don't you continue the story of Mostek's development.

Proebsting: As time went on.

Hendrie: Now are you still in P channel?

Proebsting: We're still in P channel.

Hendrie: And you had started off doing silicon gate, or metal gate?

Proebsting: Metal gate.

Hendrie: So do you have a silicon gate process?

Proebsting: Not yet. Mostek was late with silicon gate.

Hendrie: Early with depletion loads, late with silicon gate.

Proebsting: First with depletion loads, very late with silicon gate. Late with CMOS. A one transistor DRAM requires a sense amp that can sense a very small signal. You store a small charge on your storage capacitor, either a plus charge or a minus charge or a variable size plus charge or something. And there's a very large capacitance on the bit line. So as you transfer the charge from the memory cell to the bit line, the sense amp then has the task of sensing, did the bit line go up or down or what did it do, when it only went a little bit.

Hendrie: Because there are a lot of electrons on the sense line and there are very few in the capacitor sharing.

Proebsting: You're trying to put a lot of cells on the chip. So the cells are very small but the bit line is long, serving a lot of cells. So the bit line has a much higher capacitance than the cell, you'd like to have the reverse true, you'd like the cell to have more capacitance than the bit line.

Hendrie: But you can't get there.

Proebsting: But you can't even come close to getting there. The bit line has much much more capacitance, maybe twenty times the capacitance as a cell and so the bit line with twenty times the capacitance of the cell, you get a very small signal. Now you need a sense amp, many sense amps, one for each column, you need a sense amp to sense each column's result and correctly decide whether that capacitor had originally stored a high value or a low value. If you made that sense amp with hand-cut Rubylith there was no way you were going to get the L, the channel link of the transistors that were supposed to match each other. The L is just not going to match. The human can't do it accurately enough. So you're going to have mismatch in the L of those transistors.

Hendrie: On the sense amps.

Proebsting: On the sense amps. And the sense amps aren't going to be accurate enough to do the job of discriminating between a high and low. They're going to be biased. This sense amp is very biased toward reading a high, this sense amp is pretty good, this sense amp is very biased toward reading a low.

Hendrie: And your ability to adjust, they're going to all go up and whatever you do with voltages or whatever, they're all going to go up together.

Proebsting: You're just, out of luck. Then Calcomp came up with a special plotter to cut Rubylith in place of pens, they had knives and in place of a whatever the bed would be, was a solid granite that we had to reinforce the floor of the place where this thing was going to be put, for this slab of granite. I don't know, 10 by 12 feet or something like that, that weighed many many tons but now you had the computer precision driving the knife blade and although a human still peeled it, the space between the two cuts, was quite accurate. That piece of equipment came about between the introduction of the 1K DRAM which used three transistors and didn't have this problem and the one transistor cell 4K DRAM. It's what made possible the 4K DRAM, the one transistor cell DRAM. That piece of equipment is why all of a sudden, everybody who wanted to make DRAMs, who hadn't used the one transistor cell DRAM for their early stuff, now were willing to try to make a one transistor cell work. We think we can do it with the precision that the Calcomp plotter gives us. Ok, the one transistor cell DRAM, first introduced at the 4 kilobit level.

Hendrie: Nobody made a one, nobody bothered to go back and do a 1K?

Proebsting: I'm not aware of anybody who did a 1K.

Hendrie: You don't know of anybody?

Proebsting: I don't know of anybody who did it, and we could do 4K when this equipment became available, we could integrate that size chip. And why do a 1K if your competitor has a 4K, your 1K is not going to have any success in the market place.

Hendrie: Not going to have any market at all.

Proebsting: So I'm not aware of anybody who did it and if they did it, they had no success in the market place that we just discussed. OK, looking at the task of the one transistor cell, now none of us in the industry had ever done a one transistor cell DRAM. Didn't know just what the problems were. Start designing it and one of my biggest contributions to the DRAM was a recognition early in the project that you could not make use of the column address information. At the same time you made use of the row address information, you had to turn on a row first without yet turning on a column. If you turned on a column at the same time you were turning on a row, turning on the column would further attenuate the signal that you're getting on this bit line of the cell. And you don't have enough signal anyway. So you turn on the row, get the signal you need to move the bit line enough to sense it, then sense, which is a very slow operation. And after you've sensed far enough that you've separated bit and bit bar, by enough that no matter what noise you put on from addressing the column, you can't disturb what the decision that's already made, it's going to go this way.

Hendrie: The sense amp has gone over it's threshold and it's just on its way.

Proebsting: It's on it's way. Only then do you dare turn on the column. Well I recognized that the column address could come in after the row address on the same pins that the row address came in on. If the array as it was in the first 4K DRAMs, was a 64 by 64 array, 64 being two to the sixth, times 64, two to the sixth, is two to the twelfth 4K, you can save six address pins, called address multiplexing. And I was able to convince our, by this time then president, L. J. Sevin, that our circuit had enough advantages, there are several other advantages that we should talk about, over the industry standard circuit, the industry had agreed to make a 22-pin circuit, a new package, 400 mil, center to center, that is .4 inch between the rows of pins, eleven pins on each side, a 22-pin package, 100 mill spacing, a tenth of an inch spacing between each pin. And everybody used that package, except for a little start up, Mostek. Mostek introduced a 16-pin package. Well all of the huge advertising budgets of all of our competitors were saying why to use the 22-pin package. And our little baby budget was saying use the 16-pin package, and here's why. Well, we had enough advantages that the customers said "we desperately want a second source but we want the 16-pin package. If you company X, don't provide us with a 16-pin package, we're not going to buy from you." I had convinced L. J. Sevin to literally bet the company on the 16-pin winning the battle. In hindsight, it was stupid of me to be that egotistical and think that my circuit was that much better than the competitive circuits but it WAS in fact that much better than the competitive circuits, and it won. Now, I thought the biggest advantage of the 16-pin package was the page mode operation that it automatically afforded. You turned on a row with a command that I named RAS, row address strobe, you turn on the row with that command, then after you've held the row addresses for an appropriate time, you change to the column addresses on the same pins and then turn on column addresses strobe, CAS, and get the data out or put the data in to that intersection of the selected row and the selected column. Now, that permitted you to then go to a second column while the row was still open. The slow part of the circuit was opening the row, from column.

Hendrie: Getting the column, charging up and getting the sense amps, fired up and going.

Proebsting: That was the slow part. The fast part was after you've got a rail to rail signal in the sense amp, selecting this sense amp, getting that data out, select that sense amp a new column. Give it a new column address and give it a CAS, column address strobe signal, get the second signal out, the third signal, the fourth, the fifth, the sixth. And if you organize your computer such that all of this information under the same row is the same page of information that is, adjacent common information in the same subroutine of program or whatever. Then you get very fast subsequent accesses then finally you need a new unrelated piece of information, a slow row access and then fast column accesses for that. I thought that that was THE selling point that was going to make my circuit win. That wasn't used for ten years. Now it's indispensable, everybody fully makes use of it and modifications of it. But you open a row and go to multiple columns one way or another within that row, it's routinely done. But it took ten years before anybody was made use of it. Blew me away, we made use of it in testing, our bandwidth in testing was much improved just as the band width in operation was improved, you can test it faster. Whatever routine you're testing, took a lot less time. Now, the competitive circuits all had a very high capacitance input clock. Typically 150 picofarad, 12 volt clock. These clocks were made by the TTL integrated circuit companies and primarily the TTL integrated circuit companies that also made MOS memory.

Hendrie: Like TI and Intel for example?

Proebsting: Like TI and Intel for the prime two examples. And we feared, I feared that a TI or an Intel would package their parts as follows. You can buy this level converter to drive from a TTL control signal to the 12 volt clock that was needed, for an exorbitant $200, but you get 8 DRAMs with it free. Now Mostek trying to sell DRAMs in that environment, has a hard time selling a DRAM in that environment. So I didn’t want to put my customers in that position or my competitors in that phenomenally good for them position. I came up with the clock generator. Oh, this was NMOS, NMOS only.

Hendrie: You’ve switched now.

Proebsting: At this point it was NMOS, all of the first-generation 4 kilobit DRAMs were NMOS, I think they were all NMOS, ours was and most of them were. And I came up with a clock generator that consumed very little standby power but could convert the external TTL signal, driving just one small gate instead of driving all kinds of stuff all over the chip.

Hendrie: Instead of literally going on to a clock line and having hundreds of transistors all over the place.

Proebsting: All over the place, doing all kinds of things adding capacitance to that clock, my clock went into a simple MOS transistor, a single buffer that drove an output rail to rail but all the buffering was done on the chip. So that you could have a TTL-level input drive many of my circuits in parallel because they were only 5 pFs each. Whereas in the TI or Intel or other circuits, you had a clock buffer probably driving a single integrated circuit because that circuit presented a load of 150 picofarads so for each integrated circuit you had a driver and for Mostek’s, one driver, the amount of current required from that driver, the amount of current required, are switched by about 3 volts instead of 12, a factor of 4 or less, it was 5 picofarads instead of 150 picofarads, a factor of 30 less. So you could drive ours, 120 of our circuits in the same time you could drive one of their circuits.

Hendrie: So you figured out how to basically move the clock amplifier from an off and on the board, but off ram device and move it on to the chip?

Proebsting: Exactly. And my motivation was two fold. To help the user, but to not put us at Intel and TI’s mercy. They won’t sell somebody driver chips to use with the Mostek ram. I didn’t want that to happen. And so I came up with, I just said “Proebsting, figure out a way to do it”, and I did.

Hendrie: Figure out how to design a driver.

Proebsting: And I thought that was a very major advantage that my product had because the drivers were notoriously unreliable. They were made on a 5 volt bipolar process but outputting 12 volts.

Hendrie: They were?

Proebsting: Yeah. Outputting 12 volts from a 5 volt process.

Hendrie: Was this 4K that you designed with a multiplex, did it require, it still had a high voltage, it had a 12 volt supply?

Proebsting: Had a 12 volt supply.

Hendrie: Had a 12 volt supply and internally your sense amp, your driver amp would drive?

Proebsting: From zero volts to 12 volts. But do so from a control signal that had a TTL level. And the primary advantages that I though that my product had in this order, were page mode, you didn't need the driver, and finally a small package. The reasons it won in this order were a small package, the driver, page mode.

Hendrie: Just the other way around.

Proebsting: Absolutely the other way around. But the small package was so important to the users. I knew it was important, it was more important than I realized. And I got a real kick out of advertising, particularly Texas Instruments advertising of their product. They talk about their industry standard package. Now their industry standard package never existed before the 4K DRAM and was developed for the 4K DRAM. Nobody had equipment to insert it into a board or anything else. Brand new package but the industry standard 22-pin package versus Mostek's maverick.

Hendrie: Which is an industry standard form factor 16-pin package.

Proebsting: Everybody has all the equipment to plug in a 14 or 16-pin dual inline package. Everybody has that but our package was a maverick and theirs was the industry standard.

Hendrie: In their advertising, not in reality.

Proebsting: In their advertising. Well I think in reality we won, they lost.

Hendrie: Tell me a little bit about the timing of what you can remember of the timing of the introduction of 4K DRAMs, who was first was Intel, did the Intel part come out first or did TI come out first?

Proebsting: We were all within a few months of each other, of the important players, were all within a few months of each other.

Hendrie: So they all sort of probably got started reasonably around the same time?

Proebsting: I would think so.

Hendrie: You'd have to interview somebody in each company to find out when they really started.

Proebsting: And I'm guessing that it was more or less the start date was probably about the time we learned that we going to be able to get one of these Calcomp plotters that would carefully cut the Rubylith.

Hendrie: How did you end up getting the opportunity to design the 4K when you hadn't done, somebody else had the job of designing the 1K? Were you just available at the right time, what happened there?

Proebsting: I think you're putting me on the spot here, but I think that it was recognized that the 4K was a very tricky circuit, making a one transistor DRAM work, there were a lot of pitfalls.

Hendrie: So they wanted to put somebody they thought was their best, or one of their best?

Proebsting: I was hired as their lead designer and I think they.

Hendrie: You were hired as the lead circuit designer? So we better put our best foot forward.

Proebsting: And I think it required from the problems that some companies had getting a 4K, one transistor cell DRAM to work, there were pitfalls all along the way and many people fell into those traps. So I think Mostek wanted to take their best shot.

Hendrie: When you originally they asked you to do this, had you already thought up the multiplexing or you just knew --

Proebsting: Oh, no no.

Hendrie: Ok, I'm going to work on a 4K DRAM, single transistor. Now what do I do?

Proebsting: Correct, and as I got in to design it, it became clear that I couldn't turn on the column until well after I turned on the row. What the hell?

Hendrie: Turn this difficulty in terms of making timing, making it really go fast, turn it into an advantage.

Proebsting: Absolutely. And I sold L. J. Sevin our president, on this and we put a tremendous amount of our resources into this product. And if it had failed particularly in developing the process for the product, if it had failed, we might not have survived as a company. We literally bet the company on it and I convinced him, for some of the wrong reasons, of page mode being so good instead of size. I listed those three major advantages as well as some other minor advantages. But I was wrong about which was the most important advantage but I was certainly right about collectively the advantages made it win.

Hendrie: What were some of the issues in process development, what were some of the things you had to do, obviously as you said, developing the process was very expensive?

Proebsting: You had to make, well first of all it was NMOS and everything we had done up till then, had been PMOS.

Hendrie: Had to moved fab, Carrollton, to Texas yet?

Proebsting: I believe so, I'm pretty confident that we were already in Carrollton, Texas.

Hendrie: So the NMOS Fab is going to be in Texas, yes, you're not working with Sprague any more?

Proebsting: I believe that that's the case. We were still on very much a shoestring budget and could not afford to waste a whole lot of money, and if we put the resources into developing that product and it was failure, we could very well have failed as a company. And I give L. J. Sevin a tremendous amount of credit for having the guts to go with his engineer that he certainly accepted my inputs as being likely valid but he made a gutsy decision and I certainly made a gutsy decision to try to argue that this was what we should do. But the bottom line is, the customers accepted it, liked it, and we became the world leader in DRAMs, the biggest market in the industry.

Hendrie: And took it away from Intel and TI, which I guess I think probably were somehow were in a horserace?

Proebsting: And we clearly won the race, we clearly won the race. By the time the 16 kilobit DRAM came out, everybody used address multiplexing. To my knowledge, there was non-address multiplexed 16K. But, an interesting story I think. TI was doing a copy of our second 16K, our second 4K DRAM. The MK4027, our first one was the MK4096. A replacement, a silicon gate replacement for the MK4096.

Hendrie: I was going to say, why did you do two?

Proebsting: Ok, the reason was very simple. I designed a rotten sense amp on the MK4096. It was a poor conception, a poor implementation and the rest of it wasn't very good. It yielded very poorly and I had to fill out a paper form weekly about the schedule for what's going on in the 4096 and the schedule that I was filling out was meaningless because I didn't know how to design a better sense amp. I had put us in a bind. My sense amp consumed zero static power. All of the other guys had sense amps that consumed a lot of power, that was another big advantage of my product over the others. They consumed a lot of power, mine consumed zero power. But if I want to make a replacement part, the sense amp has to meet the spec of this first one, zero power. Well one weekend, at home, I figured out how to do this. Came up with a sense amp that's widely used to this day and went into Bob Palmer, head of circuit design at that time.

Hendrie: He'd moved from process?

Proebsting: He'd moved from process to circuit design, head of circuit design at Mostek, although all of his expertise was in process.

Hendrie: He was there because he was a good manager?

Proebsting: Yes. And I marched into his office the following Monday and told him I've got a sense amp that meets the requirements of zero power and will yield a hell of a lot better. "Start a project," was his response. No ifs, ands or buts about it, "you're on the project as of this minute." So I started designing the MK4027 a replacement for the 4096, a silicon gate product. Shortly after I started, Paul Schroeder joined the company and joined me on the project and he and I did it from there on together after I had come up with heart of it, the sense amp, he and I together implemented the rest of it. We had a third person doing some of our side work but the two people who contributed primarily to what the product is, were Paul and myself. And together we designed the circuit and it was, I'm trying to figure out, we were pretty confident that this design was far more advanced than any other design in the market. And we wanted to protect the design. We didn't want somebody to be able to copy it. So we built in circuitry to make it so that if they copied it, they'd have some problems. More specifically, they'd have a lousy yield. Our circuit would yield well and their exact copy, if somebody chose to do this, their exact copy would have a lousy yield. How do you that, how do you make an exact copy have a lousy yield? Oh, we stayed up nights trying to figure out how to do things like this.

Hendrie: We can change the tape and then we can discuss the details of how you did it.

Hendrie: You were telling us that you and Paul were worried about your second generation 4K RAM being copied and so maybe you could tell us?

Proebsting: Yes we...

Hendrie: What your solution to that problem was.

Proebsting: We wanted to penalize, this was before theSemiconductor Protection Act of 1988 that disallowed a direct copy of a circuit. So it was legal to make a direct copy. We thought our circuit was enough advanced that perhaps somebody would want to make a copy. What we didn't know was that there would be fifteen different companies that we knew of that had exact photocopies, and when I say an exact photocopy, there was a piece of poly silicon between two bond pads, didn't do any good, didn't do any harm, it just was an error in our database. That piece of polysilicon existed in all the copies.

Hendrie: So you could just look at it under a microscope, take the lid off and you could tell whether it was a copy?

Proebsting: Oh, it was very clear that it was identical in every respect except the logo, the Mostek logo was removed and the appropriate other logo was put in its place. But other than that, not a change in anything. Well, we never dreamed that there would be fifteen copies but we thought there was at least the possibility of a copy. And we wanted to penalize anybody who would copy our circuit. We developed it, we paid for it, we deserved the benefits of having, if it's a good circuit, our company deserves the benefits of having the best circuit. Ok. When you turn on a sense amplifier, you've got voltages are plotted vertically, you've got bit and bit bar and the sense amp has some of kind of an offset. You want it to be zero but in fact it's seldom real close to zero, it's some kind of an offset. So if you were to start sensing before you turn on the word line, before you have any signal, the sense amp has an offset that says I want to go this way, it starts sensing and it goes in this direction. Now, you turn on the word line and if the signal from the memory cell doesn't put you below this expanded offset, you're not going to work. The signal has to overcome the expanded offset. OK, if you design the circuit the way it looks, the sense amp is going to be too early before the word line turns on, you're going to start.

Hendrie: This is the way it looks after you have put in the special feature?

Proebsting: Yes, with the special, we called it a gotcha, with the gotcha if you design, if you copy the circuit what do you think you see. And for example if you're looking at a car from above the front left side, you can see perhaps the front right wheel, certainly the front left wheel and the rear left wheel, but you know in your heart there's a rear right wheel there. No, there wasn't the right wheel. What you know in your heart is going to happen, didn't happen. We had an active area that was basically a donut connected to a conductor line and a metal line that covered, a pad covering this donut and with a top-lit microscope, it looked just like there was a contact between the metal and the active. But there was no contact there, it was just an active region and a lack of active region with the metal over it. But you look at that and you see hills and valleys and the hills are in the right place, unless you have a side-lit microscope where you can distinguish between a valley and a mountain, you have no way to tell whether it's a valley or a mountain and very microscopes are side-lit. So you have a top-lit microscope, and it looks just like a contact. Just like all the other contacts on the circuit. So you put a contact there. Well that was a first phase of clock sensing, that was too early before the word line turned on. So you start doing this, then you turn on the word line, over power that, if you have a big enough signal to over power that, and it works. Or, it's developed too much signal, you don't over power that and it fails. OK, so 100% of the copies that we saw and I saw most of the competitive copies, had copied it the way we intended for it to be copied for the contact, did the sense, started the sensing early and with the sensing started early, their yield suffered greatly. Now this was a particularly nasty thing. If it just didn't work, you'd probably product engineer it and figure out why it didn't work and fix it. But a yield, much harder, yield problem, what fraction, what percentage of the circuits worked. When I was interviewing for a later job, one of the people on my interview schedule was the president of the new company I was interviewing for, and that was Don Brooks and he asked a good question. "Why should we pay relatively big bucks for a designer when other people can copy their work?" And I say "well I do my best to protect my company and make it so that people can't copy my work." "How can you do that?" I told him this story in a little more detail than here. And at the end, he says "I was in charge of DRAM production at Texas Instruments at that time, and we knew your yields better than you did," and Mostek knew TI yields better than TI did because we were across town from each other and we hired lots of their employees and they hired lots of our employees.

Hendrie: Do you remember exactly where you were?

Proebsting: So I told this story of how the DRAM, of how I had tried to protect my DRAM.

Hendrie: To Brooks, yes.

Proebsting: To Don Brooks, and after I finished, his response "I Don Brooks, was in charge, manager in charge of DRAM production at that time at Texas Instruments. We knew that our yields across the board on other products were better than Mostek's. We had a cleaner, clean room than Mostek had. But on that product, the DRAM, Mostek's yields were much better than ours. I had two meetings a day with my folks what progress they had made on getting the yields better. Clearly it could be done, Mostek was doing it. Why not, why can't you do it? Our lines as clean, or cleaner, Mostek does it, get the yields up." Then this big grin comes over his face and he says "I love it." And I got a job with them. But it was very clear, this was the first real feedback that I had, after I was leaving Mostek interviewing for that job, this was the first feedback that I had that it really, really worked. Theoretically it should have worked, but this was positive feedback, it DID work. And there were three people at Mostek who knew about that, Paul Schroeder, my co-designer, the head product engineer, and me. L. J. Sevin, the president of the company never had a clue about that. He might leave and go to another company.

Hendrie: It was as secret as the best secret is the one the fewest people know.

Proebsting: No need for anybody who didn't have a need to know, to know that, because anybody might leave, it's a very volatile work force and we didn't want somebody to leave and say by the way, did you know…

Hendrie: That's a wonderful story.

Proebsting: We had the same trap on our 16 kilobit circuit that followed. On that one, there were eighteen companies that we knew about who made exact photocopies of it. Eighteen. One of them, we count this as a company, a Russian copy that was brought in by one of the intelligence agencies, what can you tell us about the Russian state of the art based on this circuit? We obviously wouldn't have known about that, had that not been brought to us, and there may been others that we never knew about but for people to abandon their own design, and use an unknown design, ours was the fastest on the market, it was the smallest, it was the highest yielding for us. It was the lowest power and when you've got the smallest chip, cheapest to make and it's the best, when you're selling your Cadillac for Chevy prices and other people are trying to sell Chevy's and it costs them a Cadillac price to make it, it's tough to compete, so they copied. And we were egotistical enough to think that our design was in fact, enough better than the competitive designs that people might do that. It never occurred to us that so many people would do it but they did.

Hendrie: And it paid off, what you did.

Proebsting: What we did, paid off in spades.

Hendrie: What else can you tell me about the second generation 4K?

Proebsting: Okay.

Hendrie: Were there any particular problems with it, what were the hard things to overcome?

Proebsting: Well the first hard thing to overcome that I finally figured out one weekend, before the project started, the weekend preceding the start of the project, and causing the start of the project, was how to do a sense amp. That was zero power, and yet met all the other requirements, and would yield, which my first sense amp was zero power and didn't yield worth a flit.

Hendrie: Now what was the break through in the sense amp?

Proebsting: Okay. My first sense amp basically had a single bit line, not a split bit line, a single bit line. The whole 64 bits and it stored in an analog in a capacitor, it stored the voltage of the bit line before turning on the word line. Opened that circuit, disconnected that circuit, stored that voltage, then turned on the bit line, have a new voltage as a result of, turn on the word line, have a new voltage on the bit line and then compare the old voltage with the new voltage.

Hendrie: Sounds like a wonderful idea.

Proebsting: Seemed like it to me to but I would not recommend using it. And the 4027…

Hendrie: Where were the process variations that caused this to turn out to be not a high yielding approach?

Proebsting: Ok, as you misaligned one layer with respect to another, it would change the stray capacitance between a node, I don't even remember which node, and the original storage node storing the original voltage, and how much this line moved maybe rail to rail, and how much it capacitively coupled to this node, depended on physically how close it was, what the alignment of the two circuits were. As I said, it was an atrocious sense amp and it's one of the things in my career that I'm least proud of.

Hendrie: Even though it sounds like a very common-sense approach.

Proebsting: It seemed like a reasonable idea and it permitted a sense amp that was zero stand by power but that got me into a box because in order to replace the circuit with another circuit, I had to have a zero standby power sense amp.

Hendrie: So now what was your weekend break through idea that solved that problem?

Proebsting: An existing sense amp that was developed years earlier at Shell Oil Development Company by either Christianson or Walstrom, I'm not sure which, together they developed the idea of the one transistor DRAM memory cell and the sense amp that I'm about to describe.

Hendrie: They did that before the.

Proebsting: Way back in the '60's. Long before there was any technology available to make the transistors matched enough for it to work. They didn't have, they weren't doing product development, they were a think tank, generating patents. And one of them developed the one transistor cell, his colleague developed the sense amp that I'm about to describe. You split the bit line in half, which is universally done today, bit bar, and then a cross-coupled pair of NMOS transistors and the cross-coupled pair of NMOS transistors, the sources are connected together, the gate of this transistor goes to this bit line and to the drain of the other bit line. The gate of this transistor goes to this drain and this bit line, so the cross-coupled, the two gates are connected to the opposite drains and the sources are connected together. Okay.

Hendrie: It's a flip flop?

Proebsting: It's half a flip flop.

Hendrie: It wants to be a flip flop.

Proebsting: And you start bit and bit bar, both at VDD. Then you pull down slowly, ever slow slowly, and let's say you've got 100 millivolts of differential signal between bit and bit bar. You pull the source down, I'm going to make this ridiculous, but easy. You've got a 1 volt threshold voltage and bit is at 12 volts and bit bar is at 11.9 volts. You pull and there's no body affect, the threshold is exactly 1 volt. You pull the source down to 10.9 volts. One of these two transistors is on, and one is off. The one whose gate is at the higher voltage, is on. His drain is at the lower voltage but he's on, pulling the drain down. The other one is off. And as you pull the one down, you can pull the source down and get this one to go in an exponentially increasing fashion, pull it to ground. And the other one's still high. That took an excruciatingly long time. The invention, the idea that I had that Paul and I, Paul Schroeder and I, engineered, was putting a resistor in the form of an NMOS transistor, remember these were NMOS circuits, a resistor between the cross-coupled, you have the cross-coupled nodes, then a resistor to the bit lines. Now as you pull down, the resistor lets you develop a voltage between the bit line and the drain, so the sensing can go much faster. And as you pull this node all the way to ground, the NMOS transistor who's gate is at a fixed high voltage about VDD, becomes a fairly low resistance. It was a fairly high resistance when the sources were up near VDD but when the sources are down, when you're finishing your sensing, that resistor is a fairly low and you've got a high current going through the sense amp and the resistor so you can sense much much more quickly, with those resistors in there. So my idea was put the resistors in, add those resistors to an existing cross-coupled flip flop, start the bit lines at VDD and pull down in a very carefully engineered way, and pull the high one down, I'm sorry, the low one down, and leave the high one alone or at least don't pull the high one down more than 1VT. And since you're only going to turn the word line on at that time, to VDD, not a bootstrapped voltage, the highest that you can write the memory cell is VDD minus VT, so it doesn't really matter if the bit line has come down by up to 1VT. As long as it doesn't come down by more than 1VT. So that was the sense amp idea that I had without any computer simulation It was clear, this is going to work. I mean, just back on the envelope calculations, this is going to work. I marched into Bob Palmers office, told him I had a sense amp that can replace the disaster that we've got right now and started a project.

Hendrie: Because we need to crank the yield up on these.

Proebsting: Absolutely, the one yielded very poorly and we need to crank the yield up. The new circuit from the get go, yielded better than the old circuit had ever yielded. And was just, it was my second DRAM, Paul Schroeder's second DRAM.

Hendrie: He had done one before?

Proebsting: He had done some work on a DRAM at Bell Labs in his previous employment.

Hendrie: He came from Bell Labs, ok.

Proebsting: And so you learn stuff, you've never done it before, you learn A, from your mistakes, like my sense amp and B, from your successes. And so I did the, with the new sense amp, we had the heart of the circuit and using both Paul's and my ideas that we had learned and this is not a good idea and that is a good idea, just the whole circuit, was better engineered than my first circuit. You'd expect 2nd circuit to be better engineered. And when you've got a second engineer with some additional fresh ideas, it just improves the chance. So it had that sense amp that absolutely worked like a champ. That circuit had one unusual feature, it didn't really have anything you could point to and say here's the column decoder. It had a decoder, the decoder was at the end of the rows, here's the physical decoder, here are the memory arrays, and the decoder has outputs, word lines, that goes through the memory array to activate the cells. When you turn on this word line, it activates all of these cells and transfers the charge from each of them onto it's respective bit line. A column decoder was the row decoder used all over again. Remember we're multiplexing the addresses. The addressed come in on the same pins, go in to the same input buffers and then go to the same decoder. And the column is routed through the array up to the appropriate. So the same physical decoder, now you talk about saving some area. No column decoder.

Hendrie: Well that's really clever.

Proebsting: Paul and I were discussing this late one Friday afternoon, how to come up with this idea together, and both of us wondering if we had lost our marbles. And both of us came in the following Monday, ready to fight to the death if the other didn't want to do it.

Hendrie: Is that right, you thought about it all weekend?

Proebsting: Both of us had thought about it all weekend and just "there's nothing that can go wrong. It's a safe idea." And it's very area savings, it's just a good idea, maverick though it maybe, what the heck. So it had a single decoder for both row and column. The 4027 lived a nice healthy life, healthier for us than for any of our competitors but lived a nice healthy life and I had heard that our 4027, we were the world's largest volume of DRAMS, our 4027 along with all the copies of the 4027 accounted for over 97% of the market for 4K DRAMS and all other designs combined for less than 3%. I mean it was widely copied, it was not just copied by little guys who didn't have a design team.

Hendrie: Because it was so obviously what the customer wanted?

Proebsting: Well it was what they wanted but it was by far the smallest die, cheapest to make, it was the fastest, it had the fastest speed spec, it was the least power consumption.

Hendrie: What's there not to like?

Proebsting: When you've got the fastest, lowest power, cheapest, an otherwise not bad part, it doesn't take a mental giant to figure out this is hard to compete against. Our 16K was a copy of the 4027.

Hendrie: Why don't we go back. Let's stop, is there more things in the history of the 4027 that you want to cover?

Proebsting: Perhaps one. The 4027, I was at an International Solid State Circuit Conference, ISSCC, and one of the people, I was on an evening panel and one of the people on the panel with me was the president of Mosaid, a reverse engineering company, who had sold the design and reverse engineered the MK4027 and sold the design to probably all of the copiers world wide, maybe with the exception of Russia but had sold the copy, the way, what it is, how it works and all it's schematics and everything, what it was. And he mentioned to me that the timing of the sense amp seems a little early. And I responded "it seems to work alright." I knew his was early and I knew ours wasn't early but seems to work alright and then he and I were again, the evening panel all the participants of the panel get together before the panel and just talk. He and I were on another evening panel some years later and he was talking about how they knew about this gotcha in the circuit that it was clever but never fooled them. Interesting, all the copies that you helped make, had that problem and earlier you thought the timing was a little early, you did recognize that, but you certainly didn't say only if you followed the mistake that we would like you to follow. So that bought us a lot of mileage, we put exactly the same gotcha on the MK4116, the 16 kilobit DRAM, that was almost entirely a copy of the 4027, the differences, we had a new technology that gave us a much more compact memory cell and that more compact memory cell did not have the rooms in it to run the column decode information as we talked about. So it had to have a separate column decoder, the column decoder had to be in the middle of the bit lines near the sense amp. And we very carefully put three address bits above the sense amp or either A0 or A0 bar was going to transition, putting noise on this and A1 or A1 bar or A2 or A2 bar, exactly three of these wires were going to transition high. Down below A4 or A4 bar, A5, or A5 bar, or A6 or A6 bar. Now A7, well actually it was A0 but from my example, A7 was used to pick between adjoining pairs. So we had two pairs of I/O lines because we didn't want an odd number of lines, four lines, going up here, A0,1,2 bar and 3 and 3 going up here. We wanted equal noise on both. We wanted to disturb both of them in the same way. And so we had two I/O lines, even though the part was a by one organization, at the periphery we decided, use this one or use this one. Write this one, or write this one, read this one or read this one. Fairly straight forward, so we used an even number of the addresses so there could be an equal number above and below the.

Hendrie: So the noise would be equal and hopefully cancel out.

Proebsting: Yes.

Hendrie: Very good, that was clever.

Proebsting: So we were both very nervous, Paul and I were both very nervous about putting those full transition signals in that close a proximity to the sense amp. But, in both of our judgment, it would work. Obviously if the size of this wire crossing this wire is the same as this size of this wire crossing this wire, it's going to work just fine. But what the concern is, is this wire might be a little fat and this one a little thin. And just how much of that might there be. Well it turned out that whatever of that there was, was a very acceptable amount because the product, like the 4027 preceding it, worked beautifully.

Hendrie: Did you start the 16K bit RAM as soon as you'd finished the 4K or did you do something else in between?

Proebsting: There was some delay and both Paul and I were frustrated about the delay the corporate decisions that I would like to have started sooner.

Hendrie: L. J. was still in charge.

Proebsting: L. J. was still in charge but our 4027 was doing so spectacularly, I think he didn't want to jump the gun with the next one and frankly, it gave our competitors time to spend the money on their development of a 16K and then we came out a little bit late with our 16K but it was so much better, that everybody abandoned their own. Now eighteen companies that we knew about made photocopies of our circuit. So they all, those that came out earlier, abandoned what they did and copied what we did.

Hendrie: Which is wonderful, they spent all that money.

Proebsting: With the same timing problem they had on the 4027.

Hendrie: And the same resulting yield problems.

Proebsting: Same resulting yield problems and we laughed all the way to the bank.

Hendrie: Did you work on anything in between this?

Proebsting: Well the 4116, the 16K, Paul took primary responsibility for that as I was supporting product engineering on the 4027.

Hendrie: Which obviously can be, if you're in a high–volume production, there's a lot to do?

Proebsting: The only thing that really differed on the 4116 from the 4027, was the row decoder and I helped Paul with that. And the implementation of the rest of it, was our own copy of our own previous work.

Hendrie: What innovations were necessary in the single transistor cell to move from the 4K to the 16K?

Proebsting: Okay. Our 4K, let's go from our silicon gate, 4K, the 4027, the second one, to our copy of that circuit, the 16K. As I mentioned, we no longer had the ability to route the column decode through because the cell was much smaller. Above and beyond the amount smaller that it would be just from a increase in time and finer geometries. The 4116 had a transistor, here's a polysilicon gate of a transistor and here is a polysilicon capacitor that is adjacent to the transistor. The 4027 had a transistor then an active area, then another transistor on the same layer of polysilicon as the storage capacitor. Its storage capacitor was the N channel region of an MOS transistor whose gate was tied to VDD. So, here's a gate, here's a space, here's a gate, 4027. Here's a gate, no space, here's the capacitor, 4116, 16K.

Hendrie: So you actively put in a capacitor rather than just using?

Proebsting: The transistor that existed.

Hendrie: And so, by definition, it's going to make it a little smaller and also you've got more electrons to deal with?

Proebsting: I had, when I started the 4027, the second generation 4K, obviously I had never done a silicon gate process before and when I went to Bob Palmer, and told him I have a sense amp and he said start the project, he asked can it be silicon gate. And I answered something like I don't know, I'll check on it. At which point it was officially a silicon gate project. I didn't know if there was going to be any problem with silicon gate, it turned out it was actually a little easier to use, but not yet having any experience with it, I didn't know that. So I hedged and said "let me get back to you on that." From that day forward it was a silicon gate project which turned out to be just fine, actually easier to design with.

Hendrie: Why don't we change tapes now.

Proebsting: Good.

Hendrie: Alright, we're back on.

Proebsting: Okay good. So, the project was silicon gate, it turned out to be no trouble at all to design with silicon gate. You actually had an extra layer of interconnect which made things a little easier instead of using your metal interconnect layer as also the gate layer, the silicon was a gate layer and the extra layer of interconnect was very beneficial.

Hendrie: Yes.

Proebsting: This two products, the 4027 and the 4116, were incredibly successful products. After the 4116, my role and I continued in this role with any of my later employers, became not a circuit designer doing, having responsibility for a given design but rather more like a fellow, in fact, later at Mostek I was a fellow, a roving resource to help any of the designers with their particularly sticky design problems. Rather than carrying out my own design. They wanted to share my ideas over a wider range of product than have my ideas only in one particular product that I worked on for a year or two and then another particular product that I worked on the next year or two. So, the 4027 was the last product that I was the lead designer on and heavy duty responsibility for all aspects of the project, beyond that I was primarily a resource for all the other designers to tap into my idea bank, whether it was things that I have.

Hendrie: Expertise, your knowledge.

Proebsting: My knowledge. My knowledge as well as problem solving. I have about a hundred patents that have issued and many of them a colleague would come with a problem, "I've got a problem, how can I do this?" And perhaps I've seen it before, solved it before or seen the solution before and pulled it out of my bag of tricks. Or perhaps came up with the solution that was not particularly innovative or perhaps I came up with an innovative solution that deserved going after a pattern for. So, the 4027 was the last circuit that I was really the lead designer on. Now with, well I'll have to take back. One exception. Now this was after Mostek, and I was at Fairchild, that was primarily an ECL company.

Hendrie: Can we hold that till we get to Fairchild?

Proebsting: You betcha.

Hendrie: I think that's what we ought to do. You had mentioned before when we were talking about preventing items to be copied, that an earlier project that you had worked on at Mostek for a calculator chip had some, that you'd applied those ideas even before the 4K ram. Can you tell us about that?

Proebsting: I certainly can. Mostek did the first calculator on a chip, one chip calculator. Now as I mentioned earlier, I'm not a logic person and not being a logic person, I was not involved in that project at all. Except that I certainly knew the engineers involved in the project and we had bull sessions together and we feared that there was the possibility that somebody would copy the work. Can we make it so that they'll regret copying it? And the answer was yes we can. This actually preceded the DRAM. The gotcha on the DRAM. And this was a custom circuit for an oriental company and after we had been providing the circuit for six or eight months, I don't know the exact timing, they came back to us and said "we've got to lower our price, they've got an alternate source for the product." And our response was, we don't believe they can sell for that price if they spent the development money that we had to spend to develop the circuit. And if they copied ours, they'd probably made mistakes in copying it. Oh no, the circuit works just fine. Well be warned, there is a possibility the circuit does not just work fine if in fact they developed the circuit by copying ours. We've tested the circuit, it works fine. If you want to sell to us, you've got to lower the price. Ok, so we instructed our sales people out in the field at the various cities to go to the various department stores that sold that brand of calculator and check a particular problem. Two plus three equals. And see if it will handle that problem. Sure enough eventually the sales people start calling in, I've got calculators here that don't handle two plus three. So, we call our customers back, ask them to come back in think that they would like, be in their interest to and bring some of their present calculators. They do, they bring the calculators. "Have you tried two plus three equals?" "No problem, two plus three. My computer went blank, my calculator went blank. So did mine. Oh my God, we can't sell calculators that don't do that. How soon can we get some more chips?" "Well you know that price and we've stock piled them for you."

Hendrie: Thinking you might be back.

Proebsting: Thinking you might be back. The method that we used to do that. There was an active region that had a donut at the top, square area with a square hole in the middle and then a lead coming off and a metal line covering that square middle hole. And from a top-view microscope, a top-lit microscope, a valley and a hill look identical, if you're light is coming from the top, you can't tell. A binocular scope basically, you cannot tell. Well even the binocular scope, you cannot tell a hill from a valley. And so it in the middle of this "contact region" it's actually a hill, if it were a contact, it would be a valley. But you look at it from the top like everybody does and they look the same. And you know in your heart that this active region with this metal around it is a contact. So you put a contact there. Now starting again from a different tact, if you have a depletion load which we were using at that time, if you have a depletion load, you've got the gate tied back to the source, a transistor that's always on, always trying to pull up and then an enhancement pull bound transistor that over powers this load to pull the output down when you want it low and when the gate of the pull down device is low, the big transistor at the bottom is off, the little depletion load pulls the output up. It's just a simple inverter. If for some stupid reason you made the depletion transistor, the top transistor with the gate tied to the source, if that were enhancement, it would always be off. And if the bottom one were depletion, it would always be on. On our circuit we had such an inverter. A enhancement on the top, a depletion on the bottom. So the output was always low. But if you made it the way you knew it had to be, the top with depletion, the bottom one enhancement.

Hendrie: Of course you can't see through with the microscope whether it's enhancement or depletion?

Proebsting: There's no way, it's very difficult to look at the die and tell if it takes, in fact I'm not sure even any product was available then to distinguish. Today you can distinguish the very light doping difference but I don't think back then you could even distinguish it.

Hendrie: They have no idea.

Proebsting: No clue.

Hendrie: They're going to assume it's what?

Proebsting: They're going to assume it's a depletion load and enhancement transistor. Well there's a little logic that looks for the sequence of key strokes specifically two plus three equals. And if it gets that sequence of keys, then it takes the gate of that transistor the enhancement transistor, to ground, the drain goes up to VDD and that activates the power on reset circuit. So you clear everything in the calculator but on our circuit of course, the drain never went up. Because the result, because the drain was pulled up by a non existent load, an enhancement with gate tied to source and the pull down was always on because it was a big depletion. So ours, you never got that low voltage, I'm sorry, the high voltage out of this inverter, I say inverter, this thing.

Hendrie: This circuit that looked like an inverter.

Proebsting: This circuit that looked like an inverter and was copied as an inverter. And so, on the copy, two plus three equals cleared, turned on, the power on reset circuit. We did all the things that you do when you first turn on the power, cleared all the registers throughout the calculator. Ok. So, they realized they'd been had and ask "how soon can we get more?" "Well we thought you'd be back, we've got them stock piled, you know the price." So they bought more. And we said, "be very careful, we recommend that you don't use an A… don't use a copy again." Six months later being slow to learn, they come back to us, same story all over again. We instruct our people in the field, look for two plus three equals to work but look for this to fail. Sure enough, problem number two failing shows up. Six months later or whenever. And we invite them back. "We think you'll want to talk to us. Have you tried?" I don't even remember what the second problem was. "But have you tried this?" "Oh no." They assured us they had found every mistake. Well indeed we had only one mistake that worked by the depletion enhancement reversal. The others worked in totally different ways. One of them was a contact that wasn't like I just described through DRAM. They worked in a variety of different methods of operation. And one of the things that I'll never forget as long as I live, their, I think, president, I'm not sure who it was, but one of the high level officials of the company, asked out head of marketing, Barry Cash, "how many of those," I don't know what he called them, problems, traps whatever his word was, gotcha's, "how many of those gotcha's did you put in that circuit?" And his response, "enough." Enough. Well, they had found exactly the one problem that had been pointed out originally and of course they knew where to look, in the power on reset circuit. And they probably would have found the one problem in the second one that we showed them, probably. But we had thirteen different problems in that circuit, thirteen different mistakes that they could make and from our test of the first circuit, they made all thirteen mistakes. I mean they copied them the way we intended to have them copied and they all worked differently. So when they looked at it, they were looking for circuits that failed the depletion enhancement test somehow. But that was the only circuit that worked that way. So they didn't find any of the others and if they had taken the engineering time, to thoroughly check out the circuit to see if everything made sense, then they'd have spent as much money as we spent developing the circuit. They were trying to do it on the cheap and they cost their customer dearly getting back product to market, that's got to be embarrassing. Especially when you do it twice. So we enjoyed that and we spent, we got together evenings and discussed how can we build in a trap that won't be seen, and we'll get away with. And some way-out ideas, some pretty straight forward ideas but we used them all and we got our price and were able to recoup our engineering costs which would not have happened.

Hendrie: If you hadn't done that.

Proebsting: If we hadn't done that.

Hendrie: That's great. That's a wonderful story.

Proebsting: Good.

Hendrie: Let's move on to your acting as a technical senior, guru consultant as opposed to doing individual projects now at Mostek. Let's continue the story as to what happens next.

Proebsting: Nothing.

Hendrie: Do we know what year it is yet?

Proebsting: Gosh, this is more or less after the completion, I was involved with Paul Schroeder on the 16K DRAM which was introduced in about 1977 I'd say, give or take a year. And so I was pretty heavily involved with him there as well as in some cases, things that in helping product engineering with the 4027 became clear, we can improve the 4116 with such and such a change.

Hendrie: Before it even goes into production.

Proebsting: Learning from a detailed look at what happened with the 4027 and the 4K. So I was really heavily involved either with the product engineering help on the 4027 or the design of the 4116 through the completion of the 4116 and then on it's completion for a while, pretty busy with helping product engineer it. So probably about '78, is when my role largely changed and I would at that time, literally spend an hour with one engineer, a half day with another engineer, nothing particularly stands out. On one occasion, I was having a shoot the breeze session with Dennis Wilson, a DRAM designer, and we were talking about the bit line equilibration and sense amp and all of the DRAM, and together that afternoon we came up with the idea of, very today universally used idea, of equilibrating the bit lines to one half VDD. Now, this saves half the power in the DRAM. If you equilibrate the bit lines to VDD, then when you sense, am I out of the picture?

Hendrie: No, you're fine.

Proebsting: When you sense, you pull one of the bit lines all the way down, then when you got back into precharge, you pull that bit line all the way back up. And it takes the Q of C delta V, the capacitance of the bit lines, times moving it from ground to VDD. If instead you start them both at one half VDD, you sense you pull of them to ground, the other to VDD, now you're using at this point, half of the power you used to pull before to pull one up because you're pulling it from half way up to all the way up instead of from ground to all the way up. So you're using half the power from VDD. Then an equilibrate, you simply share the charge between bit and bit bar, it doesn't take any charge from VDD to do that, you're connecting them together with the shorting transistor between bit and bit bar bringing them both to one half VDD. And now you're ready to start the cycle again. Use half the power here and then no power here. Now a second item with respect to the advantage of this, the earlier circuits where you started the bit lines at VDD, and you're cell is either at VDD or at ground. If it's at VDD, and you turn on the word line, you don't get any transfer of charge, the cell is at VDD, the bit line is at VDD and you still have no differential signal. To overcome that somebody, I'm not sure who, might have been Wilstrom or Christianson, came up with the idea of a dummy cell. If we pick any cell on this half of the bit line, we will choose the dummy cell on this half and the dummy cell, one way to make it, there are a few, is to make it a half-size capacitor at ground. So it's going to pull this node down half as much as a full size capacitor at ground will pull this down. But if this is a VDD, it won't pull it down at all. So now we've got a guaranteed differential signal. If the real cell either leaves the bit line alone or pulls it down by a hundred millivolts, we engineer it so the dummy cell pulls the other side down by fifty millivolts and we've got a signal in one polarity or the other. So all of the DRAMS, expect my original 4096 that didn't have a split bit line and had other disastrous problems, all of the split bit line memory cells had a dummy cell. When we introduced the circuit without the dummy cell, where you equilibrate to one half VDD, now the cell is at, let's say it was a 5 volt circuit, the cells are either ground or 5 volts and the bit lines are equilibrated to 2.5 volts, we don't care if it's 2.4 or 2.6, just so they're equilibrated to the same voltage one as the other because we're going to compare them differentially. And you either bring this one up or bring this one down or if a memory cell is on this bit line, you bring this one down or this one up. A logic one, if written into a cell on this side brings this up, when you sense you get this. A logic one written into this side, brings this down. When you sense, you get the same result. Now there were people who didn't recognize that and actually inverted twice so that a logic one on this side, was a one, was a high and on this side was a high. So they had to invert going in and then invert again coming back out again. But if you look at what's going on.

Hendrie: You think about it a little more carefully.

Proebsting: You just simply independent, you don't pay any attention to it, is the cell on this half the bit line, or this half the bit line. You say I'm riding a high therefore I'm taking this bit line high and this one low. And either I'm riding this cell high or I'm riding this cell low for a logic one. Then when I sense, either I pull this down and sense from there, or I pull this up and sense from there and I've got the same thing that I started with without problems. So in virtually all modern DRAMS, half the cells are high voltage stored in the cell, I'm sorry, a logic one stored in half the cells, is a high voltage and a logic one stored in the other half of the cells, is a low voltage. Now, when Dennis Wilson and I came up with the equilibrate the bit line, the one half VDD, that eliminated the need for the dummy cell because now your cell can pull up or down. It also cut the power in half. Now we did this before we had CMOS]. If you have CMOS, it's trivial to pull the high one up and the low one down. A crossed couple then MOS pair can pull a low one down. The same crossed coupled PMOS pair can pull the high one up. So you do both and you've gone from a little differential signal near one half VDD to rail to rail. When you had NMOS only, you had to pull the low one down, that was still easy to do. But you had to pull the high one up. There are some very awkward circuits that do that and one of ours was we suggested an awkward circuit that takes a lot of transistors and a lot area and not very practical but it was a circuit that would work and shortly after we came up with that concept, we had CMOS available to us at Mostek and so our lousy method, well it may have been the best method that could be done but it was very limited by the technology of having NMOS only. Actually I think it was a pretty good way to do it with NMOS but so much better with CMOS just a simple cross coupled pair. So one of my many,many private conversations with individual engineers on design circuits, happened to result in that pattern. The equilibration, the one half VDD that Dennis and I co-inventors of and that is universally used today. The resistors between the sense amp and the bit lines, are universally used today but not only for the original reason, they're needed for yet another reason. Typically, a sense amp is going between these two bit lines or these two bit lines. This sense amp is serving if this array is activated, these two bit lines or if this array is activated, these two bit lines. Now you need to some way to attach or detach them from the ones that are connected and non connected. That requires these access transistors. They're doing the same job as my resistors plus they're doing another very necessary job selection of the left or the right but they still get the benefit that my resistors afforded. They are doing the resistance job as they're also doing the selection job. So they would be there today for the selection job were they not needed for the resistor but they made such a benefit for the resistor and of course again having those resistors there in the 4027 that was copied throughout the industry and then the 4116 that was copied throughout the industry, everybody knew about the existence of the those resistors.

Hendrie: This is how you do it.

Proebsting: This is how you do it. So it became a standard way of doing it.

Hendrie: Well now, how long did you stay at Mostek?

Proebsting: Mostek was purchased about 1980 I think and the new company put in a president with no semiconductor experience.

Henrie: What was the company, was it Thompson?

Proebsting: No. United Technologies. Put in a president who had no experience with semiconductors. He had been in a company that turned around and then he was with us a second, United Technologies sub, private owned company, United Technologies own company, that had turned around and then went to the second one that turned around. Now I don't know if either of them turned around because of what he did or in spite of what he did but he was a corporate hero. And Mostek in 1980 as all semiconductor companies, was hurting some. And so he came in and brought in with him a complete new set of high level characters. None of whom had any semiconductor experience, none. And they in their wisdom came up with a plan that we won't do a circuit that has any risk with it. OK. Every circuit that we had done that made us what we were, had risk associated with it. We vet the company on the address multiplexer, paid off big time but there was certainly risk there. So you don't do any circuit that has risk and it means you're only doing commodity type circuits where there's no profit margin at all. And you certainly would not have introduced the depletion load.

Hendrie: Might be something wrong with this. Don't do it.

Proebsting: Exactly. I had a technique for making a very, very large read only memory. Used only six mask steps total and could be about four times the density of any existing read-only memory. Very slow. But four times the density of any read-only memory therefore very cheap. Had error correction on it so you could have individual bad bits and have it still work and as I said, phenomenally dense. It was the intersection, here's a bunch of active areas and here's a bunch of or-ed lines. That was the memory cell and the transistor had a high threshold or a low threshold. That was it. But the whole bunch of transistors were in series so you had a very low sense current so it was very slow. Went to two local customers, Mostek certainly couldn't afford to send me out of town to visit with a customer, went to two local Dallas customers. One of whom made typewriters and were very interested in the product because they could make a spelling checker for their typewriter but they too were hurting and couldn't afford the development cost. The other company made portable electronic equipment and was very interested in a language translator where you type in one word in English and get out a word in German or whatever. They were very interested but they were also hurting. It was a time when the electronics industry in general was hurting. There was a recession. So they wouldn't fund it. Final disposition of the product, well we certainly don't do it, nobody's willing to fund it. Checked with two people both wanted it but wouldn't fund it and there's no guarantee that anybody will buy it and there's certainly no guarantee there's a market for a slow RAM. Nobody makes one so we don't know there's a market for that. Too much risk, don't do it.

Hendrie: You can't make anything that might be new innovative and open a new market.

Proebsting: Absolutely not. So the products that we had, L. J. left. This was after L. J. left. It was acquired and L. J. agreed to stay on for a year things were fine for a year, then L. J. left and this new crew came. Well then Paul Throw[ph] was there for a while, things were fine while he was there. He had a hard time making decisions. And then they brought in their crew and their crew with this philosophy was a complete disaster. In addition to all the other things, the president did not want to hear bad news. And so pretty soon, you found out that if you give him bad news, 'oh I saw your wife hit by a car," he's mad at you. OK, don't tell him about his wife begin hit by a car or anything else that's bad news. So he was in the dark. If anybody called United Technologies to tell them what was going on, it came right back to our president, George Jones called and said this was going on. George Jones, you're the hell out of here. I mean you talk about a combination of things. Well, if you were up to nine thousand employees, what do you think is the lowest number of employees, and now we're to the point where all of the mature products on the decline. What is the lowest number of people that you might have in, it was less than a year, let's say a year. How far down could you go from nine thousand to what in one year? Five hundred.

Hendrie: Oh my goodness.

Proebsting: I mean this was a complete recipe for disaster. This was not a let's play with if we can have disaster. When we had lost all of the circuit design and process team, is when I exited. It was my baby, I didn't want to leave but here I'm watching people who were hired because of circuits that I helped design, people that were hired because of me and now being laid off by the thousands. I finally couldn't take it and left. So that was very tough for all of us who were still there from the beginning.

Hendrie: When did you leave?

Proebsting: ’85.

Hendrie: So what happens next in your career?

Proebsting: Okay. The next notable thing.

Hendrie: Did you retire to the beach, a little bi?

Proebsting: No.

Hendrie: Well your stocks certainly had been worth a lot if you’d not just kept it all.

Proebsting: If you sold it along the way because you started out relatively poor, you didn’t do near as well as if you have the where with all to keep it till the end when it went way the hell up. Before it was sold at the by out of United Technologies, its high had been 22 I believe and we sold it for 62. So if you were able to keep it till the ‘60’s. If you had sold virtually all of your original founders stock and what you had left was stock option and if the option was at 15, you did a lot more than twice as good by waiting two or three months for it to go from 22 to 62. So, no I didn’t have a vacation. At Fairchild, I was, as I had been my last years at Mostek, a resource.

Hendrie: Did you look anywhere else besides Fairchild or just decided to go talk to people you knew at Fairchild?

Proebsting: Some of my colleagues had gone to Fairchild and they were in a beautiful part of Washington State, Puyallup.

Hendrie: This is not the Fairchild down in the Valley?

Proebsting: No, same company but a branch that they built in the sticks in Washington State. Beautiful countryside, gorgeous. It turns out that the gorgeous countryside is a result of the incessant rain. It makes everything lush. Everything was lush. Well my wife turned out to be allergic to mould and mildew. A lot of rain and mould and mildew are not compatible. So after two years I investigated, I had done some consulting for a group that made the Clipper microprocessor circuit.

Hendrie: We need to change the tape.

Hendrie: Yes you talking about, you had helped the people doing the Clipper at Fairchild.

Proebsting: At Fairchild, I helped the people doing the Clipper and they wanted me to move to their division and by Fairchild's rules, if the group that wants, that you've been working for wants you, and another group wants you, it's your choice. And the group at Clipper wanted me and that would get me away from the mould and mildew. And at the same time, I was concerned about the possibility of Fairchild closing that plant. They absolutely guaranteed me that it would never happen, six months later it did, but that they might close that plant and I wanted both to accommodate my wife's allergy as well as not have the risk, I'm now in Silicon Valley, where if something happens I've got a large number of job opportunities. Ok. So I joined the Clipper group and that got me to Silicon Valley. On the Clipper group, I did, I designed cache memory to go in the embedded Clipper chip. And shortly after I joined the Clipper group, Fairchild was bought by National, and the papers were already signed that are really only customer for the Clipper chip Intergrath, who desperately wanted to continue a source of the Clipper chips would buy the Clipper division of Fairchild. So I never went to National, I was never an employee of National, the moment the papers were signed for National to buy Fairchild, simultaneously with that, already signed papers had Intergrath the owner of the Clipper group. So I was with the Clipper group for the remainder of my time at Fairchild where I was just simply designing routine cache memory. Prior to that, while I was still at Fairchild, still in Puyallup, I was at a product opportunities meeting, and recall that Fairchild is primarily an ECL company.

Hendrie: Certainly that's the most successful.

Proebsting: ECL, somewhere that they're one of the leaders and they with Motorola and TI, I'm not sure in what order are the leaders in ECL, and ECL of course is a much faster technology than TTL which of course is a much faster technology than CMOS. OK. And there is this product opportunities meeting that somehow I'm invited to, and I find out about this synchronous SRAM. ECL SRAM, with very fast speed specs, that the company is going to decline to bid on saying they can't do it. Can't meet the speed specs.

Hendrie: And who wants this, who's the potential customer?

Proebsting: It was either Cray or CDC. A cache memory for a super-computer. I think it was Cray but my memory is failing me here. I'll use the words Cray as though that's correct, it might be wrong. And my response was "wait a minute, don't turn that down yet, let me see if we can do that with CMOS." Well this raised the roof with hysterics. Okay, I mean there was great deal of laughter in the room.

Hendrie: Really?

Proebsting: Yes. And I said Okay.

Hendrie: These ECL bigots didn't think much of CMOS.

Proebsting: No, they didn't. "Now that we've all had a good laugh, I'm serious, don't turn it down until I've had a chance to see if we can do it with CMOS." And I thought there had to be some way to make use of the fact that we had a clock, it was a synchronous part. Had a clock, CMOS. There's got to be a way to use that. And I thought about it and thought about it and came up with one of my very best inventions, what I call post-charge logic. Post meaning after, as compared to pre-charge. And another good name for it is pulse logic, the data goes through as a pulse, not as a level. A third name that has become very popular in Japan, self-resetting logic. And what it amounts to is an NMOS drives only a PMOS, drives only an NMOS, drives only a PMOS. So when the NMOS output pulls low, it turns on the gate of a PMOS who's output pulls high which turns on the gate of an NMOS who's output goes low. So you're not driving two transistors, you're driving only one. This inverter is driving only one transistor of the next inverter. And furthermore the other transistor is missing. The other transistor is off so it's not fighting during the first part of the transition. Only one itsy bitsy problem. How do you reset the damn thing? It goes once, but the shows over. While the idea of the post charge logic is a later stage that's many buffering stages, much bigger transistors later, resets this stage. And the next stage resets the second stage and yet the next stage resets the third stage. So, anybody's whose interested in that, a patent owned by National with me as the inventor that issued, it's got to be something about speed enhancement technique for MOS circuits or something like that, can find the gory details of just how it works. But that circuit, because the other transistor is already off, and because you're only driving one transistor instead of two, is just about twice as fast as regular CMOS.

Hendrie: For the same size devices?

Proebsting: For everything else being equal, same technology. We had there at Fairchild, a very hot CMOS technology. A 5 volt CMOS technology but a very aggressive good 5 volt technology. To make a long story short, a year and a half later, we were shipping circuits to CDC or Cray or whoever it was that met their spec. That the ECL folks couldn't do. They couldn't do it because there were so many bits and they had to share the power allotment among all of those bits so all of the ECL circuits were running power-starved, and slow. And the CMOS didn't have any problem like that and because their circuits were so power-starved and therefore so slow, and my circuit was a hell of a lot faster. It was to the best of my knowledge, it was three years before the first competitive product met half that speed. Half that speed. Three years later.

Hendrie: Now what was the speed spec on this part, do you remember?

Proebsting: This part again was in production in about 1989, I would guess, maybe 1990 and it ran at a 400 megahertz clock, every two and a half nanoseconds start a new access, read or write cycle.

Hendrie: Oh my goodness, that's really fast.

Proebsting: For that technology.

Hendrie: For that technology in that day.

Proebsting: And what was interesting is the effect that it had on Fairchild, who knew that they would for always be kings in ECL and the CMOS although it was taking over a lot of other stuff, would never threaten their ECL because it was just a different market. All of a sudden the CMOS could do what the ECL couldn't do.

Hendrie: Very unsettling.

Proebsting: Very unsettling. A real eye opener. Had to be very beneficial to them to know that, although even more disconcerting than beneficial. So, that technique was and is a very powerful way to make a circuit, and the Japanese widely use it for a number of years, and they refer to it as self resetting logic. Same circuit.

Hendrie: Same concept. Very good.

Proebsting: After that, I was at Intergrath and then became a consultant and the most recent thing that I've done is to develop an untested very very fast DRAM. It uses the post-charge logic but it uses a hell of a lot of other ideas as well, and one of them, before you every activate the bit line sense amplifier, you're already switching the output. It's got a separate sense amplifier, it's already reading without interfering with the sensing, already reading before you have all your signal. And the circuit is made to compete with SRAMS. Not quite as fast as a good SRAM, faster than a lot of poor SRAMS, not quite as fast as a real well designed SRAM but about a third of the cost. And about thirty or forty percent, twenty, thirty percent more expensive than a commodity DRAM and in a commodity DRAM, the three top criteria are cost, cost and cost. Having a higher performance is no benefit. So, mine being a larger circuit than a commodity DRAM, is not of interest to the commodity DRAM folk but people who want a filler between a DRAM'S performance and an SRAM'S performance at almost the speed of an SRAM and with virtually totally hidden refresh. I'd be more concerned frankly about the circuit activating its timeout queue to say to the computer "timeout I got to do a refresh." The probability of that ever happening is less than the probability of me getting hit by a meteorite right here and coming out right here in the next three minutes. But it could happen, it could happen but it's got almost, guaranteed, no inference from refresh.

Hendrie: Now did you do this, as a consultant or did you sort of just thinking and just came up with this?

Proebsting: It was really a culmination of a lot of ideas that didn't fit together until all the ideas were there and putting this whole group of ideas, the patents, which by the way I own on this, most of the patents that cover this are a couple of hundred pages in length and have the full recipe for the whole thing. Five pages of this patent really tell what the claims of this patent are based on.

Hendrie: And the rest is?

Proebsting: And the rest is other ideas that are covered in other patents or perhaps not covered but a rather complete recipe for making a DRAM that could… it's not addressed multiplexed. Who would think the Proebsting would be the guy to do a non multiplexed DRAM but sparks a RAS access time of under five nanoseconds and a RAS cycle time of under two and a half nanoseconds. So it's pipelined but you can start a new row address including a different row in the same array that you were in, a new row every two and a half nanoseconds. So it's SRAM like speeds.

Hendrie: It really moves, yes.

Proebsting: And not quite as fast as an SRAM but pretty competitive and I believe that there's a market and I'm hoping somebody will pick up on this. I believe that there's a market for a memory almost as fast as an SRAM, at a third of the cost. You've got your memory if you plot performance and cost, here and if one of them is up here, it's obsolete. Take core memory for example. As the semiconductor got better and better, the core couldn't keep up and it's obsolete. So as the memory got larger, I'm sorry, I think that there is a likely place for a memory at a little bit slower than an SRAM at three times the capacity or one third of the cost for a given capacity. And I'm hoping that somebody is interested in that and.

Hendrie: Somebody else.

Proebsting: Yes.

Hendrie: That's fascinating.

Proebsting: I'm trying to think of other things, have we skipped anything that we privately talked about?

Hendrie: I don't think so. So you're still.

Proebsting: Okay, I am still a consultant, I've done a fair amount of work with patent lawsuits, typically on the defense side helping defend somebody who somebody else is asserting the patent as being infringed. And I'm also doing design work with Sun, DARPA is interested in a phenomenal super computer. They asked everybody to bid on what they would do for a phenomenal supercomputer. Five companies got funding for phase one, three are now in phase two and they are Cray, IBM, I'm sorry, that's Cray, IBM and Sun. I'm working with Sun, I'll be doing some memory work with them but to date I've been working primarily on chip-to-chip interface, fast communication. And our interface will be, this is already public information, each chip will be communicating capacitively from it's four neighbor chips that are actually physically overlying it. And the communication rate from each chip in each direction simultaneously, will be measured in the terahertz range. To each of its four neighbor chips and in each direction simultaneously. So we're doing some innovative work there that's, I've obviously done some work on I/O's with the address multiplexing and beyond. And this is probably a thousand times as fast as anything I've ever done. It's more than that, it's ten thousand times as fast as anything I've ever done.

Hendrie: Sound pretty interesting that.

Proebsting: So I'm doing some interesting design work as a consultant and that pretty much is the history of Bob Proebsting's involvement in the semiconductor industry.

Hendrie: So tell us a little bit about your swimming career.

Proebsting: Okay, as I said, this is under duress. As a high school swimmer, I was pretty good, as a college I was all American and but not in the elite class, not quite good enough to make the Olympics. My swim coach at Knox College, was also the baseball coach and the cross country coach. He was not a specialist in swimming by any stretch of the imagination and he had never had a really good swimmer before and didn't really know how to coach me. When I got out of, I did place at the NCAA swim meet, which at the time there was no small school meet, I was placing among the universities and have one record that I'm real proud of. My one point tied Stanford. Stanford now is one of the elite schools in swimming who will make hundreds of points in the meet. But tying Stanford is something that if you don't go on and explain is a real accomplishment. As a masters swimmer, I had coaching that was the equal or perhaps better than, what some of the other people had and was frequently beating Olympic champions, former Olympic champions. My last meet before I got cancer, this was in 1994, was in Montreal Canada, the world championships. As expected, I won the 50m butterfly breaking my own world record, the 100m butterfly ditto, the 200m butterfly also breaking my own world record. The 100m freestyle was supposed to be a race between two others. One who had gold in the Olympics, one who had silver in the Olympics. And then a good race for third place, including me. Well I upset the plan a little bit, I got the gold with a new world record, both the others broke the world record, was the only event in the whole meet, five year age increments, men's or women's in any age group, the only event where three people broke the existing world record.

Hendrie: I think that's wonderful.

Proebsting: Both of them, within a few months, re-broke my record whereas my butterfly records remained for a while but, and in the 200 yard or meter butterfly, in my last ten years of competition, I don't think that any competitor was every within fifteen seconds of my time. I'd win it and then turn around and watch the other's race for second. I just owned that race.

Hendrie: Wouldn't that have been amazing if you'd had really good coaching?

Proebsting: I still wonder.

Hendrie: You might have made the Olympics.

Proebsting: What I might have done in the Olympics or otherwise, but I also wonder would my professional career have been what it was if I did the training that it would take to be there. Would I have gotten the academic education that I got. And I don't think the answer is yes. I'll never know.

Hendrie: But you have no regrets about your choice.

Proebsting: No regrets. No regrets, I had a lot of fun as an adult, masters swimming, beating folks who I couldn't touch when I was younger and I had a lot of fun in a career that has been good to me.

Hendrie: Thank you very much for this little post-script.

Proebsting: This was under duress.

Hendrie: Alright, so noted.

Proebsting: Good.

Hendrie: Thank you very much Bob for taking the time to do this oral history and we thank you from the Computer History Museum and just really appreciate you talking.

Proebsting: Well it's been my pleasure and it was fine.

END OF INTERVIEW

