Oral History of Brian Shirley

Interviewed by:
Douglas Fairbairn

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Fairbairn: It is May 24th, 2023. My name's Doug Fairbairn, I'm here to interview Brian Shirley, who has spent his career essentially completely with Micron Technology, right?

Shirley: That's right.

Fairbairn: Is Micron Technology the official name of the company, or is--

Shirley: It is, for all intents and purposes. Thirty--

Fairbairn: Everybody--

Shirley: -thirty-two years at Micron.

Fairbairn: Everybody knows Micron. And so, we're delighted to have you here. Thank you for joining us.

Shirley: Thank you.

Fairbairn: So, as I mentioned, we like to sort of start at the very beginning. Where were you born? When were you born? What was your early family life like, and how did that, or not, impact your future choice of careers?

Shirley: Sure. Born in Flagstaff, Arizona. But before I had any good memories of those days, my father moved the family up to Boise, Idaho. He had just finished his MBA and was hired by a large international construction outfit that was based in Boise, called Morrison-Knudsen. Morrison-Knudsen had been the builder of-- boy, going all the way back to the Hoover Dam, and several big dams, power plants, everything from train lines to very, very big international construction projects. He was the first MBA with the company, so we moved up to Boise, and that's, for all intents and purposes, where I spent my growing up years.

Boise is a little bit off the beaten path, part of what they call the flyover states. Very geographically isolated, but that's what I grew up with, what I knew. You can drive 300 miles in any direction and be out in the middle of nowhere. So, part of the Boise ethos, I think, was "Hey, we're all in this together, and we have to do it ourselves," and a little bit isolated from the rest of the country. I spent a number of years obviously growing up, as they call it, a standard Gen X child. I do remember one of my earliest memories of computers was my father taking me out to the Morrison-Knudsen headquarters, down into the basement, and getting a chance to see some of the old original IBM mainframes, and punch cards. That made a huge impact on a seven or eight-year-old, at the time, and I remember that very, very well.

Fairbairn: So, you were born in 1969, and any siblings?

Shirley: One sister. I grew up comfortably middle class, was a very, very comfortable upbringing, I'd say. The town was much smaller then than it is now, but a lot of growth at the time, a lot of folks coming into

Boise, and a lot of memories just being out on-- riding bikes in subdivisions that were getting built, and finding our way down to the local Kmart to go stare at various computers that were coming up for sale, so...

Fairbairn: So, did-- your father had an MBA, did they have any technical leanings, or how did you find yourself steered in that direction?

Shirley: He was in the world of finance and business, but he just had a great grasp of the direction technology was going, and he encouraged it. But more than anything, he just encouraged me to be curious, and ask a lot of questions. I think, to a large extent, I turned into that kid who always had to understand “why” and how something worked. He was a huge influence in that, a huge believer in education, huge believer that the world of business and the world of technology had something big to offer the world, and that made an impact.

Fairbairn: So, and as you went to high school, did you-- any particular teachers that had an impact on you, or along the way?

Shirley: Well, even before high school, I'd say at some point, when I was in elementary school, the TRS-80 computer came out, and one of the teachers actually got a TRS-80, and that made a huge impact. I'd say that's where, for me, it all started, with having a chance to actually play around and see what you could do with a computer. In later years, when the Commodore 64 came out, my best friend across the street, he and I would ride our Schwinn Scramblers about four miles, and down to the local store, and spend hours, every summer day, playing with that computer. Finally, I got one, and I think it was for Christmas, I can't remember which year, but we had just a chance to really learn the ins and outs of BASIC programming, and, frankly, how critical memory was. Because the Commodore 64 was based on 64 kilobytes of memory, and that, at the time, for that kind of low-end commercial computer, was revolutionary.

I was not an outstanding student, really. Focused on curiosities, wherever it would take me, for most of my growing up. But I was going back to, in junior high and high school years, back to New Jersey in the summertime, working for my grandfather, who had been a chief petty officer back in World War II. So, those were some pretty tough days, and I learned the value of hard work, the work ethic, and what it meant to be working outside on very hot, humid New Jersey days. He ran a spray business at the time, and this is, by the way, back in the days when-- I think it was 1985. He had started a spray business, and so, we were spraying lawns, trees, shrubs for very high-end wealthy people between Philadelphia, and New Jersey, or New York. It turns out this was the summer when the Philadelphia mob was battling the New York mob for control of Atlantic City. It turns out we were spraying the mansions, the grounds of these competing mobs, and <laughs> several of them didn't survive the summer, as it turned out. This is all told in “The Irishman”, by the way, the movie. But <laughs> very distinct memories of walking into the backyards of these gorgeous mansions, with these spray guns that could reach up to the top of the trees to get all the insect problems taken care of. Of course, as a 14-year-old kid not realizing that I'm walking back there with what looks like a gun, and surprising the heck out of several Mafia bodyguard. So, that

was a fairly vivid memory, and like I said, a lot of those folks didn't survive that summer. But high school, I--

Fairbairn: So, were you actively aware of what was going on at the time? I mean...

Shirley: A bit. There was no Internet back then. There were several high-profile murders, Sal Testa, and a variety of the folks that were clients of ours. Of course, as a young kid, I was more focused on the fact that Bruce Springsteen was finishing up his “Born in the USA” Tour, and coming back to Philadelphia, and was hopping on the rotary phone, trying to call in for free tickets. More than anything, it taught me “Hey, it's time to get serious about schoolwork.” Buckle down, find something I love, and get into a career where you're not outside having to work, and walk into people's backyards with something that could be mistaken for a rifle. So <laughter>...

Fairbairn: That’s a great story.

Shirley: But yeah, high school was good. Buckled down, got serious about it, said engineering’s going to be the thing that, I think, is for me, and I found various ways to get serious about engineering, and business as well. Hewlett-Packard had moved to Boise in the early 1980s, with their printer division, and that was big for Boise. It was transformative for the community. One of my good friends, his father actually ran that printer division. So, when you're curious about engineering and you have just a little bit of rudimentary business sense from your father, and you find the one good printer in the entire town, we figured out a good way to start up a fake ID business. I think we had the whole town wire-- hopefully the statute of limitations on that is over, but--

Fairbairn: Expired.

Shirley: -yeah <laughter>. But good days and got serious about taking engineering to the next level.

Fairbairn: So, how did you go about choosing a college, about where to go, and anything?

Shirley: Well, I didn't know much about Stanford up until junior year or so, where it became time to really get serious about applications and everything. I sent off applications to every place under the sun. A good friend had been telling me quite a bit about Stanford, and at some point, I had a chance to get down there and take a tour of the campus, and fell in love with it, but knew it would be a reach. Anyway, applied to several schools and got rejected by a few, I got acceptances at a few, and never forget the day that the Stanford acceptance came through. Jean Fetter was still head of admissions at the time and made a habit of signing the admissions letters. So, at that point, I said “Got to head to California. That’s--

Fairbairn: It’s where you're going <laughs>.

Shirley: -the place for me,” yeah.

Fairbairn: And your parents were happy to have you go that far away, or go to that kind of school, or...?

Shirley: They were. It was very, very expensive, and they had-- I was very blessed. We were not a rich family, but we were comfortable, but even back then. By the way, Stanford is incredibly tougher to get into these days. Things have really changed. But they found a way to help pay for it, but they made clear it was-- the end of this was to get into some kind of a career, where I can support myself, and repay the favor, as it were. So, I got serious fairly quickly. Freshman year was tough for a kid coming out of Boise. Physics, and in particular, electricity, and magnetism, was a notable class. I felt very depressed one day, walking out seeing that I had-- I think I received something like a 37% on the midterm, and being very depressed about it, and then finding out that there was such a thing called a curve, and that was actually ahead of the mean. So, I liked the subject material and did have a chance to say “Look, I think electrical engineering is going to be the thing for me.”

Fairbairn: Did you have a 8:00 A.M., five days a week calculus class?

Shirley: There were some early calculus classes. Back in the day, Western civilization was still a requirement, and enjoyed those days quite a bit. At that point, I hadn't fully settled on electrical engineering, but it was that summer when I came home to Boise and had to find a career, that I actually did interview, and was hired out at Micron as a summer hire. That's really the point where I said “Wow, this is the career for me.”

Fairbairn: So, tell me about your education. Was there-- how far did you go? What was your...?

Shirley: Yeah, so received a bachelor’s in electrical engineering. Every summer, I was coming back working for Micron, so that first summer I had the chance-- Hewlett-Packard was hiring for summer hires out of college, but the deal was you would work on the factory floor. My father mentioned “Hey, there’s--” this would’ve been the summer of ‘88, I guess? He said “There's an outfit on the outside of town doing memory chips.” No one in Boise really had a good handle on Micron. It was still a fairly small operation at the time. He said “That may be something you want to take a look at.” I remember the Commodore 64, and how critical the 64-kilobyte main memory was, and I said “This is something to take a look at.”

So, I found a way to get in touch with the company, got out there and was interviewed by Joe Parkinson. In those days, he was the CEO, and he still made a point of interviewing every single hire, which was a big deal. That's a lot of time. But he had keyed in that really understanding who was working for the company, and what their motivations were, what their work ethic was like, was a very, very critical thing. I interviewed with three separate departments. Again, I only had physics, electricity under my belt. No EE classes, but some rudimentary sense of capacitors, and resistors. I interviewed through the IT group, through the process development group, and then through product engineering. At the end of the day, toughest interview I've ever had, before or since. He was a very, very tough interviewer, but he asked “Which department would you like to work in?” I said “Product engineering. This thing called design is something I'd really like to learn more about,” and the rest was history. I was hooked.

I still remember that summer, working on 64 kilobit chip, Micron’s first chip. It was a nMOS design. Those were very, very difficult circuits. This was before the world of CMOS. So, every clock inverter, every new timing signal, you had to burn something like 15 to 16 transistors, a couple capacitors. There were boot

nodes everywhere. It was a very, very difficult design, but I was hooked. Being a part of that team and the sense that this was this operation, already in those days you could tell this was an operation that knew it had to be competitive, and knew what it took to fight. They had been through some tough times already. Just the fact that Micron was still alive at that point was quite a miracle. But I was hooked, came back every summer. Several times over Christmas break I'd be out there helping to plot check various designs.

As I would go back to school, through sophomore year, junior year, and really getting into the meat of electrical engineering, I was the nerdy kid in class asking a lot of questions about what this meant to DRAMs, because it was something I could relate to. Tyler Lowrey, at the time the CTO of Micron, would get in touch with me. Again, this was before e-mail, but we'd chat, and he'd ask me to go down to Stanford Research Institute and find the founder of field-emission display technology, Capp Spindt, who was doing some revolutionary work at the time, and it was something Micron was taking a look at. So, I'd go and do some research over there for Tyler; try to make some additional money. Through some pretty difficult days at Micron, with some process issues that were still swirling around, I'd find myself talking to Professor Jim Plummer, quite a bit of time with Mark Horowitz as well, and trying to figure out ways to help the company at the same time, and just--

Fairbairn: So, really down to the weeds of real practical work, trying to solve problems back in Idaho?

Shirley: Yeah, I was the junior in basic electronics class, asking some fairly intense questions about what implant doping profiles would do to leakage currents, and this, and that. But it helped to make it real, and I had considered staying around for a master's degree. As it turned out, I had a chance to take EE 216 from Professor Plummer, and then 316, which was advanced devices, and that was the master's level course. I felt like that was about all I needed, and I was anxious to get back and start making some money.

Likewise, through Professor Horowitz, had a chance to take EE 271, which was, in essence, really a fairly impactful course for quite a bit of Silicon Valley, I think, in terms of teaching them VLSI design. It was one of the first courses in the country that really formalized what VLSI design was all about. I didn't have room in the schedule, but I was able to sneak in, on occasion, to EE 371, which was the master's level course. So, eventually for me, the master's made no sense. I was anxious to get back and start making some money, and pay off, help to pay it forward, as it were, because it was a very, very expensive education.

Fairbairn: Right, right. So, then you moved back. So, tell me, what was the state of Micron? How old was it at the time? How big was it? What was the-- you said it'd already been through some trials, and...?

Shirley: Yeah, at the time, so this was the later 1980s, and I started in '88. I think the company was formally started-- Joe and Ward had got together with the original design outfit. Lot of Mostek names that were-- or history there. Roughly 1978 and then '82, I think, is when the company was formally incorporated. Did some very, very pioneering 64K DRAM designs. A lot of these circuits go all the way back to Bob Proebsting and Paul Schroeder, very impactful names in the world of DRAM memory. Ward knew how to make the smallest DRAM design out there, and the company did well in the early 1980s, but

then things really got upside down when Japan came into the DRAM industry, in a big way. This has been retold very well in “Chip War”, and even “Microcosm”, by George Gilder.

Japan, through a lot of state sponsored aid, really turned into the DRAM industry. So, everyone got out of DRAM, through some difficult years. Intel famously threw in the towel. Mostek went out of business. Still a few other US suppliers, IBM retreated to just doing DRAM for their own internal systems. Joe and Ward would tell the story better than I would, but they went through a phase where they literally had to lay off half of the company. I think this was roughly 1984 or ‘85. Very, very tough days. The company, at the time, was being partially bankrolled by J.R. Simplot, who was the local billionaire, by the way. He had made a ton of money in potato processing, so the Idaho potato farmer, as it were, and figured out ways to freeze dry potatoes and sell French fries to McDonald's, and in wartime contracts for the US Army. Anyway, J.R. was still on the board even when I joined. I got to know J.R. fairly well.

But in the late 1980s I'd say, the company was doing a bit better. We were up to roughly-- don't quote me on this, but I want to say about a thousand employees, the vast bulk of which worked in the fab. So, design was probably a grand total of 15 to 20 engineers, product engineering, roughly the same size. Process engineering was probably 30 engineers, or so. The cool thing about that, though, is that this was a company where product engineering was not some small, closeted operation that just did test code, and no one really paid attention to. Product engineering was really part of the key triangle with design, and process engineering, because the whole company was based on how do you get the lowest cost memory bit? Through those difficult days of Japan coming in, the company really figured out “Hey, we have to be the low-cost leader.” Ward’s designs gave the company the smallest die size. Tyler Lowrey had figured out how to get the lowest mask count process. So, this was an nMOS process that Tyler had figured out how to take from 11 masks, down to 7, and that was unheard of at the time.

Shirley: As a matter of fact, in one of those summer hire experiences, I was pulled aside by Ward, and I had started out doing alpha radiation studies on these nMOS products with a lot of boot nodes. Crazy things happen with radiation and boot nodes, and everything else. So, it was a difficult problem for the whole industry. But Ward pulled me aside and put me in charge of plot checking the 1 meg [DRAM]. It was a 1 meg design that the company was in desperate need of, because it was really the first mass production CMOS design. NEC had-- I think it was NEC, moved their process from nMOS over to CMOS, and as soon as they did that, you couldn't sell an nMOS product in the industry if you wanted to. CMOS was so much lower power, so much faster.

That’s all great, except for the fact that it latches up, and this small problem with CMOS circuits that the second you probe, you apply voltages to these circuits, if you haven't done your layout carefully, they would completely self-destruct, with these currents that were going into a syndrome. So, my job was to plot check this device, and add all of the right wells, and tie downs, and everything else, to make sure the device didn't latchup. Again, that just helped to sell me on Micron as a company, and the fact that I'm just a summer hire, but I felt like I could make an impact, and part of why I really wanted to get back there and go full time.

Fairbairn: So, what was the mindset, or the technology, or whatever, that kept Micron in the business at that time? And maybe-- you mentioned die size, obviously critical, and mentioned number of mask layers. But it sounds like it's sort of an overall company philosophy, or whatever, that, I mean, you survived when Intel and others did not. Can you delve a little more in-- deeply into that?

Shirley: Sure. Several things. This is late ‘80s, early ‘90s, there were market cycles then. So, if you could survive a market cycle, you would get a little bit of wind in your sails. I think it was MS-DOS 3.2 had just come out in the late ‘80s, and that was starting to really supercharge the world of personal computers. So, ironically, after a lot of concern in Washington D.C. about the state of American industry, and the forming of SEMATECH, and a lot of companies saying “Look, the US can never be competitive at memory manufacturing again,” the industry did recharge. Japan won big out of that. Micron did okay. We were very subscale at the time, but the focus was on smallest die size, lowest mask count, highest yields, get the most bits out of the fab as possible.

One other key thing that I don't think was appreciated well at the time is that Micron, unlike just about every other memory manufacturer out there, decoupled the process from the actual design density. So, the progression of Moore’s Law, when a new process would come along, most memory manufacturers would use that almost exclusively to go start trying to mass produce the latest, greatest, largest density product, and Micron didn't do that. They would say instead “Look, we're going to use this to go mass produce the highest volume density that's still around.” So, you got to smaller die sizes, and you could really get the most output out of the fab. Through the 1980s, that helped save the company, because there were still cycles, and we found a few.

Part of the trick of memory manufacturing, or memory production, is that it's so high volume that any trick you do to save the company, in one upturn everyone's going to figure it out the next upturn. So, we had to go find new things, but really at the time, and for most of my history, being lowest cost producer was everything. In fact, after I graduated, I came back, started Micron full time back in product engineering. That was invaluable education. Not long after that, I moved to design, but the education you would get in product engineering trying to fix design problems, was the best education in the world for a designer. Designs always look good on paper, it's what happens when you start manufacturing thousands of wafers a week that you really figure out what the big issues are.

So, the history, the education that I got in product engineering, learning what worked well, the fact that you needed some spare circuitry because there would be downstream issues that you would have to fix. Looking at your layout under the microscope and seeing what each layer really looked like, off-datasheet specification issues, figuring out how the memory was really used in the systems, it was a spectacular education. Still a lot of issues, a lot of things we had to fight through. For quite a bit of time, I had the Micron record for the most microprobes used in debugging a circuit problem. If you remember the old microprobes, where you could land needle tips down on the wafer and help to reverse engineer a problem. I think I had 12 microprobe tips down, and it was about a good three-week effort of a lot of coffee trying to figure out why a certain sense amplifier was imbalanced and finally got down to the root of the issue. But it was tough days even then. This was early ‘90s.

At the time, by the way, the company had-- I don't remember the exact history, but we had a-- we were in the SRAM business as well, seeing if there were any more profits that could be made there, and had a fairly small SRAM cell. We tried to license that to IBM. IBM took a look at this small cell, and they said "Hey looks great, but the fact of the matter is you're violating several patents that we have on this, that would in-- this infringes on." So, we ended up having to go through a big cross-licensing, and through that cross-licensing, we actually got access to IBM's 4 meg process and design. It was really interesting taking a look at how different that was from what we were doing. It was a--

Fairbairn: Yeah, I'll bet that that was-- they have a totally different <laughs> perspective on things in history.

Shirley: Yeah. We called it the best design that money could buy. It was a trench process, by the way. We were still using planar cell processes. Just some wild technology, very, very interesting circuit designs, very interesting process things. It was a very expensive design, and it never yielded all that well. It taught us a lot, though, about what the other folks were doing out there, right? Tyler Lowrey, by the way, IBM, with that trench design, had pioneered CMP Technology, chemical, mechanical polishing of wafers. Tyler figured out a way to apply that to stacked cells, which transformed the industry.

Ultimately, Micron was forced to choose between stacked and trench cell. It was a very, very critical decision in the world of memory, and we chose to go stack, and that was about one of the toughest decisions I remember. This was probably mid-90s, or so. The bulk of the other manufacturers out there had gone with trench. So, IBM was trench, TI was trench, Siemens and Toshiba were all trench because of the IBM JV, and NEC was trench. I think Samsung, and it would've been LG and Lucky-Goldstar, and Hyundai, at the time, had gone with stacked cell, and maybe Hitachi. We ended up going with stacked, and at the end of the day, stack is the only thing that won. Trench suffered a slow hard death. So, it was a phenomenal, phenomenal move by Tyler and the rest of the process team to get us on stack cell.

Fairbairn: So, going back to the mid-80s, when Japan really reared its head. The big thing, at the time, was most US companies didn't believe, you know, that they were yielding what they claimed, and that they were under selling, you know, dumping product, and that sort of thing. So, the whole thing of quality and yield was a huge, huge factor. Where was Micron on that in terms of where were you in terms of your quality, your yields at the time? Did you-- how did you address that issue, and to what extent was it--

Shirley: Yeah, great questions. My sense, from what I saw anecdotally, is that Japan really was as good as they claimed in yield. They had a huge advantage in scale. So, the incoming assistance from the state really helped to build the right scale operations, great R&D operations. But there was just something, and I think this has been well publicized through the travails of the automotive industry, for instance. Japan's ability to get something in production, and yielding well, and high quality, at the time, was unmatched, to put it bluntly. Micron did very well there in yields just through sheer force of engineering. I give Tyler, and Ward, Randal Chance, a lot of the original Micron folks, the ethos at the company was it was nothing fancy. We're not here to go pioneer anything too radical. We have to be the lowest cost producer. Through the learnings on yield, on low mask count; low mask count really was just such a huge deal, because it gave us faster cycles of learning, an ability to pull up things. Japan at the time, even they were

focused on these championship densities that really were tougher to pull into production. So, I do credit the push towards more of the smaller production densities is a big piece of the early Micron success. Quality was a big--

Fairbairn: When you say production densities, what do you...?

Shirley: Well, for instance, even in the mid-90s, when .5 Micron or .435 Micron would come along, most companies out there were tethering that process node to a 16 meg, for instance. Micron, we were basing all of our production on 4 megs, and you could move those cost effectively, and loadings and computers were such that 4 megs were more than fine, for the vast bulk of the market. Part of that, by the way, when I moved to design, my first design, the design that I was the lead designer on, it was a .435 micron 4 megabit design, and the whole charter for that project was get a certain number of die per reticle. So, this was underappreciated by the rest of the industry when the semiconductor industry moved from steppers that could photo imprint an entire wafer, to having a smaller fixed reticle size. The critical thing that determined how much output your fab could get out was how many bits could you cram into that reticle, and if you were doing 16 megs, it was very tough to plow all that many bits into a single reticle.

We learned this the hard way. I think our .5 Micron DRAM, I was still in product engineering at the time, but we thought it was a pretty good shrink. The cell was 35% smaller than the previous generation. We thought this was going to be a good moneymaker. John Aiton, the head of the fab called me up, and he said “Hey, we're not going to be able to get much more production out of this shrink compared to the last one.” I said “Well, what are you talking about? The company’s spent a lot of money getting ready for this next generation node.” He says “Well, there's just--” it's only 10% more die per reticle, from the previous node. He says “I took the amount of square footage in the fab. I've got scanners that maximize the output, and if you're only giving me 10% more bits per reticle, we're only going to get 10% more bits. I don't care how much smaller the cell size is.”

So, I moved to design, and my first design, at .435, was, in essence, how do we get die per reticle up over the previous node by about-- I think it ended up being about 80%. We were able to do it. It was a small design team, I think myself, two other designers, three layout engineers. We went to a backroom for probably a good solid three months. It's kind of the 120 hour weeks, got that design layed out. Nothing all that revolutionary on the design side. The mantra was if it ain't broke, don't fix it. But we crammed, and pushed, and squeezed. We put circuitry between pads, we cut down circuit size. We did some innovative things with the sense amps, but we got the die per reticle that made a difference, and the company ended up making a ton of money <laughs> on that design. It was a huge moneymaker. Part of it was Windows 95 had just come out, and that supercharged the industry again. But it was by far the cheapest cost per bit in the industry.

By the way, we rode that wave for a few more generations. So Tyler, Mark Durcan, and in process development, Chuck Dennison. I mentioned the experience with IBM's DRAM designs and CMP. It was at that time, the next generation node that we had to make the move to either trench or stack, and we did choose stack. We were very scared about it at the time, but we used stack cell higher capacitance to get even larger arrays. So, the next design we did, it was something called a mini stack process. Mark

Durcan was in charge of this process node. My design, again, nothing revolutionary, you just had to be ready for production as soon as the process was. Mark eventually became the CTO of the company, and then the CEO. His process, this mini stack process, nailed stack cell production with fewest number of mask layers in the industry, and that became the successor to my first design. So, .435, .35, and then .3, we had this road map of production that was just unmatched in the industry. It was really like catching a good wave. In military terms, we were inside the decision cycle of every other company out there. Tyler had thought through how to use CMP processing to really make stack cells work. So, IBM was busy with CMP on trench cells. We were using CMP for stack cells, and we just piled up so much cash. I think we had seven or eight quarters, with the gross margins in the company north of 65%, which for--

Fairbairn: Okay. For the DRAM <laughs> business, that's--

Shirley: -the DRAM business was unheard of. It was just fun, design, product engineering, process engineering, everyone were coequals. There were no egos. It was you'd get everyone in a room, Tyler himself would sit down and help you figure out the right design rules to push to make a sense amp work. We just got things out the door fast, and those three nodes we just-- again, with the help of Windows 95, and some would say bloated code from Microsoft that needed a lot of memory, we--

Fairbairn: <laughs> Right. They ate up memory like crazy.

Shirley: Yeah. We made a ton of money. It got pretty rough after that, but those were-- what Tyler, and Mark, and Chuck did with those process developments was phenomenal.

Fairbairn: So, you had-- you sort of got through the tough years in the mid-80s, and then really caught the wave. You rode three or four product cycles. What was the next hiccup, or what was the...?

Shirley: Well, it was through those process developments, again, we had piled up a ton of cash, and it was time for the company to think about expansion. We were small and tight, it was all in Boise. It's great having your production right where your R&D is, and everyone on the same campus, and in a lot of ways, Micron is very insular because of this geographic. Sometimes we were just too stupid to know what we were missing. We didn't get caught up in too much that was happening around the rest of the industry. But to answer your question, it was roughly around, gosh, '96 or '97. Well, '95, we said "Look, it's time to expand. We need to get something outside of Boise just for risk management reasons, if nothing else." At the time, the company-- Boise was 100,000 people, and Micron was employing several thousand now. So, it was an unhealthy reliance in the economy on just Micron.

So, we decided to start a fab, and in Lehi, Utah, and this was going to be the start of 300-millimeter production for us. Already, there were glimmers that 300-millimeter would be critical out at someday. We had taken some of this cash and we upgraded our existing Boise facilities from six inch to eight inch, and Ken Smith had done some very innovative stuff where we took all of the, what you would call, kind of the dirty parts of the process, the CMP steps, the implant steps, moved them into a separate operation so that the really clean steps, like photo, didn't have to contend with those particulates. So, we were good, but we started expanding in Lehi, Utah, and this was a big fab. We were going for scale. Scale was

critical, and this fab had to be ready for 300-millimeter at some point. We were spending hundreds of millions of dollars a quarter trying to get this fab built, and the market started to turn, and we could feel it turning. So, we made the decision to try to go even faster, and so we had everyone working. It was construction twenty-four hours a day, a massive project in Lehi, Utah.

I still remember, though, this downturn. Prices were going down and going down, and we were getting worried about things. We thought we were okay, though. Intel was a big customer at the time. They were buying DRAM to place on their motherboards. They were out of the DRAM business at this time, but most DRAM was still mounted directly on motherboards, and in Intel, that was a pretty big business for them. I'll never forget, I think it was in '97, they called up, and they said "Not only do we not want this week's shipment of DRAM, we're going to send back to you the last three month's shipments of DRAM, which we haven't paid for yet. So, we're allowed to do that." The bottom just dropped out of the market. It was killer.

At the time, the company, again, we were doing okay on production costs in Boise, but we had no 300 millimeter, and all of the company's cash was tied up in Lehi, Utah. So all of the goodness of those successive generations was sitting in an empty shell in Lehi. So that, and by the way, you know, Tyler had left at that point. Mark Durcan had became our CTO. Tyler and Steve Appleton had a bit of a run in, and so from the engineering side of the company there was a lot of angst because the CTO was gone, and we were heading into quite a downturn. But we watched cash. The company had essentially no debt at the time. Joe Parkinson's mantra had always been, you know, for a construction company, we are going to avoid debt like the plague. So we did okay, we got through. And then eventually in 1998 we had the opportunity to do the first of our large acquisitions which was the memory business of Texas Instruments, and that really helped to right the ship for some period of time, so we made it through that downturn okay.

Fairbairn: What about the Lehi fab?

Shirley: Well, the Lehi fab sat empty right up until 2006 when Mark Durcan helped to engineer a deal with Intel in NAND memory. And so Intel was doing NOR memory, so this is solid state storage as opposed to DRAM main memory. And we were looking at NAND, it was clear that NAND was a big thing. Toshiba and Samsung had started off on NAND memory, and it was clear it was growing like a weed. And so at the time in 2006 we got into a JV. Intel put in a lot of cash into the deal, we put in a lot of good technology-- both sides put in technology-- and we were able to start up Lehi, Utah as a JV doing NAND production.

Fairbairn: All right. So you managed to survive from the mid-1990s through the mid-2000s without an additional fab? Or how did you-- where did you--

Shirley: Boy, these were tough years. I was running design at the time, and there were some upturns and several downturns. In 1998, I believe it was, maybe late '97, things got so ugly in the industry that most of Japan was struggling at that point. So there was a lot of consolidation in Japan, the South Korean companies, Samsung and what became Hynix eventually in 1997-- don't quote me on the exact timing-- but I believe Hyundai which had turned into Hynix merged with Lucky Gold Star which was LG,

and that became Hynix. This was the 1997 Asian debt crisis, and part of this was the DRAM industry, but part of it was just struggles across the macroeconomy. It was clear that there was carnage everywhere. And Texas Instruments wanted out of the memory business. And Rich Templeton, who was CEO at the time-- well, no, I'm sorry, he was number two at Intel at the time under Tom Engibous-- called up Steve Appleton--

Fairbairn: Number two at TI.

Shirley: At TI. He called up Steve Appleton and said, hey, this memory business is not for us, we have this thing going in digital signal processors, we think this is going to make a ton of money. You know, would you like to buy our memory operation from us? And that sounded great except for the fact that we had no cash. And it was a very transformative deal, and I'm not sure Steve wanted to do it, and so in some senses it actually turned into the perfect negotiation just because we really could have walked away from that whole deal. There was a lot of concern that TI had a set of 200-millimeter fabs all over the world, and these had been structured fairly well using subsidies from various countries such as Singapore, one in Japan, one in Italy. And TI had been on trench cell, and a lot of good engineering. But, again, I think they started to struggle with trench, and they started to struggle at various points with some of the other issues we mentioned and just in yield and cost per bit, and they wanted out.

And so Rich and Steve spent a lot of time negotiating that deal. And for us, again, it was a tough call. This was transformative to the company. It was going to roughly triple the size of the company but take us from this small, tight Boise operation to being a multinational company with fabs all over the world. And finally the deal got to be so good that Steve couldn't pass it up, and I remember him looking over at Mark Durcan and myself, and he said, “You know, if we're not growing, we're dying, so we're going to do this.” And it was a very good deal, an essentially seller-financed 800-million dollar deal where Micron purchased all of TI's memory operations, design teams, everything else in exchange for convertible debt because we just didn't have the cash. As a side note, TI ended up making a ton of money on Micron stock out of that deal, so everyone won.

Fairbairn: Everybody won.

Shirley: Everyone did well. A huge piece of that deal, by the way, is that we received a 10-year royalty-free license to all of TI's memory patents, and back in the day, TI--

Fairbairn: Yeah, they had--

Shirley: --oh boy, their patent portfolio was ferocious.

Fairbairn: Yeah, they were coming after everybody.

Shirley: And so that may have been a huge piece of that deal. It was still tricky for us because the supply and demand really hadn't quite reconciled yet in '99, and we were busy trying to put stack cell processes over into these fabs, and everything else. And I was trying to get my feet underneath me

running design teams in various cities, and Dallas, and teams all over the world, we had a team in Japan. Various other things happening in the DRAM industry, this is when Rambus DRAM came along. I had spent some time with Professor Horowitz back on the original Rambus. He had showed me some initial thoughts of how he was thinking about it. This ended up being a pretty big battle in the industry, Rambus DRAM versus DDR. But anyway, in terms of the industry, eventually that downturn ended and we tore into the 2000 upturn, really the dot-com boom, and then obviously quite a crash after that. But for a few years we were focused on 200 millimeter and how we got these fabs getting the kind of output we needed to really work.

Fairbairn: Yeah. It strikes me as being incredibly difficult to integrate a much larger operation that must have had a very different mindset. I mean they were on a different process, they didn't have this sort of minimum cost, minimum die size. I don't know what their philosophy was at the time, but it was clearly going to be different.

Shirley: Yeah. It was a lot of integration challenges, but I'll tell you, we got some just phenomenal engineers out of that. And that's something I think we learned over time is that those in the world of memory-- there's something about memory, and you could probably say this about any field-- but I've just found time and time again, good engineers in the world of memory, it's almost like they're kin --

Fairbairn: And brotherhood, huh?

Shirley: And John Schreck, Roger Norwood, just a ton of good names that really came out of TI. And they knew that TI could be more competitive, they had been trying very hard, looking at what we were doing, some of the things we were doing right, a lot of the things-- You know, we made a ton of mistakes along the way as well, obviously, nothing that was ultimately too killer. But they brought a, you know, Texas Instruments just had an engineering culture that I think ended up really helping Micron in some ways. It gave us a little bit more rigor in certain things. But they very much appreciated understanding how tight we were as a company between process and product engineering and design, and I think both sides really benefited each other.

Fairbairn: Wow. Yeah, that was a quite a transition, so--

Shirley: Yeah. You know, just kind of going on chronologically, so we did some good stuff around those days design-wise, things that the world had never seen before. I credit John Schreck and a lot of other people across the operation. I think something we really were believers in from the initial days. Ward and Tyler had spent so much time at big companies like TI and Mostek, and there was a culture about who you could listen to and who you wouldn't listen to, and that was really distasteful to them. So, when they came into Micron there was a spirit of democracy, there was a spirit of we will listen to anyone. It's not a question of who you are and what your title is, it's a question of how good is the strength of your idea? And so we continued that. And some fantastic innovation, we pioneered the use of electrical fuses in memory. This was a huge deal. So rather than laser fuses for redundancy and everything, we could do electrical fuses which gave us field repair capability, and it gave us the ability to trim circuits and backend test. We had a test cost that was bar none the best in the industry, and a lot of this came back to some of

how we were doing burn in, how we were doing memory test which, you know, at the time memory test was chewing up everybody because it was getting to be so expensive, just these factorial problems of how you find issues.

And I remember back to Tyler's original, Mark Durcan's mini-stack process. When we were doing polysilicon cells up and over the access device, we had defects in polysilicon like no other. And Chuck Dennison likes to say that Eskimos have a hundred words for snow-- we had a hundred different words for polysilicon defects, I mean it was really chewing up the company, but we found ways through that. John Schrek in particular found a way to get us to what we called 6 F squared. So most DRAM cells out there were using a technology called 8 F squared. John found a way to get us to a cell that was roughly 25 percent smaller than the previous cell, and that revolutionized the industry. Everyone quickly copied it, so within three years, Samsung, Hynix, you know, the other big guys out there were all doing 6 F squared production.

In some ways, though, we were keeping an eye on in those 2000s, or the year 2000, on the fact that there was going to be another downturn, and we were nothing but 200-millimeter, and that was just very, very scary for the company. And sure enough, the 2001 dot-com bust was just absolutely killer to the company. You know, we were watching it closely. We had fabs all over the world, demand fell off a cliff, and we were watching out there. We had made some inquiries about the possibility of merging or acquiring Hynix over in South Korea, and that was nixed by South Korea, and frankly I don't know how we would've financed it anyway. But at the end of the day things got so bad that eventually Hynix filed for bankruptcy and was bailed out by the South Korean government.

And that was about, I think, as scary and depressed as I remember being just because here we were with essentially no cash, 200-millimeter fabs all over the world, trying to compete against Samsung, which was already moving to 300-millimeter, demand was horrible out there. And it was clear that other governments were basically making the statement that their industries would be bailed out. It was clear in the US there was none of that, no one was paying attention to the memory industry by this point. And so we were on our own and forced to just continue sticking with our knitting and find ways to get the cost of production down. We idled some capacity, we kept focusing on getting yields up everywhere we could, 6 F squared technology, and we ended up coming out okay out of that downturn although the rest of the 2000s were still pretty tough. We just didn't quite have the scale.

We eventually ended up being able to put together the 300-millimeter scale that we needed, but those 2000s were really, really tough years, difficult times. I remember looking one time, the retained earnings of the company-- so really a metric about how much lifetime profitability was in the company. In roughly the year 2001, I think we were sitting on something like a positive 4 billion dollars of retained earnings inside of Micron. By 2009, which was obviously the Great Recession, we were down to minus 2 billion dollars. So the company was all paid-in capital. R&D bills in the memory business are spectacularly high, so we're having to figure out how to continue funding R&D through some very, very difficult days. And I don't think it was until 2014 that the company went positive retained earnings again, and that was after the Elpida acquisition, and we finally got the scale and the R&D capacity that we needed.

Fairbairn: So let's go back. Back in the mid-nineties you were building Lehi fab, and you were focused on DRAM, you were expanding production, things went south. When did you make the transition to NAND and how did that-- to non-volatile memories?

Shirley: Yeah, so it was really in these 2000s. So through the 1990s we were nothing but a DRAM company. We played around with NOR for a small period of time, NOR non-volatile memory, but the nineties were all DRAM. And the nineties, by the way, is when Japan retreated somewhat from DRAM, but South Korea came up in a big way. The 2000s, these difficult years, is when we were really struggling to keep a company that was just not quite the right big enough scale afloat through the bookends of the dot-com crash and then the Great Recession. We had done the TI acquisition. And then it was roughly 2006 that Mark engineered the deal with Intel to get into the NAND business, and we started doing NAND in a big way with Intel.

There were a few acquisitions before that. In 2003, Toshiba-- which was one of the big mainstays of Japanese DRAM production, doing trench by the way, but they had enough, you know, and it was another brutal downturn-- we purchased their Manassas, Virginia fab, I believe it was for roughly 250 million dollars. We had to idle it immediately, partially because it was tooled for trench and we had to eventually move it over to stack, but that was our first 300 millimeter fab in the company. And, again, through a lot of difficult years we were only able to get it ramped up to about 50 percent production just because we didn't have the cash, but that fab actually ended up doing some really good stuff for Micron in later years. 2006 we did the Intel JV and got into the NAND business.

Fairbairn: So what did you bring to that, and what did they bring? What was the--

Shirley: Yeah, yeah. So what we put in-- I don't remember the exact terms of the deal-- but they came in with a lot of cash. We put Lehi into the deal, so each company walked away with half of an ownership stake in the Lehi facility. They had some operations or some potential operations starting in Singapore, so we collaborated over in Singapore for additional fab capacity. There was a set of non-volatile expertise that Intel brought into the picture, and then we brought in a ton of processing expertise including some of Tyler's original patents on how to do double and quad patterning, which eventually became the mainstay for NAND production, and to this day is still something that's really used by just about every NAND manufacturer and, you know, a lot of companies that are trying to push photo as far as they can. Intel came in with a few other pieces. We were collaborating on something called 3D XP, and this was a new non-volatile technology that had been developed by Tyler over at a company called Ovonics, and that Intel was working with Tyler on, and Intel put that into the JV as well, and so a lot of pieces to this.

And to Mark's credit and a lot of the folks at Intel, that JV actually lasted longer than most. JVs are tough in the world of business, but up through the mid-2000 teens that was a going JV, and both companies did well. NAND for us was something that we were looking at specifically for coupling together with DRAM to go into cell phones, so it was a very big mobile play. For Intel it was much more around solid state drives and how they could help the x86 franchise. We were trying to do solid state drives as well, that was a tough transition for us, we didn't have any controller expertise in the company or firmware expertise.

Sanjay, in later years, Sanjay Mehrotra who came in from WD and SanDisk, helped to really fix a lot of those issues, but solid state drives, that was all new technology for us, so some very difficult years.

So NAND in roughly 2006. In 2008, again, DRAM demand was lackluster in general, and it was clear that the world was headed for some kind of big financial event. Of course, this eventually became the Great Recession. We were in discussions with Qimonda at the time. So if you think about European DRAM operations, it was essentially Siemens in Germany that then spun off the memory operation or all the semiconductor operations into something called Infineon, and then Infineon spun off the memory operation into something called Qimonda. And roughly 2008 we started talking with Qimonda to see if we could engineer some kind of a merger because it was, you know, things were getting pretty brutal out there. And we ended up purchasing their stake in a Taiwan fab, it was called in Inotera at the time, and a pretty expensive fab, it was roughly $400 million for half of the fab. We felt like we overpaid, but frankly we were thinking that was a way to help out Qimonda because they were really struggling over there. And we had to idle the fab quickly because it was old trench production, and the profit sharing just really was not favorable, but we purchased that.

But pricing, again, continued to go down and down, and eventually the world, in late 2008-- I'm sure you remember-- the entire financial system just seized up, and it went from being okay to just horrible overnight. And that was probably as close as Micron came to having to cash it in again, that downturn. Ron Foster at the time remembers well, you know, we thought we were doing okay on cash, we had a little bit of cash, the company was still operating cashflow positive, we just weren't able to invest in any new things.

But in December of 2008, a Japanese consortium of banks that we had taken out loans from for this fab in Japan called their loans, and all of a sudden we had to come up with 90 million dollars, and we just didn't have it. And what Ron ended up having to do, you know, thank gosh for bankers that are allies, you know, Morgan Stanley ended up doing some good stuff for us that got us through those difficult times with some convertible debt. By the way, that debt converted, and the owners made a ton of money on Micron stock. There's a pattern here you can see coming. So in the year 2000, Micron stock, in the middle of the dot-com upturn, we were trading for something like $97 per share. April of 2009, we were at a buck sixty. And I remember standing in front of my all-team-member meeting, and you're talking to people whose entire retirement savings have been predicated on Micron stock, and you try to come up with answers, and you just-- look, all we can do is focus on what we can control.

And Steve Appleton was a master at that. I give Steve, who was the CEO at the time, just a ton of credit. He was masterful. When these downturns, you know, well before the bottom of the downturn, Steve would see it coming. You know, he had worked at Micron since 1984, had been part of the founding days. He would take his own salary to zero before anybody else, and I think through most of the 2000s he made no cash. It was basically his way of saying, look, I'm here with the rest of you, and before we do anything else I'm going to take the hit, and that made a statement to a lot of folks, And by the way, I mean back in those days we were still trying to hire engineers in Boise through a lot of the 2000s. In those days it was tough to get people up to Boise. Once you got them there, they never left, and so the--

Fairbairn: Right. Yeah. That was one of the big advantages, turnover there was much lower.

Shirley: Very, very small turnover, and so we did well in that sense. Anyway, April of 2009, stock at a buck sixty, and through Ron's help, through Steve and Mark Durcan's navigation, the company made it through. And DRAM demand took off, and I think within three months stock was back up to $6, which doesn't sound like much today, but relative to the low it was up 400 percent. So, and tough days for everyone, and Qimonda didn't survive those days. At that point it was really down to Samsung, Hynix, Micron, and then a company by the name of Elpida over in Japan, which was all of the old Japan DRAM operations put together-- Hitachi, Fujitsu, NEC, Matsushita, Mitsubishi, etcetera, was part of Elpida. And, as a matter of fact, it wasn't long after that--so, well, 2010, we had a bit of an upturn. Steve was really tired out at that point. I think he was, you know--

Fairbairn: It takes it out of you, yeah.

Shirley: Yeah. And through those years I remember sitting in board of directors meetings in 2008 and '09, and the board of directors, they'd ask us-- so, look you know, maybe it's time to get out of this whole thing called memory. And for us that was like telling United Airlines maybe it's time to get out of this whole airline business or something, you know.

Fairbairn: Yeah, there wasn't anything else, right?.

Shirley: What else do you know? Steve had been trying to build a business in imagers which turned into Aptina memory which eventually was purchased by ON [Semiconductor]. And that did okay, there were times when it was a good business, and then there were times where it was really just a distraction inside of the company and tough to marry up imagers and memory. And we missed a couple cycles because we were focused on the wrong technologies, you know, gearing up for imagers when memory would've done okay.

But 2010 was a good year and, by the way, in 2010 we were able to purchase Numonyx, which was the collection of Intel's and SG Thompson's memory businesses, NAND and NOR primarily, lower density NAND. And I'll give Steve a ton of credit, he understood that the businesses they were in were just going to be stickier in a lot of ways than the businesses we were in. We had done a pretty good job in the 2000s through these difficult days where PCs just weren't growing the same way they used to. We had pushed hard on the world of server memory, and I'll give the design and product engineering teams a ton of credit. In applications marketing, servers were a growing business, and we figured out how to get in and get a good leadership position with IBM and HP and Dell, and that turned into a pretty good business for us.

And then networking memory in particular turned into a very good business, and I credit-- networking memory-- we had some product lines that even in the depths of the downturn were still 70 percent profit margin kind of businesses. They weren't large businesses, but we were sole sourced out to the networking companies, you know, the Ciscos, Ericssons, Junipers of the world, and that helped us weather the 2009 downturn. But 2010 we purchased Numonyx, got that merged into the company.

Things started to go south again, but we were doing okay. And then unfortunately in February of 2012 Steve Appleton passed away in a plane crash, and that was very impactful to the company, you know?

Fairbairn: I was going to say, that must be a huge shock to the company.

Shirley: Yeah, it was tough. Steve had been a part of the fabric there since the day he started back in 1984, and I just had a ton of respect for some of the calls he had made. I credit him with giving us the wherewithal to get through all of those acquisitions and just through a lot of tough days, you know, Rambus lawsuits. I could tell you some tough stories about days, you know, bet the company kind of days where we had to decide whether we would go to court and fight what we knew was the right thing to fight for, but Steve was the one that really helped us do that.

The morning that it happened, Steve was coming in, I was going to meet with him about-- actually I was trying to buy some land from him in Boise on the other side of town, and he had said to come by at 8:30. And so I walked up to his office and saw April, his admin. And she said, oh, Steve's a little late, he decided to stop by his hanger at the Boise Airport, he's going to take out his experimental aircraft-- it was called a Lancair aircraft-- for the first time that morning. And she said, why don't you come back up about 10:00 a.m. or so. And so, I went back to my office which looked out towards the Boise Airport. And, geez, about 45 minutes later April called up, and she was crying, and she said, boy there's reports that there's been a plane crash out there of a single engine aircraft. And, of course, it was Steve.

And so Mark Durcan took over the company and did a fantastic job stepping into some big shoes to fill. But thank gosh for Mark because it gave us a chance to really rally around somebody else that knew the company inside and out and knew the technology and knew the value of production and everything else. But Steve is still missed, he was very, very important, impactful to the company.

Fairbairn: So throughout all these acquisitions, you were running engineering operations throughout that period, right?

Shirley: Yeah, yeah, became a VP of the company roughly 2006, and prior to that had been running the DRAM design group. And then 2006 started running all the business units in the company, and engineering which was really the DRAM and non-volatile design teams as opposed to the process development teams-- that was all under Mark at the time, Mark Durcan. And, yeah, my focus was on the getting products out, making sure that we understood the businesses, trying to look for the value-added businesses, putting some stickiness out in the market.

Fairbairn: So we've focused on the business stuff, which is great, and I really wanted-- happy to cover that. Are there some major sort of R&D breakthroughs, challenges, events that you'd like to highlight as part of that that really made an impact, or decisions? You mentioned the issue of some process technology choices which turned out to be big, big winners. What about on the sort of design side or the product side?

Shirley: Yeah, no, great question. So DRAM design through most of those days was make it smaller, faster, cheaper cost per bit. A lot of innovations that we did, and I'll credit a ton of teams across product engineering and design. My job at certain points was to come up with those ideas, so I've got 82 patents, a number of which are still used today. At the time the world was figuring out how to do sense amps and arrays better, how to get to CMOS, how to make the designs lower power, higher performance. But, again, we didn't focus so much on where the idea came from, we focused on could this make an impact in production.

So first to electrical fuses, lowest test cost in the business. We were first to using something called fuse id, which was a very innovative way of being able to know exactly which wafer location, all of the test information, fabrication information of any die that came back to us, and that made it infinitely easier to tell if there was a quality issue out in the field. Because there's always challenges out there, you know, you're never going to be perfect. Networking companies in particular, I mean these are companies that would go and put a thousand memory chips soldered down onto one board for high-end networking, and, boy, you better have low DPM quality figures for that kind of business. And you're going to have challenges on occasion, there's no doubt about it. How you react as a company through those kinds of challenges determines ultimately how good you are.

And ultimately a lot of that business turned into sole sourced business for us where these companies were comfortable enough buying from only Micron even after a quality issue or whatever. Sometimes it was because Samsung, who was making a ton of memory much larger than we were, was also in the business of doing their own cell phones or their own networking gear, whatever else. And Samsung at the time had a little bit of history of leaving some companies high and dry where, you know, if their cell phone business took off they would use their own memory, so that was a net advantage for us.

But to answer your question, most of my focus at the time was on technology in the sense amps, in the row drivers, and how we could keep things lowest cost per bit. So Micron was, we stayed with single metal. We had one routing layer all the way through 16 megabit generation. Most other companies had moved to double layer metal or triple layer metal, even starting at one meg. We stuck with single level metal through most of 16 meg, and that was unheard of at the time.

Fairbairn: Yeah, that's remarkable.

Shirley: And how you had to do power delivery, how you had to do routing through the arrays, how you got everything timed up. That's really where the bulk of my focus was.

Fairbairn: So you were describing things through 2010. So what was the, you know, 10 to 20, what were sort of the major--

Shirley: Sure. You know, the biggie, Steve passed away in February 2012. Later that year under Mark Durkin the last big acquisition happened which was Micron went into talks with Elpida memory in Japan. And Mark drove a fantastic deal. It was expensive, we took on some debt which we didn't want to do, but it was a two and a half billion-dollar deal, roughly another half a billion to purchase something called

Rexchip over in Taiwan that Elpida had been involved in, so roughly $3 billion of debt. But this was finally the DRAM capacity as well as the additional R&D space we needed to really be at scale in both DRAM and NAND, as well as to have all of the research and development we needed to do both NAND and DRAM well, so that was transformative.

And by 2014 or '15, the company was in good shape, and we were finally over the scale cliff, we were finally at a good leadership in both technologies. Still had some challenges in certain product lines, solid state drives still were not easy. But by 2017, '18, '19, the company was doing very, very well financially. And, you know, credit to Sanjay Mehrotra who came in. Mark retired roughly 2016. Sanjay and Manish Bhatia came in, Sumit Sadana, gave a great transition, and really know the memory business well and have kept that going admirably, and they're doing some fantastic stuff. Scott DeBoer, the CTO, he is leading the industry now both in DRAM and NAND process geometries. You know, the company's-- there's some geopolitical challenges out there, obviously a lot happening with China. I retired in 2019 on good terms. I still talk with Sanjay, Scott, Manish quite often. But it was time for me after 32 years in the memory business to find something different.

Started helping out the CHIPS office, saw a little bit of a front row seat to the start of the discussions around the CHIPS bill which went all the way back to 2019, some discussions inside of the Defense Department, and seeing-- it started up in Defense, moved over to Commerce. But tried to help out there with some perspective about what it takes to be successful in the world of memory, and some of the things that we learned in Asia, some of the things that are critical to memory operations. It is as tough and competitive as a business as you'll ever find. I just feel blessed to have had a front row seat through those years with just some massive geopolitical business challenges, the shifts. And I'll just say I was blessed to be under the leadership of Joe and Ward Parkinson, Steve Appleton, Mark Durcan, Sanjay Mehrotra. Every one of these CEOs really focused on what does it take to be a long-term leader in this business?

And through all those crazy, cyclical years that I mentioned, the one thing the company never lost sight of is protect the core, invest in core research and development, without that you're dead, and thank gosh we did that. The company had no safety net, and there was no one ready to come riding to save Micron. And, again, we made a lot of mistakes. I will say, without a safety net we were forced to be nimble, we were forced to acknowledge our mistakes and get them fixed. If we had a chance to do certain things a different way there's hundreds of them we would've done. But ultimately the company was pretty good at, with no safety net, rallying up what had to happen to save the company, and proud to see it thriving today.

Fairbairn: Well, as I listened, I've always been fascinated by the success of Micron, you know, in spite of everything, in the toughest of all businesses, often the netherlands and, you know, it's like how did they pull this off? And it's really been insightful in terms of some of the core values, focusing on the lowest cost per bit, keeping cost, cost, cost, cost. The fact that you had no safety net, I mean there were plenty of chances to bail out and go somewhere else as other companies did. They just said, well, the other things are better. You had no better, so you just had to make this work.

Shirley: Mind your knitting and keep at it.

Fairbairn: And then some incredible leadership. People like yourself, people like CEOs you've named. And the fact that you were at least based in Boise and separated from the rest of the world sort of worked to your advantage in many cases. So, there's all these things I can see came together to make for a very unique and tremendous experience, and congratulations.

Shirley: Oh, thank you. A lot of good people. I'll tell you, just the opportunity to work with all of those people, learn from them. You know, if you're not learning new things all the time, it's a challenge. And, bringing in some of the folks we did, finding them from schools across the country that no one had ever heard of, hungry people that wanted to come, and saw the magic happening out at Micron, what it took to keep that company afloat. They came in, and these were some of the hardest workers you will ever find. They wanted to be a part of that success, and they were hungry. No egos. Everyone put their ego aside, and we got down to just a lot of hard work and saving the company through a lot of different innovations, a lot of different things it took at various times. But my hats off to Joe, Ward, Mark, Sanjay, Steve Appleton, the whole crew, it's been an incredible blast, so--

Fairbairn: Yeah. What an incredible run of CEOs and leadership and so forth. So I'm sure there's a lot more we can talk about, but I think it sounds like we've run our course for today, and hopefully we can meet again some other time.

Shirley: That sounds great. Thank you.

Fairbairn: My pleasure.

END OF THE INTERVIEW

