Oral History of Sanjay Mehrotra

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Kapoor: On behalf of the Computer History Museum, I'm Uday Kapoor. I'm a volunteer in the programs here that we record oral history. Along with me is Doug Fairbairn. And we welcome you, Sanjay Mehrotra, for your oral history. You are a very well-known executive in the non-volatile memory business. You recently moved from the company SanDisk to Micron. And you were the founder of SanDisk. You also – so, SanDisk, of course, is a company that has changed the world in terms of the flash business both in the hard disk drive – taking away business from hard disk drive business, and also for the cameras. There is no longer any film in our cameras. So, then, of course, you moved to Micron, which is an iconic global memory and storage company headquartered in Boise. And you've guided the company to record revenues in fiscal 2018 of thirty billion dollars. And you continue to lead Micron with a focus on execution. So, with that, we get started. Let's start with your birthplace. You were born in Kanpur. And just tell us about your early childhood.

Mehrotra: I was born in Kanpur, India in 1958. I grew up in a joint family that had included my uncles and aunts and my grandfather and grandmother as well, in a large, big home. And I was still just a few years old when my parents actually moved out to another house in Kanpur. And we were raised in a middle-class family in India. But my dad and my mom, they were always very passionate about education and wanted to make sure that their kids go to the best schools possible. And I grew up in Delhi until I was – I'm sorry. I grew up in Kanpur until I was about ten years old, which is when my father moved to Delhi.

Kapoor: So, you have certainly mentioned your dad as a mentor of yours. What did he do? What was his profession? And how did he influence you?

Mehrotra: Yeah so, when I was in Kanpur being brought up there, he was a liaison officer for the cotton industries. And Kanpur had cotton mills, Lal Imli cotton mills. So, he was actually a liaison officer. And when I was ten years old, in that same job function, he moved to Delhi. And in Delhi, I went to Salwan Public School. At Salwan Public School, I did my seventh, eighth, and ninth grade. I used to live in Jangpura Extension, which was kind of far from where Salwan Public School was. It was in Rajendra Nagar.

So, I used to take a public transportation bus, which used to be extremely crowded and usually very early in the morning to get to the school. And in ninth grade, I was also taking mechanical drawing. So, that required us to carry those big mechanical drawing boards on which you learned drawing and did the mechanical drawings. I used to carry that mechanical drawing board and the T that would go with that on that bus. And as a small kid, it used to be a little gruesome journey. And that's when my dad decided that it was too far for me to go to school, and he switched me. And my parents encouraged me to switch over to Sardar Patel Vidyalaya, one of the top schools in Delhi today. I joined that school for tenth and eleventh grade.

And of course, my dad and my mom always have been a major force in my life. Certainly, dad was extremely dedicated to looking after the education of all of his children and even while he would be busy with his work. And as I mentioned before, we were raised in a middle-class family. I think they gave us good values and good attention in terms of education and focus and doing well in school. That was always important in our family.

Fairbairn: So how many siblings did you have?

Mehrotra: I have one brother and two sisters. I'm the youngest of the four. So, soon after we moved to Delhi, my elder brother, who had graduated from Bombay IIT, he moved to the U.S. to go to his graduate school here. And he later did his master's in industrial engineering as well as his MBA from University of Chicago. And he has been in Chicago area. And now he's retired in that area. And he always worked at hospitals in the IT part of the hospital industry in Chicago.

Fairbairn: So, when you were growing up, your parents emphasized education. Did they care what you did? How did you end up being steered towards technology?

Mehrotra: I think I got steered toward technology because I was always interested in math and sciences and did well in those subjects. So, I enjoyed studying them, but also, perhaps most importantly, got influenced by my elder brother, as well as my elder sister, who were both engineers as well, who studied engineering. As I mentioned earlier, my elder brother did his BTECH in mechanical engineering from Bombay IIT. And my sister had done her bachelor's in electronics engineering from Roorkee University. So, they were both elder to me, and I think they influenced me toward studying engineering. And that was not a hard choice for me because I enjoyed math and science kind of subjects in my high school.

Kapoor: So, you graduated from the Sardar Patel school with higher secondary.

Mehrotra: That is right.

Kapoor: And after that you were looking to go to Pilani, I understand?

Mehrotra: Yes.

Kapoor: Your dad steered you into Pilani because – can you recount what happened there?

Mehrotra: Yeah so, then I graduated from Sardar Patel Vidyalaya in New Delhi with my higher secondary, which was eleven years of high school, at that time, I applied for admissions to various engineering institutions, IITs as well as Birla Institute of Technology and Sciences in Pilani and Delhi College of Engineering. I was admitted to IITs, but I was getting admission at IIT Kharagpur, which was kind of far from Delhi in the field of interest for me. But my dad always felt that I should go to BITS Pilani because, at that time, BITS Pilani was in collaboration with MIT and Ford Foundation. So, my dad always had the vision actually to send me to the U.S. for my undergraduate studies. And I just want to point out that in those days, especially coming from a middle-class family, it was a pretty big vision on his part. It's not like we had all the financial wherewithal for me to come to the U.S. and study in the U.S. on my own. Not necessarily knowing all the answers on how it will financially be funded, he had that vision. So, actually, after my higher secondary, I had explored admission into the U.S. But they told me that because I had eleven years of high school, and in the U.S., you do twelve years of high school, I was not eligible to apply.

So, my dad always thought that I should go to one of the engineering colleges where I can later transfer over to the U.S. Because of a Ford Foundation and MIT collaboration at BITS Pilani, he thought that

would be the right school for me to go to because it will help me to come into the U.S. given the strong connections BITS had with the U.S. institutions. So, I went to Pilani. And during the course of the first year, I actually applied again to come to the U.S. schools. At that time, they said that your eleven years of high school plus one year of college corresponds to now twelve years of high school, so I can come in as a freshman in college. And somehow, I didn't like that idea because I had felt I had done one year of college.

Anyway, long story short, we go through the second year at BITS Pilani. And during the second year, I applied again. And this time, lo and behold, I got full credit for all two years of college done in India. I was admitted as a junior transfer student to the U.S. universities. I actually had three admissions at University of Illinois Urbana-Champaign, Illinois Institute of Technology, and University of California Berkeley. And I had only applied to these. No, I must correct myself. I had applied to MIT as well and actually got declined there, didn't get admitted at MIT. And the reason that two of the schools were in Illinois because my brother was in Chicago. And really, he was a source of big support for me when I joined and, certainly, a source of strength to my parents to be able to send me as an eighteen-year-old to the U.S. because they knew that he is here. And he can help me if I needed any assistance. So, no doubt that my brother was very instrumental in me getting started with my education here in the U.S.

Kapoor: So, how did you choose Berkeley then?

Mehrotra: So, Berkeley was an extremely renowned university, right? It has been for more than a hundred years around the globe. So, Berkeley had a great name. So, I was thrilled when I got admission at Berkeley. And actually, my brother's good friend had gone to school at Berkeley. He had gone to graduate school at Berkeley well before me. So, through him, also knew about the university quite well. But most importantly, the university was well-known in India. And it was well-known as a top science, liberal arts, engineering institution around the globe.

Kapoor: So, I understand you were only seventeen years old at that time. And I understand that there were some issues with the visa, and you have talked about that several times. I'd like for you to maybe say a few words about your dad and how he inspired you.

Mehrotra: Sure so, it was the summer of 1976 at the end of my finishing second year of college at BITS Pilani. As my admissions were coming in from U.S. institutes, my dad and I went to the U.S. embassy to get student visa to come to the U.S. And we got denied the student visa. That was with the admission from Illinois Institute of Technology. And then came the admission from University of Illinois Urbana Champaign. So, we said okay, we'll use this new admission letter and go apply for a student visa again. That was the second time. We got denied again within a matter of a couple of weeks. And soon after, an admission letter comes from University of California Berkeley. So, my dad and I go marching into the U.S. consulate – U.S. embassy in New Delhi again applying for a visa. And we got turned down the third time.

And the third time when my visa got turned down, my dad said that he wants to talk to the U.S. consul there to understand why they keep turning down my visa. And we really had no connections, or U.S. embassy would just not talk to anybody. The consul would not talk to anyone. They did not have to give any reason for why they were turning down my student visa. And they said no, my dad can't talk to the

consul. Somehow, my dad had seen the U.S. consul's picture in the lobby of the U.S. embassy there. And somehow, he had gathered the information that the consul was actually on a lunch break. So, my dad said to me that let's just wait here in the lobby. Maybe he'll come through those lobby doors after his lunch hour, and we might get a chance to talk to him.

And sure enough, that's exactly what happened. And as soon as he – the consul walked in, my dad tagged along with him. And I followed my dad with him. And my dad tried to talk to the consul about my case. The consul was trying to shrug his shoulders off and not interested in talking to my dad. But somehow, my dad managed, as the consul entered his office, to be in his office as well with me following him into the consul's office. The consul said he doesn't have to talk to my dad. And he said, "Your son is old enough. Why do you have to talk to me?" And my dad said that, "He's not eighteen yet. I can represent him. He's not an adult." And for the next twenty minutes, my dad really literally pretty much blasted the consul that how can he deprive me of admission to such a renowned institution, opportunity to study at such a renowned institution like University of California Berkeley. And does he realize what does it mean for my future? And for the next twenty minutes my dad really went at the U.S. consul, who quietly listened to him. And my dad always had a very strong presence, a very handsome man, very articulate man, very passionate, short tempered, and always not taking no for an answer in things that he believed in. So, for those twenty minutes, it was like he was my, not only a detective at that time in the lobby, finding out that the U.S. consul would be coming, he was like my trial lawyer. He was like my manager and of course my parent. And at the end of the twenty minutes, the consul said, "Okay, give me your passport." He went back, stamped the visa, came back.

My dad hugged me, and you know I just could not believe. It was the performance of a lifetime that I'd watched at that time. And that's the moment when I truly learned, and it has stuck with me, that if you seek success, start with tenacity. And that's what I like to say. At that moment, my dad had absolutely shown tremendous amount of tenacity, and passion, and conviction, in terms of pursuing the case for me. And I can't even imagine that if he had not done that, and if I had not got my visa at that moment, what would have been my life. I don't know. So, and that does also go to show that luck absolutely has a lot to do with it. There is no doubt that, at that moment, we were lucky that my dad got the chance to talk to the consul. And we were lucky that the consul actually was gracious enough to be able to give my dad a chance to present our case. So, those are all really very humbling memories that have always stayed with me and have absolutely shaped my life.

Kapoor: Thank you. So, then you came to Berkeley. Tell us about your early life in Berkeley. And did you have a scholarship at Berkeley, or how did you fund your--?

Mehrotra: So, when I came to Berkeley, my brother in Chicago, his name is Pramod Mehrotra, he had committed to sponsor me. And he did sponsor me financially. And I'm very grateful to him for doing that. He, himself, actually was a young man. He was only thirty years old. And he was taking the responsibility to sponsor his brother. Perhaps as eighteen-year-old, didn't fully appreciate what that means. But as I grew up later, I really gave him tremendous credit for helping me out as well.

Fortunately, I needed financial assistance for one quarter at Berkeley, only one quarter. And after that, I was able to find on campus jobs as well as was able to get financial aid at Berkeley to support myself

independently. So, you can say that pretty much from eighteen-year-old onward, I have supported myself on a financial basis. So, I supported my undergraduate as well as graduate education. I'll tell you the first job that I took on the campus was in the International House dormitory on the campus, the dining room in that dormitory, collecting the dirty dishes that was all after every – all the students had finished their meal. They would leave their dirty dishes in a certain window. Collecting those dirty dishes and making sure they get emptied and get loaded into the dishwashers, that was my first job.

But I'll also tell you I just did not like it. And very quickly, I figured that I need to find something else. I just did that only for a few days. And I was able to then find additional jobs related to grading homework of the students, becoming a reader there. And I had learned from my dad's persistence. So, I went to the financial aid office and would routinely go talk to the people in the financial aid office expressing that I would like to get assistance and file my applications followed through successfully. And University of California Berkeley, especially after looking at my grades during the first quarter, the university actually gave me financial aid as well. So, between the financial aid and between the various jobs that I did on the campus is how I supported my education there. In those days, you could not do a job as a foreign student off campus. It had to be a job on the campus.

Fairbairn: So, what was your experience coming to Berkeley for the first time? You had grown up in India. You had never left India before, is that correct?

Mehrotra: That's right.

Fairbairn: So, what was it like coming to California?

Mehrotra: It was an incredible experience. Not only had I not left India, I had actually never even sat in an airplane before taking the flight from Delhi to come to Chicago first to see my brother, and then from Chicago fly over to San Francisco. And I remember that the friend of my brother's who had gone to University of California Berkeley many years before, he had told me at the time, and this we are talking about 1974, and my brother's friend had gone to Berkeley in late '60s, I remember him telling me in that summer of 1976 that there is lot of grass in Berkeley. Sit on it, but don't smoke it. Okay? So, yeah, and I didn't quite get it that what is he really talking about. So, I came to Berkeley. And Berkeley was just a delightful experience for me. When I landed at San Francisco airport, Berkeley had a great arrangement, International House, that they would send one of the foreign students to come meet you at the airport, pick you up, and bring you to the campus. And a friend of mine that you might know, Rama Shukla, he's also in Bay Area, has had a hugely successful career at Intel Corporation, he was actually doing his Ph.D. in Berkeley at that time.

He came to pick me up in San Francisco airport. And he was kind enough that he let me stay in his apartment for like slightly over a week because I did not have any housing arranged when I came. And I remember that I had never encountered such a housing crunch, which, believe it or not, used to be there even at that time in 1976 in Berkeley. And because I was coming in very late, all the housing was already committed for. So, I was trying to find a roommate. And so, I had found another student to partner with. And we both were together searching for an apartment to share. But I also used to go stop by International House every day trying to tell the administrator that I needed a dorm room in that dorm. And

she would tell me that it's all totally sold out. It's all booked. There is nothing left for the quarter. But I would still go to her every day and keep asking for it. And again, the same tenacity that I had learned from my dad just keep on checking every day, keep on trying every day, not giving up. Sure enough, a vacancy came up. And she gave me then actually a room in the dorm, of course, a room to be shared between two. And that was a huge relief for me.

But during those first ten days or so when I was still trying to figure out where am I going to stay, whether am I going to find an apartment, and apartment hunting at that time, and school had already started was very hard. I remember it was a very tough period for me. I used to, on Bancroft Way in Berkeley, sometimes sit there and just cry wondering where am I going to find an apartment and – but anyway, that experience in International House was excellent for me because that's a place that students – mostly, they were graduate students. I was one of the very, very few undergraduate students in International House. Most of them would come from all over the world. So, it was a great melting pot. And it was really, for the first year of my education at Berkeley, a great place for me to stay. So, in terms of the hassles of being in an apartment and managing my life, it became easier because the choice of living that dorm for the first year was easier for me.

On the education front, I remember that the first quarter, Berkeley at that time was on a quarter system, the first quarter, taking basic electronics and some math and some physics and some chemistry course, I remember that I was quite struck by the amount of intelligence that would be in the classrooms and how great the professors were. And I really felt quite inferior to all the bright minds in the rooms, and worried that am I really going to be able to compete here and do well here among all these kids.

In other part, I remember in those early months of education at Berkeley was that the labs and the system of hands-on experimentation and the equipment that was available for you to work with in the labs was really head and shoulders above what I had seen in the labs back in India at BITS Pilani. And so, I clearly remember how much I was taken aback by the ability to do so much in the labs. And it took me a little getting used to to be able to work with all that equipment, while all others seemed much more comfortable tinkering with stuff. That combination, even though it was intimidating in the beginning, but it really channeled me into focusing on working hard, learning hard. And I was also quite impressed with the system of – the office hours that the professors had where you could go and easily ask questions and the genuine interest that the professors showed in you, I think that all just helped me learn. And coming from India, even in the beginning, getting used to all the American accent and stuff in the classrooms also took a little while.

Kapoor: Also, the classroom sizes used to be pretty large.

Mehrotra: Classroom sizes were large. But even the setup of the classrooms, right, all of that was absolutely foreign and definitely quite intimidating and worrisome. I remember writing to my dad that I'm taking a class from a Nobel prize winner here in physics. And I don’t know if I'm going to be able to make it through this class. And there to be such really, really sharp students here. And my dad, later in his life, often reminded me about that letter and those feelings. And he always used that to remind me that how many times in life things can appear very daunting, but life has amazing ways of showing you how you

can get through them. And you look back at them, and they – it's hard to believe that, yes, you came through all of that.

So, my experience at Berkeley was amazing. I loved Berkeley, great university, beautiful campus, excellent students. I got a really warm reception from all the students, American students or foreign students. It was just a terrific place. I really give Berkeley so much credit for my education, my learning, and what I have achieved in life. I really feel that – an amazing institution, and, again, I feel lucky to have got admitted there. I don't think today, if I applied with the competition that is there, especially in electrical engineering and computer science, coming in as an undergraduate, I doubt that I would get admitted if I was applying today if I was an eighteen-year-old doing that. But so, my experience extremely positive from Berkeley.

Fairbairn: So, did you begin straightaway with electrical engineering/computer science? You'd already chosen that as a path?

Mehrotra: Yes, I had. That's what I had applied for because I was coming in as a junior transfer. And they had given my full credit for the two years of work I had done in India. So, I actually finished my undergraduate when I had just turned twenty. Actually, when I graduated, I was still technically not twenty yet. And then I went on for my master's at Berkeley as well. And for my master's, I actually chose an advisor, a well-known professor, Professor Bill Oldham, very renowned professor at the time in integrated circuit processing.

So, I actually chose to work with him for my master's thesis and research work. I got the research assistantship with him. And that – as a master's student, I took all the courses in IC design as well as device physics and integrated circuit processing, but my research focused on IC processing. And I remember working in the labs, I think it was the 4th floor in Corey Hall, on the University of California Berkeley campus at all hours of the night running experiments for my master's research. And my research was dedicated on photoresist modeling at that time. From the work that I did in the research, I got through the research and got my thesis done, but I knew that I did not want to be a process engineer. And I decided that I really want to go into design.

Fairbairn: Were there any other professors that were particularly influential in your time there?

Mehrotra: Absolutely, Berkeley had I think at that time absolutely the top program in integrated circuits, which was absolutely a hard field. We are talking about late '70s at that time. Semiconductors was the field to study. And Berkeley absolutely I believe had the top program in IC design, process, device, excellent mix of instructors there. So, yes, amazing professors that I remember extremely fondly that I took classes from, took graduate classes from not only Bill Oldham, but Professor David Hodges, Professor Donald Pedersen, Professor Paul Gray. I mean you know these were like the – today, the industry legends in terms of the contributions that they made. Even Alberto Sangiovanni-Vincentelli on the CAD side, I took classes – actually, I was a teaching assistant for his classes. And just really – I loved it. I loved my days. I learned a lot. And it was professors, the labs, the research opportunities were simply outstanding. And I was able to soak it in.

And my classmates, amazing classmates at that time, Charlie Giancarlo, who became well-known at Cisco and, today, is also the CEO of Pure Storage, was actually one of my classmates at that time. Charlie Sodini, another classmate of mine, who is now a professor in electrical engineering at MIT. There was a Peng Cole who has gone on – I mean amazing researcher, went off to – now, I think he's in China and became a leading professor in China. Also, Mark Liu, which is the – today – I mean became the CEO of TSMC and is the chairman of TSMC today, also a classmate of mine. So, it was really a terrific bunch of students there who especially IC, semiconductor, Berkeley was the premiere institution. And the classmates went off to accomplish amazing things all across the industry, all across the globe.

Kapoor: So, on the family front, you were connected with your parents and your siblings and so on at this time?

Mehrotra: Absolutely, you know those days, it used to be mostly writing letters, typically writing letters and those aerograms that used to be there in those days. Once a week, I used to write to my parents and used to regularly receive letters from my parents. My dad also was a prolific writer. So, letters that he would send would tend to be very, very long and very inspirational. Sometimes, he would even write some poems in those letters. And it was always a thrill to be receiving those letters. And phone calls would be expensive. And I really did not have that much money. So, phone calls would be a very rare thing. And actually, at our home in India, in our home, we did not have a phone. So, if I ever had to call him, or call my mom, which was very, very rare because of the expense involved, it typically used to be at a neighbor's place that you would call. And a neighbor would get ahold of them. And then we would talk to them. So, times are today very different. We all have phones in our pockets.

Kapoor: Were you getting any pressure from your parents about finding a mate and getting married?

Mehrotra: No, I was still very young at that time. And I was at Berkeley, right? When I finished my master's, I was still technically only twenty. But so, I was still very young. And then the focus was on getting a job. And in terms of getting a job, here I have to give credit to the second mentor in my life, to the professor, professor Bill Oldham at Berkeley who was my thesis advisor. My first mentor for my life I always considered as my dad, who absolutely shaped my life all throughout my growing up years and later in life, as well. But Bill Oldham, I call him as my second mentor because, even though I decided that what I was doing research with him was not an area of interest for me to pursue in the industry, when I was looking for a job, he understood that my interest was to go work in design. And he said that there are three great designers in the industry that you should go and talk to.

And one of them was Bob Proebsting at Mostek in the DRAM area. Another one was George Perlegos, who was at Intel Corporation working in EPROMs then. So, the third was Federico Faggin at Zilog at the time. And he said these are the top designers in the industry today. And you should go talk to them. And he set up my interviews with each of these three professors.

So, just imagine a graduate school professor taking interest in a master's degree student to set up – and it's not like emails were that prevalent. I mean they were not prevalent at all. They were nonexistent at the time, but he set up my interviews with those three professors. And I was actually very particular. I wanted

to make sure – my heart was sort of set on Intel even before the interviews, because Intel was well-known on the campus, you know, as the company to work at and, you know, moving fast kind of company. So I actually made sure that before I interviewed with these three companies I had several other interviews to get practice. And I really enjoyed the experience there because I was – this was 1979, when I was going around the country interviewing, which was kind of cool for me, that I had lived on a very frugal budget all those years and now companies were paying for my airfare to fly me places, and interview me, and, you know, dine me. I did not drink at that time. So I can't say "wine and dine" me. But they were definitely dining me. So it was a cool experience. I ended up with 11 offers, but I absolutely made sure that Intel was one of my last jobs to interview.

I got to work with George Perlegos at Intel, and that was really, really life-changing for me, because I had got great education at Berkeley, but George is the one who really taught me how to design well and not to focus only on design. He was very good at focusing on innovation and finding practical innovative solutions to problems. You know, such as device problems that could be addressed through design and EPROM design at the time. But also George very much focused on – that, when you design, you need to understand device and process well enough so that you really have a holistic view of a design and not only stop at that. Think of yield. Think of how you will test the product, how you'll make test efficient, and how to then implement test features in the designs. So this is, you know – I considered it really incredibly fortunate of me to have had a chance to work under George as my first job out of school. Because think about it. You know, designing for test, designing for manufacturing, designing for quality – all of these things became buzzwords in the industry much later. Whereas he had ingrained those aspects in me from the day one of my job at Intel Corporation under him. And Intel itself was just a great university, because not only did you learn about the job and people that were so driven, so passionate at the time there, but Intel invested in you in terms of teaching you a lot of other things, too. Right? You know, in terms of how to manage a project, you know, how to be a manager even though I was an engineer, but I saw that there was a great environment of learning. All the time. Everybody, even managers, focused on learning. So I really felt that I got great lessons from George Perlegos as a mentor, but also Intel Corporation was yet another wonderful university for me.

Kapoor: So this is the time of the non-volatile memory domain that you were involved with.

Mehrotra: Yes, so my first job that I started after leaving UC Berkeley graduate school was working in non-volatile memory. It was actually an EPROM. Working on an EPROM test chip which had a full-blown 64 kilobit of EPROM at that time. So I'll just repeat. At that time, it was 64 kilobit. I mean, you know, now we talk about 64 gigabyte level of chip capacities, but at that time it was 64 kilobit. This is what I was designing in 1980. And George was the golden boy of Intel in non-volatile memory. He took me under his wings. He taught me design, and he gave me the responsibility to design that whole chip by myself. And I know that today the chips are much more complex, and they have, you know, a lot more logic as well as analog functionality on them. But even at that time to have a responsibility for a new college graduate to do a full-blown 64 kilobit chip, which was a test chip, but still, having a full responsibility – and it was a test chip on the next generation process. It was really a wonderful opportunity for me. And I was so excited to work on it. I used to work until seven, eight P.M., go home, quickly eat dinner, and come back, and then work until two or three A.M. So those were my single days. Right? I was wedded to my job.

Kapoor: Was Dov Frohman there at that time?

Mehrotra: Dov Frohman was absolutely there, and actually I had, you know – one of the things that I worked with George also was oxide injection modeling. And Dov Frohman was a well-known authority in oxide injection modeling, not only for EPROMs but also for electrically erasable programmable read only memories. And so I had the opportunity to interact with him as a young college graduate and just learn from him. And I many times saw him in action in the meetings and, of course, he's one of the pioneers of non-volatile memory. And he was there. At that time, also, Eli Harari was there at Intel Corporation. Eli Harari was a peer to George Perlegos in a different group. My introduction to Eli happened at Intel when I presented to Dick Pashley, who was also, you know, one of the well-known figures at that time in the industry, who was George Perlegos and Eli Harari's boss at the time. In Dick Pashley's staff meeting one time, I presented on redundancy modeling and yield gain as a result of redundancy and modeling all of that. And Eli – and this is all happening within my first year out of college. And Eli was actually quite impressed with my presentation and he came and reached out to me, introduced himself. And Eli had this great ability to stay in touch with people. Especially – and I saw that in him all throughout the years, you know, many decades, even to this day, in terms of staying touch with people, especially technologists, engineers – and that's where I got to know Eli. And, sure enough, eight years later, Eli and I and Jack Yuan, you know, partnered to start SanDisk Corporation, where Eli, of course, was the lead founder of the company.

Fairbairn: You were only at Intel for a couple of years, right?

Mehrotra: That is right. I was at Intel for a couple of years.

Fairbairn: How did that play out?

Mehrotra: Yes. Yes. George Perlegos, at that time, he left Intel to start a company called Seeq Technology. It was S-E-E-Q. And it was a startup spun off from Intel, and several of Intel executives had actually started that. So, George was one of the founding members of Seeq Technology. He was the boss that, you know, I had close ties to. I was learning a lot from. And I absolutely felt that I wanted to follow him to Seeq Technology. And I do remember that Eli Harari actually had, in the same timeframe, left to go to Synertek. And Eli had tried to recruit me to Synertek as well.

Kapoor: Yeah, there was a big effort to – for Flash. You know, he built a big Fab in Santa Cruz, basically looking at division. But anyway, that's another <laughs>--

Mehrotra: Yes, yes. So I followed George to Seeq Technology and that was in 1982. And I was there until 1986. So I joined Intel Corporation in 1980, January, and I moved – actually, for six months I went to a company called ZyMOS. And I left – after Intel and after ZyMOS I went – I did not like the work at ZyMOS – and I went to George Perlegos at Seeq Technology, which I joined in 1982.

Fairbairn: So given how much you were learning and excitement at Intel, what got you to go to ZyMOS?

Kapoor: So, in fact, related question. At Intel, were you already looking at the Flash technology and research?

Mehrotra: At that time, we were not looking at Flash, but Intel was, of course, a pioneer, a leader, in EPROM memories. But E^2PROMs, electrically erasable read only memories, they were in their early days in those days.

Kapoor: With a floating gate.

Mehrotra: With a floating gate. Electrically erasable read only memory. And in those days, you know – the first – before the EPROM that I worked on, it used to need 12 volt for programming. The prior generation actually had needed 21 volts for programming. E^2PROMs at that time also needed like 21 volts of an external power supply. And the innovation that was being talked about in the industry at that time was how to make a five-volt only E^2PROMs. So when I left Intel that had not happened yet. Five-volt only innovation had not happened yet. It was actually Seeq Technology that did the first five-volt only E^2PROMs and, at the same time, Zycor Corporation, which was another startup at the time, had also done five-volt only E^2PROM breakthrough. Both Seeq and Zycor were competitors.

Fairbairn: So what got you to ZyMOS?

Mehrotra: Yeah. So ZyMOS was about ASICs in those days. And so there was a part of me that said, okay, you know, ASICs is an upcoming field. And I said, you know, I'm doing memories, but maybe I want to learn about ASICs as well. So I joined ZyMOS because it was a startup in ASICs and I definitely wanted to join a startup.

Fairbairn: So you had the entrepreneurial spirit early on.

Mehrotra: So it was not starting a company, but absolutely being part of a startup was absolutely in me and I wanted to experience that. So I joined ZyMOS because I thought it would be a startup, as well as it would be in an area toward ASICs, so I thought this will be cool for me to engage in this. But I must admit that I didn't quite – in those days, at least, the work at ZyMOS I didn't quite enjoy. And then I think I'd got the non-volatile memory bug and I went to Seeq Technology.

And earlier you were asking me – parents talking about marriage, right? So my parents actually came to the U.S. in 1981, and they actually lived with me. And then, in 1984, while I was still at Seeq Technology, my parents went to India, and I actually went to India, and that's where I met my wife. My parents introduced me to my wife, so I had, you can say, a classic arranged Indian marriage. But I had a chance to meet my wife, and we went out on a few dates, and then we decided we both liked each other and you know. Those days, in Indian system, you didn't mess around too long. You had to decide whether you were getting married, whether you're serious, whether you were committed or not. And I think we were married within about a couple of weeks of us meeting for the first time. And so this was in 1984. So this year I'm completing 35 years of my marriage in April.

So getting a visa for my wife in those days would take a while. I had – when I joined Intel, I joined on a foreign student visa, on my H visa. And Intel had sponsored my green card. And through Intel I had already received my green card, but as a green card holder, for my wife to come to the U.S. it would take a long time. So George Perlegos left in 1984, Seeq, to start Atmel Corporation. There were going to be four co-founders of Atmel: George; his brother Gus; and T.C. Vu, a process technologist at Seeq; and I. And I had resigned from [Seeq]. And Floyd Kvamme, who was a board member at Seeq and actually was – through Kleiner Perkins, was an investor in Seeq – he got wind of it, that I was going to be leaving the company. He took me to lunch, tried to talk me out of not going to the ATMEL team, with the Atmel team to start Atmel. And very smart of him that, at that – during that lunch, he figured out that I was newly married and that my wife could not come to the U.S., and he exploited that to the fullest. He suggested that he will arrange for me to go to U.K., to Europe basically, and work for Seeq in Europe so that my wife could come to Europe, because U.K., coming in at that time for her just as a visitor was easy. She could not even come to the U.S. as a visitor until her green card was completed, which was like a good one year-plus cycle.

As a young man, you know, I jumped at the opportunity to be with my wife in the U.K. So I immediately – within a matter of less than a month actually I was in U.K. And George was still trying to get his funding. So George said, “Go ahead. You go to U.K., and once I get my funding then you come back.” Once I went to U.K., my wife came there. I was European Applications Manager in U.K. Before that, I was always doing designs. I had done EPROM designs and at Seeq I was doing E^2PROM designs, doing five-volt only E^2PROM designs. I had done the first five-volt only E^2PROM with Hamming code-based error correction inside the chip, and I had actually presented that at the 1983 International Solid State Circuits Conference as well. But in U.K. I worked as European Applications Manager, and it was really a humbling experience for me and truly transformative, because until then you are designing the chips and you think you are the hottest designer, and you think you design the best chips in the world. But then, when you see how customers are applying them in their applications, and when you see some of the challenges that they face, and you learn from those challenges, it really is a humbling experience on how you can do your designs even better and how – I learned how you can keep application in mind, not just data sheets in mind, in terms of how to design the right solutions. So I think that experience, which I just stumbled upon in terms of working so closely with customers very early in my career, I stumbled upon it because of Floyd Kvamme who, you know, encouraged me to go to the U.K. to be with my wife during that period. That really turned out to be a very, very valuable experience for me. So I was there for one year. In the meantime, my wife got her green card. And while I was there, a few months into being in the U.K., George Perlegos calls me and says that he has got the funding. And he says, “Now you come back. Join me.” I felt very guilty that Seeq and Floyd Kvamme had done so much for me in terms of enabling this opportunity and enabling a great learning experience professionally, but really addressing my personal situation at that time, enabling me to be with my wife while she was waiting for her U.S. green card. I felt guilty and I decided not to join Atmel at that time.

Kapoor: So there was another question I was going to ask you. So did you have – did you interface with Dado Banatao?

Mehrotra: Yes. Very much so. So--

Kapoor: Dado and I actually were at Synertek together, then he left to go to Seeq to work on processors.

Mehrotra: Yes. That's right.

Mehrotra: Dado was amazing. He actually worked on ethernet controller chips at that time, and processor chips. He was absolutely amazing and had wonderful opportunity to get to know him at Seeq Technology as well. So after Seeq, where I had done five-volt only E^2PROMs, I actually went to Integrated Device Technology as the Design Engineering Manager, and I – IDT had – was well-known for static RAMs, but they had started a program in integrated device – in E^2PROMs as well. IDT had started a program in E^2PROMs which was not going well. So they recruited me to turn that program around, and I remember debugging chips that were designed by somebody else, and trying to figure out what all was wrong in those chips and really microprobing those chips on the micromanipulators in those days, which required – to debug, you know, a circuit that was fairly broken, I remember I used to put four or five microprobes down manually to try to force signals, to try to debug what was happening in the circuit. And we got it to work. We actually had a five-volt only 16 kilobit E^2PROM that we got to work, and we did designs of 32 kilobit and 64 kilobit E^2PROMs.

And this I'm talking about now 1986, 1987 timeframe at Integrated Device Technology. However Len Perham was the CEO there at that time. John Kelly, again, well-known figure, was chairman at Integrated Device Technology. Extremely successful company in static RAMs, but it is absolutely correct that E^2PROM was a total distraction for them. Not really of – adequately resource program. Len Perham, very rightfully so, decided that E^2PROM is not something that IDT is going to pursue, so they canceled the program. And I remember they gave me a choice at that time, that I can move into static RAMs – they wanted to keep me there – or I will have to part ways with the company because they had canceled the program. And I chose that I – I loved non-volatile type memory so much I decided that I did not want to go into SRAMs. And that's when, actually – it happened to be quite a coincidence that Eli Harari was also actually leaving Wafer Scale Integration where he had gone to after Synertek. And the two of us got in touch because he was already – had left, essentially, Wafer Scale. This I'm talking about April of 1988. And so Eli had worked with Jack Yuan, the third co-founder of SanDisk, at Hughes Aircraft, even before he had come to Intel. So he knew Jack Yuan even before 1980 timeframe. He knew him from seventies timeframe. So the three – Eli brought in Jack Yuan, and Eli and I knew each other from Intel days. I had just left Integrated Device Technology. Eli had just left Synertek, and Eli absolutely had the vision for Flash technology at that time.

Kapoor: So I want to ask a question. So up until now you're talking about E^2PROM, and that was byte erasable.

Mehrotra: Yes.

Kapoor: So all of the applications were really at byte level, right?

Mehrotra: Yes.

Kapoor: So there was not a concept of the block or the large data, right?

Mehrotra: That's right.

Kapoor: Okay, just wondered.

Mehrotra: So EPROMs used to be UV erasable, right? Electrically programmable but UV erasable. E^2PROMs were electrically programmable as well as electrically erasable. But yes, when you erase them, you erase them a byte at a time, and, when you program, you program them byte at a time. This is – mid-eighties is when Toshiba Corporation had first started talking about Flash EEPROM. And Flash memory was about large blocks that you would erase together, and when you programmed you would program large amount of data together as well. And this memory was called NAND memory that they had pioneered the architecture--

Kapoor: The gentleman's name was Masuoka.

Mehrotra: Masuoka-san. Well-known figure, father of NAND Flash memory from Toshiba Corporation. So Flash was just being talked about in that timeframe. Although the markets, the industry, the prevalent technology was all around EPROM and E^2PROMs at the time. EPROMs in – around the period of 1987-88, used to have higher chip capacities. They used to have chip capacities of 256 kilobit, 512 kilobits, etc. Whereas E^2PROMs used to be more like 16 kilobits, 64 kilobit. And Flash gave you the opportunity, because of its density, to really be designing much higher capacity points. So--

Fairbairn: So SanDisk was founded around Flash.

Mehrotra: SanDisk was founded around Flash. It was founded, actually, around, you know, Eli's vision that Flash, which was just being talked about in the industry. That Flash technology could be designed and processed in a fashion that is most optimum to give you the lowest cost, but also feature set that is really optimum to design system level solutions. And the vision was, believe it or not, in 1988, you know – and really gave tremendous credit to Eli here – designing Flash technology and products that ultimately make an SSD. So from day one it was not about only designing a proprietary Flash technology to give you low cost media, but also, using that Flash memory technology chip and making it work with a controller and firmware to give you – the vision was solid state drive products, right?

Fairbairn: So Toshiba had invented this. Was there proprietary issues? Were there patent issues, you know, things you had to get around? How did – was that an issue starting up the company?

Mehrotra: So Toshiba had invented the NAND Flash memory. The memory that SunDisk started with in 1988 was actually a triple poly NOR memory, so very, very different architecture from Toshiba. So triple poly NOR was absolutely a unique device and device and chip architecture at the time. Triple poly NOR had the feature that it would program like an EPROM, but it would erase through poly-to-poly tunneling. Okay. So basically the second poly was the word line. The first poly was like the floating gate where charge would get trapped. And when you program you are applying the high voltage on the second poly

and on the drain, and you will be putting electrons into the floating gate. And when you are erasing, you are applying the high voltage on the triple poly, the third poly, which will then have electrons leave the floating gate and leave floating gate positively charged.

Kapoor: So this is the follow NOR tunneling.

Mehrotra: So this was, you know – through poly-to-poly asperities, you know, this was follow NOR time tunneling for erase, and hot electron programming for – hot channel electron mechanism for programming, and it was a split-gate architecture as well. Virtual ground split-gate architecture at the time for this. So this was an amazing technology. The first chips that we designed were four megabit chips. So Eli came with the vision, raising the money, being the technologist – device technologist. Jack Yuan was the process technologist, and I was the designer. So our triple poly technology and the chip architecture did not actually have any patent or IP issues with others because it was a unique innovation. And of course we patented it. But also we patented a lot of features around design. And one of the patents that – in the first few months of the company we actually focused a lot on implementing ideas in terms of circuit, in terms of process, device technology, chip architecture, system architecture, and patenting those ideas. The first few months were all about focus on patents because we knew that this is eventually IP and patents can be, you know – can help us achieve a level playing field. And this really turned out to be very, very valuable later on for SunDisk. To have strong fundamental patents that absolutely – at the chip level as well as at the system level, because we were the first ones doing system level memory.

We pioneered a lot of innovation and today all Flash is system-level Flash. But we, in 1988, were the first ones. Actually, many – even venture capitalists at that time said that our system-level solutions, which was a very different approach compared to Intel, which was really all about component level Flash, that our system level solution is not going to make it. That we should really just do component Flash just like Intel Corporation. Many venture capitalists and others dismissed our IDL system level Flash.

Kapoor: Did you also call it “Data Flash?”

Mehrotra: Yes. I mean, it was also – you know, it was also referred to as Data Flash. Absolutely right.

Fairbairn: Where was the manufacturing or fab done?

Mehrotra: So when we first did our chips, because it was a totally different chip technology, we, of course, had to make the first cells, triple poly split-gate cell, with channel and hot electron injection programming and poly-to-poly erase. It was a unique concept. We had to demonstrate that it works. So first wafers that were processed – the test structures that were processed, they were actually at a local foundry fab here in Silicon Valley called Orbit Semiconductor. So these were your four-inch wafers where we actually demonstrated the functionality of the cells.

But Eli, while we were doing all of this work, he was also, of course, working with, at that time, Western Digital and AT&T, as well as venture capitalists, including Irwin Federman, who was at the time, if I remember correctly, was with Concord Partners, to raise the funding for the company. And if I remember

correctly I think the first round we – the company had raised eight million dollars. And if I remember correctly, two million had come from AT&T, two million had come from Western Digital, and then from venture capitalists. So soon we moved silicon processing from Orbit Semiconductor to AT&T. This was in Allentown, AT&T Labs. And you know that AT&T was absolutely a powerhouse in those days in terms of semiconductor physics and technology. So we are talking about late 1988. We started working with AT&T in terms of bringing up our process technology at AT&T so that we can process our wafers.

And I was focused with working with Western Digital on system level chip definition, because we knew that we want to architect the chip not like any prior EPROM or E^2PROM. We wanted to design the chip so that it has the best interface to give us the most efficient implementation of SSD at the time. You know, solid state drive application. Western Digital, of course, was well-known in hard disk drives at that time, and they had interest in exploring Flash for solid state drives. Remember, in 1988.

Fairbairn: So they bought into that idea early on.

Mehrotra: They bought into the idea early on. So I remember I used to go to Irvine, California all the time, working with their chief technology officer and scientists and engineers, defining the memory chip. Together we – in the early days, Western Digital and SunDisk defined that chip. I designed the chip. But it was clear that this was too early for solid state drives. Hard disk drives were moving fast in terms of their capacity and cost, and Flash still was not quite there.

So Western Digital, actually, very quickly abandoned that program. Our collaboration maybe lasted about a year-and-a-half to two years and then they abandoned the program. But just imagine that this was in 1988 that Western Digital and SunDisk had partnered. And then, in 2016, Western Digital actually, at the time of – they purchased SanDisk in 2016. And at the time of the purchase agreement announcement, the valuation at that time was nineteen billion dollars. So they had put in two million dollars at the very beginning, and they walked away from it a couple of years later, and many years later, almost twenty-some years later--

Fairbairn: Had they maintained their position, though? Their original position in the company?

Mehrotra: No, no, no.

Fairbairn: They had sold it.

Mehrotra: Long ago, they sold this.

Fairbairn: So you came in with relatively little management background, coming into this company, right?

Mehrotra: That is absolutely right. So my management background at IDT was managing – if I can remember correctly, directly reporting to me were three or four engineers, and we were together designing the chips. But, of course, as I had been taught in the very early years, with tremendous focus

on product test engineering as well that I'd learned from George Perlegos. So even though I was doing design, I was very actively at IDT also very closely working with the product engineering and the test engineering teams. So I really was managing the whole program there, essentially.

And at Seeq, in my late years, I had a very small team, as well. But you are absolutely correct. I mean, you know, when I came into SanDisk, I came in with more of a mindset of project management, design project lead, design project management. But I was extremely enthusiastic about the idea of designing Flash memories because that was now the most state-of-the-art technology. Even though that technology – nobody had imagined that it will get this big as it is today, but we were excited that this technology is going to have some exciting applications in the future, related to not only solid state drives and computers. But, yes, we knew that it could become digital film in the future. We thought it would be in the fax machines; it would be in the copiers; it would be in the various electronic devices. So even though technology was in the labs, we were very excited about the potential that technology could have in the future.

And I personally was also very excited that I was not only designing EPROMs and E^2PROM that were just coming from data sheet. I had an opportunity to architect a chip from scratch and tremendous opportunity for innovation – defining interface, defining how the sense amps and the programming circuits would work. Because the cell architecture and device mechanisms were totally different. So not trying to chase and design a memory that was five nanoseconds faster, but really how to design a chip that was best suited for storage architectures and best possible cost. And yes, best possible performance and reliability aspects. So that was very exciting for me.

Kapoor: So a couple things. One, you initially kept referring to SunDisk.

Mehrotra: Yes.

Kapoor: Because it was initially called SunDisk and then Sun Microsystem, I guess, sued you and the name had to be changed to SanDisk.

Mehrotra: That's right. That's right.

Kapoor: So the other thing is endurance. I think the issue of endurance cycle, reading and writing – when did that issue surface?

Mehrotra: So E^2PROMs always had the issue of how many cycles you can program and erase before the device will go bad. Flash had similar issues that you can – even though flash was about erasing very, very large blocks of data electrically, and programming them, many cells in parallel, but still it had the same issues because these issues were inherent to the wear-out mechanisms of oxides through all the charged trap that an oxide injection that was taking place during programming or any Fowler-Nordheim tunneling that was taking place during the erase mechanisms. So a lot of the charge trapped eventually would lead to device wear-out mechanisms that you could only program and erase so many times. And the physics of it was such that it will be few bits that will wear out first, and most of the bits will still have

the capability to be programmed and erased much longer, and trying to figure out which are the weakest bits was a huge challenge. It was a huge challenge in terms of testing that during your screening test you had to figure out which were the few bad bits. This is where SanDisk drove innovation that it basically said that you can work with imperfect media and chip can be imperfect, it can have plenty of bad bits. In fact, it can have plenty of portions within the chip, large portions that are bad, yet whatever is good in the chip you want to be able to use it. So this is how we focused on lowering the cost, that you could live with defective media.

Kapoor: But the same thing was happening in DRAMS, right? They had defective bits and they would have ECC and--

Mehrotra: So there they were implementing ECC, they were implementing redundancy, which is all – that all used to be done in E^2PROMs as well and EPROMs used to have redundancy. One of the designs, early designs, I'd done, one of the first CMOS memories I had designed was E^2PROMs with error correction capabilities on the chip. But all of that, that increased the cost of the chip. We focused at SanDisk that you can have a memory that can have defects, let the controller, let the firmware take care of those defects so that to the application, memory looks perfect, right? That was our innovation. So we realized that inherently the media is weak, and it will fail at some point. But we said let all that error correction take place in the controller. Don't burden the chip with those circuits. Let controller detect when bits go bad. Don't try to test them all at the time of the factory test, even if the bits are failing later in the field, they're latent failures. Controller should have enough intelligence to detect those and correct for them, and doing it in one controller rather than doing it in each chip helped us to achieve a lower cost because the chip size got smaller, and these storage systems that we designed used many chips. So it was not about one chip working with one controller, it was about many chips working with one controller. So it was actually cheaper to put all that intelligence in the controller rather than the chip.

Kapoor: But the endurance algorithms for controller to manage depended also on the application, right? If you had BIOS which did not change very often the bits didn't go bad, right?

Mehrotra: Yes, that's right. So absolutely it all depended on the applications, but the controller had the wherewithal to figure out what is happening to the memory. And not only controller could detect the best, but controller could actually move around the data. This was called wear leveling, that, you know, if some parts were being written too many times, it will move that data, that address, to a different location so that it will even out that how much of the endurance, how much of the write cycles were being spread out in the media. So all these things ultimately extended the life of the product at the product level. So even though the chip may not have that perfection, but the products with intelligence in the controller and firmware had that perfection.

Kapoor: Yes, interesting that the controller created its own vocabulary. You had terms like garbage collection and wear leveling, as you mentioned, write amplification. Sophisticated software was used too, so this was amazing.

Mehrotra: Absolutely. All of these things were really happening before our eyes. Our teams were doing it. You know, garbage collection is all about that when you identify that some area has been written too many times, right, and you move something somewhere else, then you are creating pools within the memory that are becoming unusable. So garbage collection was just, you know, cleaning up those areas and making them usable again, right?

So this was all a wonderful time, but a great innovation that SanDisk drove was multi-level cell, and this was a design innovation. Typically, a memory cell would store only one bit, a zero-state and a one-state. And in the very early days of SanDisk, actually the very first few weeks of SanDisk, we were talking about doing multi-level cell, and we patented ideas. I patented several design concepts in those early days. And one of the patents that I filed that actually became extremely useful to the industry later was the 538 patent, that's how it was known. This was about the concept of that when you are programming a cell, you carefully apply programming pulses to it, and at the end of each programming pulse you monitor what is the threshold level it has achieved. So this was, typically if you're just programming one bit, you have an erased cell and you can brute force a programming pulse, have a lot of electrons go into the floating gate, and fast take that cell threshold high. You didn't care. And you get the cell to move from a zero to a one.

But when you are trying to program multiple states in a cell, you can imagine you need to very carefully monitor how much charge you are putting into the floating gate because now that same threshold window of a program cell is actually split into four different windows, and you're trying to program your cell very distinctly into one of the four windows depending upon – actually one of the three windows, one is a erased window and three programmed states, depending upon the data that you are expected to write in one cell. And that data corresponds, let's say, to two bits, you know, four states in a cell.

So this required innovation that you have to program many cells in parallel because you have to be fast in programming. But each cell because some cells could be programming – could be getting programmed to a one, some could be getting programmed to a three, some are getting programmed to a two. How do you program all of these in parallel and yet do it fast rather than go through one cycle of programming all the ones, then another cycle of programming all twos, third cycle of programming all threes, you want to program them all in parallel. So our innovation in the 538 patent, you know, my innovation there was that you program, you verify, and if it has achieved the right threshold, you inhibit. You inhibit this cell, while other cells in the same group are still continuing to program because they need to achieve a higher threshold. And once they achieve their right threshold you inhibit those cells while yet more cells in that big chunk may be still be continuing to try to – may still be needed to be programmed to the third level. So this was a huge innovation. It became a fundamental patent. You could not do multi-level cell programming whether with a NOR structure or with a NAND structure without using this patent. In fact, even in two-state memory, that means one bit per memory, you know, companies like Intel started using that patent in order to achieve the highest reliability, so that they would – while some cell is still continuing to program, if one cell is programmed, they would stop the programming of that cell so that the reliablity mechanisms are better.

Kapoor: So the endurance got worse when you have multi-level, right?

Mehrotra: So multi-level definitely, you know, led to more device issues, but those kind of issues got managed at the system level through the controller. So this patent became a very powerful patent for us. And, in fact, in NAND this was an essential patent even for one bit per cell operation. So NAND manufacturers were using this. Intel was smart, they very quickly licensed our patents, and I remember I think we got $10 million for them. For a start-up at that time having a $10 million license was meaningful.

But Samsung was using our patents, and SanDisk and Samsung actually got into a litigation over these patents, and our case went all the way to ITC, International Trade Commission, and actually we prevailed, and Samsung's products were barred from getting shipped into the U.S. in 1997 because of our patents. That led to Samsung licensing the first Samsung five-year license where they paid substantial royalties to SanDisk, and that led to really a start of a licensing program for SanDisk. Not only did Samsung license patents from SanDisk using royalties as well as license fee, but Toshiba, Hitachi, Sharp, all of these companies licensed from SanDisk, and this led to, as the industry grew, it led to a substantial royalty income for SanDisk. In its peak years, SanDisk was making $400 million a year from royalties, and this I'm talking about early 2000s kind of timeframe.

So this connects back to what I said earlier, that we knew that when we were starting the company, filing IP was extremely important. Because there was that sense that one day this could help us level the playing field. Royalty was being used, the royalty income that SanDisk was generating, was being used to put back into R&D to really continue to keep up with the likes of Samsung, and later Hynix and others because these were much bigger companies, they had a lot more R&D dollars available to them. But our royalty income was really used to fuel, to fund our pipeline of future R&D and really became an important source of leveling the playing field, and frankly leveling even the cost structure because others would be paying us royalties. So it was extremely valuable IP portfolio that SanDisk had, and I just want to point out this is before Qualcomm made IP licensing such a big thing in the industry. I mean, SanDisk had already really looked at the business model of product revenue as well as royalty revenue. This was the vision that already existed in 1988 at the company, and, again, I give credit here to Eli Harari.

Fairbairn: So going back the early product times, I mean, you're doing this process development. What was the first application? What turned out to be the first major driver in terms of application, and was that one that you foresaw or one that you kind of happened upon as you developed the product?

Mehrotra: Wonderful question. So the first products, as we said, we were trying to actually design solid-state drives. So the first products were, the chip that we designed was 4 megabit, with those 4 megabit we made 10 megabyte flash cards. Those flash cards were being put into a 2.5-inch ATA drive format at that time, and that 2.5-inch had our controller, all the hardware from us to manage the flash that was in those 10 megabyte cards. And, you know, one of the first applications was around IBM ThinkPad and basically the pen computing in its early days. We thought that this would become a nice big market for us. It was actually a nice part of revenue fortunately for us. But, as you know, the early pen computing in the '90s did not takeoff. The early pen computing devices all failed, were a flop, even though they initially showed promise. So we were like a solid-state drive solution, storage solution, for those early products. That was like the early adopter market for the flash technology, and then we were in the chasm for quite some time.

Fairbairn: Yeah, you couldn't cross the chasm, right?

Mehrotra: Yeah, we couldn't cross the chasm. We crossed the chasm really with digital film, right? And digital cameras along with internet, you know, around mid '90s, you know, both of them coming together is what really got digital film going. Cameras improved enough in the resolution to have good enough picture quality. Internet gave you the opportunity for sharing those pictures, and digital camera gave you the instant gratification of seeing the picture. Flash cards gave you the opportunity to have that digital film. All of this really led to the first major market of digital film. I have to say though that SanDisk was, even from its very start, was actually working with leading camera manufactures.

Eli was absolutely evangelizing this with various camera companies in terms of how to define a standard for a digital film, and here there is a very interesting story that SanDisk used to work with the Canons and the Nikons and the Kodaks and the Fuji camera, all of these guys at that time, to define, to understand what would it take to make a digital film out of flash, right? Kodak in those days, and, you know that Kodak used to be the giant of imaging, right? Kodak in those days actually wanted us to make our film exclusive to them, whereas SanDisk vision was to make a standard film that all camera manufacturers could adopt. Kodak actually offered the company for exclusivity a few million dollars. It was a gut wrenching decision for the company, for a start-up company, very easy to gain exclusivity from a giant like Kodak, such a powerhouse, global brand, but I give credit to Eli that he had the vision that the right solution is not an exclusive solution for Kodak, but right solution is an open standard that others can make the film as well because that's what would ultimately make the market bigger. That absolutely turned out to be the right decision. We made CompactFlash cards. These were the first film in the digital cameras. Sony actually chose its own standard of memory stick, and that memory stick standard, that was only good for Sony cameras, and that memory stick camera actually failed later on. It was proven that absolutely--

Kapoor: This was beta--

Mehrotra: Yes. Intel was trying to make its own card. I'm just forgetting the name of the card right now--Miniature Card. Intel was making Miniature Card, so there was a CompactFlash, there was a Miniature Card, Toshiba was making its own Smart Card, but the standard that prevailed was the CompactFlash. Because CompactFlash had the strength that you could use any generation of memory chip in it, it would be transferred into the user. So interoperability of the card from one platform to the other platform because all the controller resided inside the card was a big factor. Other big factor was you could go from one generation to the other generation, it's seamless operation in the digital camera. So CompactFlash became the big factor, then, of course, it was that you need to make these cards smaller because cameras were getting smaller. Then Panasonic actually came to SanDisk, SanDisk had already established that, you know, it can create standards. It had created a name for digital film innovation. Panasonic came to SanDisk to partner to create the secure digital card. So after CompactFlash it was really secure digital card, and the three companies that partnered to create the secure digital card were Toshiba, SanDisk, and Panasonic, and secure digital even today, you know--

Fairbairn: SD cards.

Mehrotra: It's SD cards that are still used in a variety of applications, and then came NTT Docomo with phones, you know, wanting a card to get yet smaller, and Japan was leader not only in cameras, but in the early phones as well, right? In your hand-held phones, Japan really had led a lot of innovation. So Japan for the phones wanted a card, and wanted a card that was even smaller and thinner than secure digital card. So that actually led to a mini SD card, which was used in phones.

Then came Motorola, and Motorola said they want something even smaller because, you know, phones were getting smaller, right? Motorola phone used to have those flip-phones, et cetera, StarTAC, those phones were very small. So that led to a micro SD card. So we went from a first ATA cards, you know, that were going into 2.5-inch phone factors, solid-state drives, then CompactFlashcard, secure digital cards, then came MiniSD, then came MicroSD, and today MicroSD is still in use. I mean, all Android phones use the MicroSD cards, and MicroSD, if I remember correctly, was innovated in collaboration with Motorola in 2004 or so timeframe, and still it is a prevalent card. And at that time when we innovated it with Motorola it was called TransFlash. But Motorola, with the support of Motorola, we actually made that into yet another standard card calling it MicroSD. So we put it under the umbrella of SD Association to make that card also not just unique to a Motorola design, but to make it a standard, and today that is a standard in all Android phones, right?

So this was the first mega market that our technology actually addressed. This is what really enabled the company to even, you know, become the billion-dollar company. We went public in 1995. In 1995 our revenues were mostly around usage of flash and various industrial applications, okay, like routers, et cetera, used to use flash cards. Then the big market that drove our growth and increased our valuation and increased our revenues was the digital camera market. Following digital camera market, the next big market opportunity was supposed to be the MP3 players, the music players, right? And this was like everybody and their mother in China was really doing MP3 players with flash being used to store music in those. But MP3 also very quickly flopped, okay. So what sounded like a great emerging market opportunity for flash to store music disappeared fast, and USB drive really became very big. USB was like poor man's PC.

USB became a huge market for us, but soon Apple was developing iPod, and iPod initially were with hard drives, but then they were all with flash, and then finally music became really another big market with iPod. Music players became, digital music player, became the next big market, and another big market after that was mobile phones, and today mobile phone is the mother of all markets, and mobile phone for flash as well as for DM actually, is the biggest industry, and after mobile phones then came the SSDs, SSDs in notebook computers. So just imagine SanDisk got started with the vision of SSDs, and then by 2011 timeframe we were working on SSDs again for notebook computers, and not only SSDs for notebook computers because they give you small, fast, low-power, longer battery life, cooler form factors, all those abilities.

But SSDs also now are going into enterprise applications, going into datacenter, and that is today a big growth market for flash. So, this is really the kind of product history of flash, and through this period the reason all these applications got spawned from flash is because technology was advancing at a ferocious pace, you know, all initially 8-inch wafers, later going to 12-inch wafers, technology going from 1 micron

early flash to, you know, today. I mean, at the last generation of 2D in 2015 timeframe, 2016 timeframe, it was like 15 nanometer of flash, and what that did – Along with feature-size scaling came logical scaling, that means instead of 1 bit per cell initially going to 2 bit per cell, then going to 3 bit per cell, right?

Kapoor: Is that the current state, 3 bit per cell?

Mehrotra: So 3 bit per cell is the dominant production in the industry today, yes, and as always SanDisk led the 2 bit per cell innovation and the 3 bit per cell innovation. So that then brought cost down by a massive amount. Today the cost is down by more than 200,000 times compared to the early flash on a per gigabyte basis. The chip capacity's increased, and that's – cost coming down, chip capacity increasing, while, you know, various performance solutions were found for end market applications, this is what created these multitude of markets, and, you know, in 2018 flash was like a $70 billion overall market, right? And it just started in late '80s in that industry. So in 2016, you know, we sold the company to Western Digital, and--

Fairbairn: The company that you'd started with.

Mehrotra: The company that I started with, the company that I stayed with, an amazing journey of 27 years, incredibly gratifying.

Fairbairn: Were there ongoing relations between the companies? Was there any regular contact?

Mehrotra: I would say in the late years of the company I would meet with Steve Milligan, the CEO of Western Digital at that time, once in a while because, you know, we were industry peers. Of course, Western Digital was all about hard disk drives. SanDisk had all the flash solutions, and, you know, that was the technology of the, certainly technology of today in terms of growth, but also technology of the future for storage applications, and it really did make good sense for us to sell the company.

Of course, you know, as a co-founder, when you have created a company from day one, and you have been with it all throughout its journey to become a large, multi-billion dollar company, we had taken the company to over $6 billion in revenue as well, you know, it is not an easy decision. However, it was clear that the customer ecosystem was becoming very large. Customers were becoming very powerful, therefore it was important for suppliers also to bulk up, to become larger, in order to, you know, in order to be able to become valuable partners to the customers, to be able to meet their needs at scale, to be able to provide them with diversified solutions, and do all of that in a healthy, profitable, growing fashion for the company. So scaling up was important. The combination at that time of SanDisk and Western Digital really created a powerhouse in storage solutions, with Western Digital having all hard disk drive capabilities, SanDisk having tremendous of flash capability.

Fairbairn: What are the relative sizes of the companies at the acquisition?

Mehrotra: We were about, you know, $5.5 billion, $5.5 to $6 billion in revenue, and in total revenue Western Digital, you know, similar size, maybe HDD at that time slightly bigger. You know, today I would

think that at Western Digital flash and HDD revenues are about the same, you know, approximately, you know, $18 to $20 billion revenue company, you know, somewhere in there.

Fairbairn: Okay. Can you trace your own career path through those years. You came in as a relatively junior member of the team. You exited as a CEO. When you started did you envision, I mean, at what point did you say, I want to be CEO, whether this company or some other company? When did that come into your mind and become a goal of yours?

Mehrotra: Yes. So SanDisk started with three of us as co-founders, but I also want to recognize Bob Norman who was really the fourth stool of the company in terms of system-level solutions, right? So from day one I worked very closely with Eli, you know, Eli is the lead founder, the lead visionary, you know, definitely the face outside for the company. But on the various aspects of strategy, various aspects of execution, various aspects of operations, I was very much involved throughout in the early days of the company as well. Very much focused on the memory chip technology as well as working with system designers to really productize our technology, always worked very closely. Again, had that DNA in me that was really ingrained by George Perlegos that you don't just design the chip, you absolutely focus on the product and product engineering tests. So these are the things I focused on from day one, design, product, test engineering, and over time I got increasing responsibility in terms of design device as well as process technology and all system engineering.

So from my early days of designing chips, I took on the responsibilities for product and test engineering, and then later on all of engineering at the company, and then in 2001 I became the COO of the company. I remember that the press release announcing me as the COO of the company went out on 9/11 because that press release was slated to go out in the morning of 9/11, and, you know, of course, you know, that was such an unfortunate day, such a sad day in the history of mankind. But that press release had gone out on that day announcing me as the COO, and as COO I had responsibility for moving from all of engineering to also all of operations of the company as well as running the OEM business of the company, and over the course of the next few years I got additional responsibility for the retail side of the company as well, and in 2006 I became the President of the company as well. Until then Eli Harari was the President and CEO of the company, and Eli chose to retire in 2010, and, you know, the two of us were partners in everything that we did together, and, you know. I then became the CEO of the company starting January 1, 2011.

I would just also like to point out that one of the transformative things in the history of SanDisk was certainly all about technology and system-level solutions, but also creating a retail brand, you know. That was also a very visionary aspect of the company because semiconductor companies were – design solutions were OEMs, but flash was being used in digital cameras. So there was a great opportunity that instead of somebody else selling the film, or the camera manufacturers selling the film, we realized that there was a large aftermarket for flash cards. So taking flash cards in the aftermarket, the retail channels, initially in the U.S., but then making it a global brand, that really was a transformative piece of the company's business and its history. From 2000 to 2010, all of the growth of the company, most of the growth of the company really came from retail, and the retail brand of the company, and today SanDisk brand is well known across the company.

But while we were driving retail brand, we were, of course, focused on other growth opportunities as well such as OEM, such as solid-state drives, again, and mobile solutions. So I grew in my responsibility over the years from engineering functions to operational functions to business functions, and I absolutely look at Eli Harari as the third mentor of all my career. George Perlegos taught me how to be a great engineer and most of the things good engineers should focus on to be successful. Eli Harari really transformed me from an engineer to a business leader, and I feel fortunate to have worked with him because he gave me increasing responsibilities, trusted in me with increasing amount of challenge.

You know, for example, the joint venture with Toshiba Corporation, which was set up in 1999, is another aspect of SanDisk that totally transformed the company. Remember I told you that we worked on triple-poly split-gate NOR memory cell early, which was a proprietary flash technology of SanDisk. It became clear by early '90s, you know, after a few generations of that technology that this technology cannot be scaled too far, and it became clear that NAND had greater scalability in it. So this was a major decision for the company that the technology that was our baby, that we would abandon that technology at some point and switch over, switch the technology horse to NAND technology. That arose out of our IP licensing agreement with Toshiba.

Remember I talked to you about how Samsung had, you know, lost the case against us and that led to a license, IP license, like we went with Samsung for NAND. Toshiba soon followed suit, they got an IP license agreement with us. But Toshiba figured out that instead of paying royalties to us, they said it would benefit to partner with us so that they don't have pay royalties and take advantage of our innovation capability, design capability, and product innovation capability, because we had already established that we can establish standards by then, and get the benefit of combined joint scale of production and technology R&D collaboration. So Toshiba instead of renewing the first patent cross-license, they actually said let's create a joint venture together in R&D and manufacturing. We were good with that because we knew that our technology was running out of steam, and we needed to switch the technology horse. So it was a great timing for us, and actually it was me that used to work on that, you know, our technology of triple-poly in the labs all the time trying to make our products work.

And I could see from early '90s that we will have to switch the technology, and that's when I said to Eli that, you know, let's work on this with Toshiba on NAND, and I want to work on NAND, I don't want to be looking at future scaling paths of the triple-poly NOR technology. So I began to dedicate myself to the NAND from 1999 onward, and by 2001 timeframe it was clear that NAND was the way to go. That's when I became the COO of the company as well. But aside from system-level solutions, retail, joint venture with Toshiba, you know, these really totally transformed the company, and these are the kind of things that really totally led us to our values at the company. Our values at SanDisk was always about innovation, execute and exceed, adaptability and agility, and when you look at innovation, I mean, creating a retail brand, creating system-level flash solution, those were our values. Adaptability and agility, transforming from triple-poly NOR to a NAND, and transforming all the business and all the products with a NAND technology was a big thing, and then ultimately, you know, the joint venture with Toshiba required tremendous adaptability and agility as well. So this was my career at SanDisk, when the sale of the company happened in 2016 I really thought that I would be retired and probably moving on to other things.

Fairbairn: Before you get to that, can you say something about the manufacturing strategy throughout all this? You know, you did some – you're using Orbit and AT&T and so forth. What eventually, you know, how did the manufacturing strategy evolve?

Mehrotra: Yes. That's a great question. We first started manufacturing our flash at AT&T as I had mentioned earlier. Soon it had become clear that AT&T in terms of really manufacturability and yield would not quite be the right place and Richard Newton from UC Berkeley actually recommended that we talk to Matsushita Electronic in Japan. So while we were doing manufacturing at AT&T we partnered with Matsushita Electronic for our Triple-Poly NOR with using Matsushita Electronic as a foundry, bringing up our proprietary NOR process technology in their fabs. That turned out to be a huge success. We were able to ramp up yields at Matsushita very fast. It was good business for Matsushita selling wafers and for us getting good cost structure, good yields.

After Matsushita we actually also began manufacturing at NEC in Japan. We were manufacturing at Matsushita as well as at NEC and we phased out of AT&T and soon we started manufacturing at Lucky Gold Star in Korea, so we had multiple foundries. Later even UMC in Taiwan. So we had a broad, diversified manufacturing base. We brought up our technology in multiple fabs. And but that was all with the Triple-Poly NOR technology that SanDisk had pioneered which really lasted us very well for a good ten-plus years as a production workhorse. And then it ran out of steam when we switched to NAND for our products.

Of course then, all our manufacturing was in the joint venture with Toshiba and that joint venture really, that partnership with Toshiba lasted for 18 years before SanDisk was acquired by Western Digital and really, really, I believe the best example of a joint venture in the semiconductor industry. And it was such a successful joint venture because both parties contributed tremendous value. Toshiba brought its decades of semiconductor manufacturing expertise. It brought the innovation of NAND technology. SanDisk brought design and system level expertise, ability to create new standards and create new market opportunities. SanDisk also as a public company brought strong ability to tap into U.S. markets for raising capital that is needed in large fabs, et cetera. Of course, Toshiba had that capability as well, being a Japanese public company. Hugely successful joint venture which started in 1999 and even today, that joint venture continues in terms of R&D collaboration between the companies. Today it is Western Digital and Toshiba and manufacturing.

Kapoor: But in terms of the futures, I think you have talked about data, a lot of data that is goodness for flash. And that you've talked about IOT and Cloud. So all flash arrays, I know that the latency times are less than a millisecond and a lot of reliability, 3 bits per cell and 3D NAND flash. So are these things that are things that are ripe for the future?

Mehrotra: I mean, absolutely, flash is displacing hard disk drives fast. Flash is displacing hard disk drives in your notebook computers because it enables these thin, sleek, low power high performance, fast, long battery life kind of notebook computers, right … instant-on type of features.

But flash is really replacing hard disk drives in data centers as well because flash enables fast access to data. And it also provides lower cost of ownership because flash footprint on a per gigabyte basis, physical size is smaller compared to hard disk drive. It has no moving parts, so mechanical reliability much, much better. It is lower powered, so when you look at enterprise or data center applications, power is a big deal in data centers, right. Flash saves power. Because flash is faster it also helps with needing fewer servers, so it saves cost of servers. It needs fewer power supplies, fewer cables. All of this leads to the lower cost of ownership of flash. So data centers is a big opportunity. Enterprise as well as cloud data centers are a big opportunity of growth for flash.

But also, you know, today the smartphones, when you look at multiple cameras, look at so many images, when you look at high resolution video capability in your cameras, they require more and more flash as well. And so very diversified markets, you know, for flash, and certainly when you look at IOT, surveillance cameras, you know, they need flash, right. So IOT is another emerging market opportunity.

Kapoor: Thank you. So--

Fairbairn: Okay, so let's move on to Micron, so--

Kapoor: <laughs> How did that happen?

Fairbairn: Yeah, how did that happen?

<laughter>

Mehrotra: Yes.

Fairbairn: You thought you were going to retire.

Mehrotra: So I thought I was going to retire. I actually took 2016, my wife and I were traveling and I was really starting to think what would I do next. But I absolutely wanted to take some time off. And I never thought that I would be going back and becoming a CEO of another company, but I was certainly looking at other opportunities.

And then I was also, you know, approached by Micron some time in December of 2000, it was December of 2016. It was actually, perhaps, an exploratory call by a recruiter and that's when I chose to leave the Western Digital board because I thought that if I'm going to explore any opportunity at Micron, I cannot do so without first getting off the board. So I did not have any conversation with Micron. In fact, Micron's CEO, Mark Durcan, at the time, a great leader of the company who was also with Micron for very many years and contributed tremendously to the growth of the company. His resignation was announced in February, his retirement was announced in February. And when his retirement was announced I thought that if I was to consider the role, I must resign from Western Digital board as well. So I did not consider the role, even though I was approached for it earlier, but I had not considered it until after I resigned from the Western Digital board.

And I had always competed with Micron because Micron, a powerhouse of 3D NAND manufacturer, but also had flash technology for several years. So I had always competed at SanDisk with Micron and I really had always tremendous respect for Micron as a company, but I also felt that the company had much greater potential than it was able to realize. So when I was approached by Micron in that 2017, early 2017 timeframe, I felt, I mean, I really felt deeply honored and privileged to even be considered, because I considered Micron as an iconic company. I really look at Micron as a national treasure.

The company turned 40 last year. Over the course of 40 years, the Micron company itself including the acquisitions that it has made over the years has contributed nearly 40,000 patents to the industry. So a prolific inventor. If you just think about it, that's like 3 patents a day, right. So I had tremendous respect for Micron. I considered it like an iconic company. I thought it's a great innovator. I thought it has great teams, tremendous technology capability, great manufacturing footprint, although complex, because, well-diversified all throughout the globe as a result of various acquisitions that the company did over the years. But therein lay its strength as well of having a well-diversified manufacturing footprint. So I looked at it as a national treasure.

And when you think about it, it's a company that is so tenacious that in DRAM industry when it started in the seventies and eighties and nineties there were scores of companies around the globe that were making DRAM. And today in the world there are really only three companies that make DRAM. Two of them are in South Korea, Samsung and Hynix. Micron is the only one in the Western hemisphere that makes DRAMs today and actually, the only country in the Western hemisphere that makes DRAM and flash today. And so I thought this is a national treasure. And, you know, with the, you know, all the assets that the company had, all the capabilities that it had, I thought, you know, it's an exciting opportunity for me to join the company and to see if I can work with its great team to transform it and to take it to the next level. Not only its technology capabilities but its products – making those products higher value solutions to the benefit of our customers as well as to the benefit of the company and through that process take the company's financial performance also to the next level in terms of consistency and profitability of the company. That's what excited me about joining Micron.

I thought starting a company from scratch and taking it, you know, to a $6 billion dollar company and then having an exit with sale at the time of the announcement of the deal at $19 billion dollars is absolutely a hugely rewarding journey, a very fulfilling journey. But I said, how many have really done that after such a journey such as SanDisk’s journey, go to another large company, take on the challenge of taking that company three times bigger than SanDisk and not only having flash but having great DRAM technology and being a powerhouse to take that company to the next level. That challenge of, you know, going to a large company and running it, having enjoyed the experience of taking a company from scratch to becoming a large company I thought was extremely exciting and I'm really, really privileged to be at the company today.

It's a great team. I'm having a lot of fun. The company, Micron, is two-thirds DRAM revenue today; one-third is NAND. And in NAND, particularly 3D NAND, Micron has innovated a lot and really has led the industry with what we call CMOS Under the Array. As you know, that in a memory chip there is a memory array and all the logic is around the memory array, so it consumes area, silicon area of a chip. CMOS

Under the Array means all the logic gets put under the memory array which obviously gives you the benefit of a smaller die size, which is a significant benefit in terms of cost. Micron has pioneered CMOS Under the Array in NAND technology and actually has been great at bringing 32-layer, 64-layer and now 96-layer NAND technologies.

And certainly in DRAM, the company has a very rich history of innovation, tenacity, you know, over the years acquiring several companies, driving consolidation in the industry to the benefit of the health of the industry, to the benefit of the customers as a result of the large scale of production, but to the benefit of the company today as well. So Micron is a powerhouse today not only in DRAM and NAND and as I said, really one of the only three companies in the world that have DRAM and NAND capability and the only company in the Western hemisphere.

But also Micron is a company that has tremendously powerful emerging technology solutions of the future. One of them is 3D XPoint Technology. And 3D XPoint is an exciting technology that Micron over the years has developed in collaboration with Intel Corporation and going forward, we announced over the course of last year that, you know, Micron and Intel are going separate ways. Micron has chosen to follow its own path with respect to technology path both on the NAND side where it used to collaborate with Intel as well as on the 3D XPoint Technology where we used to collaborate with Intel. Going forward, we'll have our own technology path in both of these areas. But 3D XPoint is a technology that is non-volatile, but it is much faster than NAND. A little bit slower than DRAM, but close. In latency, fairly close, but non-volatile, like NAND and, you know, tremendous capability to read and write. And of course, you know, capacities that are, chip capacities that are better than DRAM, therefore, lower costs than DRAM. It is a new memory solution that is placed in the memory hierarchy between DRAM and NAND and it will have huge implications in terms of future memory and storage architectures.

It's a technology that will have a lot of appeal on the memory semantic side, but also on the storage semantic side. Of course, you know, that technologies like this take several years in the industry to really become a meaningful part of the industry in terms of product and revenue opportunities. But we are on a very good track with that technology. So I like to say that we are the only company in the world that have DRAM, NAND and the technology of the future such as 3D XPoint.

Fairbairn: And you say Micron is also unique in the sense that it's in Boise, Idaho. <laughs>

Mehrotra: Yes.

Fairbairn: Far from Silicon Valley.

Mehrotra: Yes.

Fairbairn: Can you say, you know, what – how that's helped and hindered. What happens there – you have an operation here as well, here in Silicon Valley, I presume.

Mehrotra: Yes.

Fairbairn: So tell me about the cultures between Boise, Idaho and Silicon Valley.

Mehrotra: So Micron was founded and started in Boise, Idaho 40 years ago and Micron really went global in terms of its operations once it acquired the TI DRAM operations in 1998, if I remember the history correctly. Before that, all Micron operations, semiconductor, manufacturing, assembly test, all of this was in Boise, Idaho. As they acquired the DRAM of TI, all of a sudden it found its operations in Japan, in Italy, in Singapore, so it became overnight a very global company in operations. And later, of course, Micron acquired the Numonyx business, you know, which used to be between ST and Intel. Micron acquired Elpida, a DRAM manufacturer over the years.

So Micron drove multiple acquisitions over the course of the years. The beauty of the company being in Boise, Idaho has been that the team, the culture, the family spirit and total commitment, you know, to the company really is like nowhere else. And a company that went through such difficult periods of DRAM industry consolidation, periods of boom and bust, really needed that culture to stay together in a place like Boise. Otherwise something like that in Silicon Valley, people would easily jump ship and perhaps go to other places. Whereas in Boise, absolutely, to the team, it brought in tremendous value of family, people and the belief that together we can overcome any amount of challenge. And that rich culture, while absolutely continuing to fight against all odds, that company after all was in Boise, but it was fighting against all odds even in driving innovation, you know.

I think it was in the eighties when Micron had created shockwaves across the entire memory industry, across the globe, when it came up with a DRAM process that had very, very few masks. I mean, those masks were like, you know, 12 or 13 or so, while everybody else used to be operating with many more masks. So that was all through the sheer force of innovation that the company had and focused on low cost and focused on being extremely scruffy. The company was extremely good in leveraging operations to the max in terms of driving maximum productivity, efficiencies and lower costs. So very rich culture, very, very suitable for what you need in an innovative memory player.

Certainly, culture has been different from let's say Silicon Valley culture, but as Micron became more global, you know, starting from late nineties, I think it embraced diversity across the globe and leveraged how to work with various sites, you know, really quite well. And what's important to understand is that even though we are headquartered out of Boise, Idaho, we have 35,000 team members worldwide. We are in Singapore. We are in Japan. We are in Taiwan. We are in China. We are design centers in Germany and Italy. We have manufacturing plants in Manassas, Virginia, Lehi, Utah; and of course, our huge R&D facility in Boise, Idaho as well. So today we are a very, very global company.

Fairbairn: How many of those 35,000 are in Boise?

Mehrotra: About 6500 today are in Boise.

Fairbairn: In Boise are you the largest employer?

Mehrotra: That is correct. That is correct. Not only in Boise, we are the largest employer in the State of Idaho. You know, other than government, of course. And so we are very important and we absolutely consider it to be our responsibility to be a good citizen of Idaho, a good citizen of U.S. for me, personally, as well as for Micron.

And that's where there's a good match of our cultures. It's very important to not only drive for excellent results of the company and great financial performance of the company. You know, drive for value to the shareholders as well as to the team members at the company and our various partners, but it's very important to give back to the community as well. So Micron actually has given back a lot to the State of Idaho, to the City of Boise. Micron has a $100 million dollar fund that was established a long time ago. Today its Foundation is $100 million dollars and over the course of the last several years, actually we have given away almost $100 million dollars as well to the various community causes including Boise State University, University of Idaho, plus wherever our sites are, we are – we believe in giving back to the communities in those areas. For example, here in Silicon Valley we take part in various food drives, various STEM education initiatives.

We partner with universities to create grants that are advancing study by women and underrepresented minorities in STEM fields. Last year we launched Advancing Curiosity grant. The first pieces of those grants were given to Stanford University for AI research in the medical field as well as to Berkeley for AI research and an organization, AI for All, which really supports girls, particularly minority girls, towards study of AI while they're in high school. So Micron takes our responsibility as a global leader very seriously in being a good corporate citizen, not only in terms of corporate philanthropy but also in terms of initiatives related to environment, in terms of how we do manufacturing, in terms of sustainability efforts, in terms of making sure that in our manufacturing water recycling, energy consumption, you know, waste disposal, safety, all of these really get top consideration. And of course, diversity and inclusion is close to our heart. And a lot of work needs to be done at Micron in that regard, just like it needs to be done at all tech companies, even here in the Valley. But we are focused and slowly and gradually, you know, continuing to advance our agenda in all of these ways.

Kapoor: So how much time do you spend there? Do you spend a lot of time here versus there ?

Mehrotra: So as the CEO of a global company I'm traveling around the globe meeting our customers and going to our various sites as well as – sometimes involved with various government activities as well. So when I'm not traveling, you know, I would say I am spending most of my time either in our Silicon Valley office here, which is also expanding, or in our Boise office. I certainly spend a few days a month in Boise, a few working days a month in Boise. I would say that perhaps a little bit more here in Silicon Valley compared to Boise when I'm not traveling to other places.

Fairbairn: Okay. So I think we're running short on time, but I wanted to just conclude on your own personal thing. You've talked a lot about the civic responsibility reflected in the company and you, yourself, have been honored for your own philanthropy. And so tell me a little bit about your own personal, you know, where did that come from, what's your goal, what's your sort of fundamental beliefs in terms of your own philanthropic efforts?

Kapoor: And advice to young people.

Mehrotra: So, I learned it from my dad. Even though our means were limited, my dad and my mom were always very kind-hearted, generous people and always taught me the value. And as they saw me over the years, here in Silicon Valley as an engineer and then as a manager and a business leader, as they saw me do well, my dad always reminded me, saying in Hindi that, "<Speaks in Hindi>." And what that means is that when you are gifted, then, give it away, give it away enthusiastically. Throw it away, that's what it literally says, but what it means is that give it away enthusiastically. So I think that is a part that's important to both my wife and I. My wife, Sangeeta, is definitely a very, very big-hearted person and always focused on taking care of people who are maybe somewhat underprivileged that are around us.

But our focus has also been a lot on education, and particularly giving back to the university that I came from – giving back to Berkeley. Over the years I have done Stanford Executive program for MBA as well. I did that in 2009. So, we give back to Stanford University as well. But very much focused on education and focused on the STEM areas, advancing science, advancing technology in areas where it makes impact. So, these are the kind of areas where we have given.

And I firmly believe that when it comes to giving you have to have focus and you must partner, collaborate with the right partners and must look for results in your giving. It's just same as – same fundamentals as business. To achieve success in business you must have focus, you must have right partners, you must have collaboration and you must be looking for results. You have to look on ROI.

So when it comes to giving, I like to focus in certain areas. Our focus is more in the area of education and universities rather than scattershot across multiple areas, because when you focus you can achieve bigger impact, and your dollar can go farther. I like to collaborate with the right partners where basically there is low overhead of operations. So we are focused of course on giving here, but we are partnered with organizations such as American India Foundation, which has, actually, very low overhead, and through that foundation we are able to use our dollars for the good in India, again tracing back to our roots and trying to help there.

Of course, we engage with other organizations as well that are here in Silicon Valley. Foundation for Education is another organization run by Indians where we do contribute. So these are some of the organizations where we like to participate in and organizations that we like to collaborate with, in terms of making an impact on giving and, again, really do look for results; that means organizations that truly make a difference.

Fairbairn: All right. So just to conclude, one of the things that we like to ask each of our interviewees is what advice do you have for new people coming up, for kids, for these people in middle school, high school? What advice do you have for them in terms of looking to their careers, future careers?

Mehrotra: So when I look at, you know, what I tell my daughters – I have two daughters and, you know, both actually did their undergrad in engineering as well, and both went to grad school, and have pursued careers in technology area as well. And what I have always told them, and what I like to always tell young

people is that they must be curious. I think it is very important to ask questions, not be hesitant, stay curious. When you are curious you can absolutely learn a lot. And I think it's also very important that you find at the right stage in your life a mentor. Your mentor can be a teacher. A mentor can be your boss. I think it's very important your first job, the boss that you get in that job really can unleash so much potential in you. I think that makes a difference.

So my advice to young people would be that absolutely stay curious throughout, whether you are at school or in college or in early part of your career or advanced stages of your career, curiosity should never die. And my advice to young people also would be absolutely find your own mentor, and your heart will tell you who is the right mentor for you. And especially in your first job, try to focus on finding that right boss, that right mentor. It can make a very big difference. And beyond that, I always like to say that you have to take calculated risks. You know, you cannot have all the answers, all the data upfront before you move with a decision. You need to be able to move with 70 percent of information, which does mean that you have to take risks. Because it's okay to fail. You take risks, some of them you will fail, but that's really the only way to grow. That's the only way to find the next breakthrough is through learnings that come from failure.

And the fourth piece of advice that I would say is really at the end of the day, it's all about learning and growing. Especially when we look at the future today, this future is going to be shaped in ways that we can't even imagine by artificial intelligence. It's going to be impacting every part of our lives. It's going to impact all industries. It's going to change jobs. Some jobs will be lost as a result of it and some jobs will be gained as a result of it as well. So for young people, it's extremely important to learn and grow and make sure that they're on the right side – being on the jobs that actually will be growing as a result of this revolution that the world will be seeing with AI. And I just want to point out, while we are on the subject that AI is a tremendously exciting opportunity for me, personally, at Micron, because I look at it as AI is all about data-driven technologies. It's all about data insights. And data lives in the products and technologies that Micron makes, whether it is DRAM or flash. So as we look at AI, we look at that being a big driver of growth for Micron as a company. So we are extremely focused on really driving our technology, our product roadmap, that meets the requirements of our various customers that are in our various end markets, and all of those end markets in one way or another will be touched by AI.

And AI is also important for me at Micron. We are in the very early innings there to look at how can we transform our business at Micron, become nimbler, more adaptive, more productive of a company leveraging AI. And then how to tackle the challenge of reskilling of the workforce as well, so that we can train our team members so that they can take on the opportunities that are really unleashed by AI in the future. So, I do want to mention this also as really a very exciting, emerging trend for us. Data is at the heart of it. Micron's memory and technology and solutions are at the heart of it. And we are preparing Micron to embrace this for the future as well. Just like, I'm sure, all companies and all industries are looking at embracing AI and figuring out what does it mean for their businesses as well as how are they going to run it? But what does it mean in terms of their market opportunities in the future as well?

Fairbairn: So I was going to ask you a little bit about that in terms of…you come from a non-volatile memory background. That must play a role in terms of what you think the future of Micron might be. So why don't you talk a little bit about that.

Mehrotra: So, future of Micron is absolutely it's very exciting because it's all in these diversified end markets that we are handling today. And the future of Micron, as well as present today, is very different than it ever has been for Micron, so that's why we like to call it "new Micron," because the markets are more diversified than ever. It used to be that Micron markets were about PCs and later mobile phones, but today they are about PCs, they are about mobile phones, they are about data center, they are about automotive. I mean, think about autonomous vehicles of the future, how many sensors they will have, how many radars they'll have on them, how many cameras they'll have. So much data will have to be processed in split second, they'll be like data centers on wheels with gigabytes of DRAM and terabytes of flash inside those cars.

So these are all exciting opportunities, you know, from the data center, from the Cloud, to the autonomous vehicle, to the phone in your pockets, right. And Micron memory and storage is in all of these devices. So, our industry is more diversified than ever. Micron today is absolutely a new Micron because we are extremely focused on moving fast with bringing new technologies to the markets. Bringing products that meet the needs of these diversified markets, whether it is multi-chip packages that contain both DRAM and non-volatile memory in them for smartphone markets, or solid-state drives for enterprise applications or a high bandwidth memory, that means DRAM, high performance DRAM, for Cloud data center applications.

We are absolutely focused on driving innovation and product portfolio towards high value solutions, while we also focus on technology and cost and making sure that we are moving fast and continuing to lower costs for the future. And all of this, you know, keep a lot of the strategy also in addition to cost, in addition to high value solutions, is all about execution and absolutely staying, maintaining a razor-sharp focus on execution because that is key. No amount of strategy is good if your execution is no good. And doing all of this while really partnering with the marquee customers in the world today that are truly shaping the world. That's another important pillar of our strategy, to make sure that we are developing technologies and products today that are going to meet the requirements a few years down the road for them.

And last is top talent. At the end of the day, it's people that really make all the difference, so we want to make sure that as a place of top talent, we are able to attract top talent, we retain our top talent as well as how we develop our top talent on an ongoing basis as well. So this is what the company is focused, and I really believe we have a very sound strategy and with solid execution I'm really excited about the future opportunities here at Micron.

Fairbairn: Great.

Kapoor: Thank you.

Fairbairn: Thank you very much.

Mehrotra: Thank you.

END OF THE INTERVIEW

