Oral History of Atiq Raza

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Fairbairn: Okay, this is May 11th 2018. I'm Doug Fairbairn, and I'm sitting here with Uday Kapoor. And we are interviewing Atiq Raza. Atiq is a long-time pioneer in the world-- in Silicon Valley in a wide range of technologies from microprocessors, communications devices, and other related things. And we're here to learn his story and how it all came to be. So, welcome, Atiq, glad to have you with us.

Raza: Thank you so much.

Fairbairn: So, what we'd like to do is step back in time to where you were born. What was the family environment like? What was the social, and cultural, and national environment that you were born into, and especially interested in those things which might have influenced your direction in terms of career? So, take us back. Where were you born, and what year were you born?

Raza: I was born in 1949. And I was born in the city of Lahore, which, at one time, was one of the cultural centers of India, and in the pre-partition days, pre-partition meaning before India was divided between India and Pakistan. And my mother was a school teacher. And my father was an engineer. At that time, engineers were engineers. They weren't electrical engineers or mechanical engineers. But he was more an electrical engineer from his professional career than anything else. And both of them had a very profound impact on how I grew up.

Fairbairn: Do you have brothers and sisters?

Raza: I have only one brother. And basically, he is retired and living in Pakistan. He's younger than me. So, I am still very active.

Fairbairn: Yes, you are. So, you were born in '49. What were the early events which shaped your career and direction in life, I should say, not just your career.

Raza: So, direction in life has to do with both what my career became, which was much later, but first how I started thinking about the world and about life. And the thing that happened is that I first went to a school, which was a relatively prestigious school and an expensive school and a little bit beyond earning capacity of my parents. But they really stretched in order for me to go to this school. Then at one point, they couldn't keep up with the fees that was required to go to that school, and they transferred me to a Catholic school. And I spent six years in the Catholic school and finished the equivalent of high school, which is called O Levels by the British standard. And then for A Levels, I went back to the same school. And now, I was older. I was sixteen years old, and I was most sensitive to the fact that I was, relatively to other people in my class, the poorest guy in class. But the most important thing that happened is, during my A Levels, I was exposed to a philosophy that impacted me a great deal in how I thought about life going forward. And that was that we had a mathematics teacher who was a lightning calculator, which means that he could take any problem and give you the answer instantaneously. He said that he never makes a mistake in his head. But he might make a mistake when he actually writes it on paper or on the blackboard. And he introduced us to a very major epic in Hindu philosophy because he was basically born before partition. And it was an eye opener because in Pakistan, already there was a polarization that

Hindus are bad, and Muslims are good. That is the short summary of how the partition occurred. And the bad guys are on the other side of the border. And we are the good guys on this side of the border.

Fairbairn: So, Pakistan was a Muslim dominated culture. And India was a Hindu?

Raza: Correct, it's overwhelmingly a Muslim country. I think there are only about ten percent non-Muslims, which is represented by the white stripe on the side of the flag.

Fairbairn: I see.

Raza: So, but that basically caused me to actually started thinking about the boundaries of what a religion is. And I started reading about Islam in English, which was an eye opener because suddenly it didn't look as much a divine delivery as it was when I had not read it in English. So, after that, I don't know how it happened that-- about the time I was finishing A Levels, I ran into a secondhand bookstore. And I saw a book by Bertrand Russell called "Why I'm Not a Christian." And I picked it up. And I read it. And it basically justified why people should think about their religion and the things that their religion says and not take it as divine delivery of a message. Now, in the meantime, I had already finished A Levels. I had joined the premiere college in Lahore called Government College Lahore.

Fairbairn: Before you get in to that, what subjects-- were you naturally attracted to technology or-- I shouldn't say technology but math and science and that sort of thing?

Raza: Physics.

Fairbairn: Physics and-- but you had interest in other things in--

Kapoor: You mentioned philosophy.

Fairbairn: Philosophy or religion.

Raza: So, that's where I was going.

Fairbairn: And whatever. So, did you have a-- was there a question as to what path you should pursue in the future?

Raza: Absolutely. Absolutely. So, I just was saying, after A Levels, I joined Government College Lahore for physics. But my interest in philosophy grew very high. So, about one year into the program, while I was doing bachelor's in physics, I decided to start a bachelor's in another campus of the same university in philosophy. So, I had a 50cc little moped. And I used to use it to run from class to class. And so, I was doing two degrees at the same time. There was no double major. And--

Fairbairn: In different campuses?

Raza: In different campuses. And finally, I did well on both of them, but when the time came for me to be awarded the second degree, which was in philosophy because I started it a year later, it went to the university administration because you are not allowed to do two degrees at the same time. So, I went and appealed it, and they gave a waiver. And I got both the degrees, philosophy and physics. But this was rubbing my dad really badly because he was opposed to my doing physics. He wanted me to do either engineering or medicine. Those are the two choices every good Indian or Pakistani has. So, he basically was really out of his mind about my doing philosophy also. So, he--

Fairbairn: Physics is somewhat worthless, and philosophy is really worthless.

Raza: Really worthless, exactly. So, he basically asked me to leave the house. And now, in philosophy, I talked to the university, and there were only three scholarships that were given to the top three guys, which was actually quite a generous scholarship. So, I took that scholarship, and I basically decided to move on my own. But then my mother got very distraught, and she somehow persuaded me to come back. And I came back. I made it up with my dad. And my dad basically sat me down and said, "I think I have saved some money, not a lot of money. This is all I could save. But I'm willing to invest all those savings if you do electrical engineering in England. I can't afford sending you to the U.S." So, my interest in going to England was less to do with doing electrical engineering but just to see England. And I took him up on the offer. And that's how I ended up with a third degree in electrical engineering.

Kapoor: So, what became of your interest in philosophy?

Raza: It remained. It remained because even while I was doing electrical engineering, I would never go to sleep without reading a book on philosophy. And I was there for a little while. And I was one day crossing the university campus at Imperial College. And I saw a board over a room which said Socialist Society. So, I knocked on the door, and the door opened. And there were a bunch of kids sitting around reading something. So, they looked at me and said, "Yes, what can we do?" I said, "I just saw the board saying Socialist Society. So, I came in to find out what it's all about." So, one of them says, "Where are you from?" I said, "Well, I'm from Pakistan." And they said, "Are you familiar with Marxism, Leninism, Mao Zedong thought?" And I said, "No." They said, "Then you are a running dog of American Imperialism." So, that got me interested in reading what is Marxism, Leninism and-- and a year later, I went and confronted them. So, it was interesting.

Fairbairn: So, you had a bachelor's degree in philosophy and physics and then another bachelor's degree in electrical engineering?

Raza: And the third bachelor's degree in electrical engineering.

Kapoor: So, what happened with your brother? What's-- through all this episodes of selection of subjects and all--?

Raza: So, interestingly enough, my brother basically was not as interested in studying as I was. And he didn't do as well academically, which used to bother my dad a lot. And on one occasion, he made a

remark which characterizes some of the biases and social thinking, both in India and Pakistan, that my dad sat me down and said, “You know, you’re superior to your brother in every respect except the color of your skin,” which meant I was like a half a shade darker than my brother.

<laughter>

Raza: So, that’s what happened with that brother. But I have maintained contact with him through all these years very regularly and do whatever I can. If he needs anything from me, I’m always there for him.

Fairbairn: So, you came to England. You were interested in going to England. Before your father made you this offer, had you sort of decided or thought that you wanted to go abroad? Did you have any-- what was your thought in terms of career at that point?

Raza: Doing a PhD in philosophy not in electrical engineering. But that would have been a longer road. And this electrical engineering, even though it was very distasteful for me when I first arrived, to do engineering-- I mean you can imagine going from studying philosophy into doing electrical engineering. It was a tough transition, but I made it. And I started enjoying it to my own surprise.

Fairbairn: I was envisioning you on your little moped going between campuses like going between two different worlds, the physics world and the philosophical world. And you had to sort of get your mind turned around between the two of them.

Raza: That’s right. Well, luckily, actually at that time, electrical engineering had quite a bit of physics in it, which I enjoyed. But I started enjoying electrical engineering also. These are the days when electrical engineering, as it was taught at that time, was very different from what it is today.

Fairbairn: So, what year did you go to England?

Raza: ’69.

Fairbairn: Okay, and how long to get the degree?

Raza: Just two or three years.

Fairbairn: Okay so, ’72 by the time you got your degree.

Raza: Exactly.

Fairbairn: Then was there any particular insight, influence, a-ha moment that happened during that period that sort of guided the next step?

Raza: Yes, I had gone back-- I was going to do my PhD after that, but instead of doing my PhD, I went to Pakistan again. ’72 was one year after Pakistan had gone through a civil war followed by a war with India,

which was-- decimated Pakistan pretty much. And I arrived, and I was shocked at the state of affairs. And I decided that I was going to stay and do what I can to give back both from an egalitarian point of view as well as just doing something from the country of my birth. And it took me six months to find my first job where I had to compete with eight hundred people in first a written exam and then interviewed by a bunch of Pakistani and German engineers to join Telephone Industries of Pakistan as a research engineer. Telephone Industries of Pakistan was jointly run by Pakistani engineers and engineers from Siemens because Pakistan basically had contracted with Siemens. It's very strange that that allowed Pakistan to have fairly advanced technology for its time. And in return, Pakistan sought from Siemens the ability to export the product, that the product has to be of a quality that can be exported. At that time, there were restrictions on exporting to various countries in the world, particularly Portugal, which was a fascist country and had trade embargos on it, and South Africa, which had Apartheid and had trade embargos on it. But since they couldn't be exported from Germany, they used to export it from Pakistan, which had not signed up for the trade embargos.

Fairbairn: So, you say there were eight hundred people competing for the job. That's because the economy was in such poor condition that--

Raza: In poor shape, exactly.

Fairbairn: Everybody was looking for a job.

Raza: Exactly, there were so many engineers that were unemployed that just a single job opening would cause a huge amount of competition. It was the toughest job I got in my career.

Fairbairn: So, how long did that-- how did that work out?

Raza: So, I was there in Telephone Industries of Pakistan in the research department for three years. But while I was there, in the evenings, I would go and do social work because there was such a contrast between even the standard of living of engineers versus the standard of living of even workers within the factory and much more if you moved away from the factory and took a look at the agricultural workers. It was just mind-boggling contrast, and it was very difficult not to try to do something. So, I started organizing university professors and doctors and started doing various things like setting up libraries, setting up Red Cross boxes in villages and in labor colonies, and then applying for fresh water, and writing notes on how to take your relatives to a hospital, simple things. But in that process, I would also express my opinions. And my opinions did not comply with some of the mores of that time. And somebody reported me to I think the government authorities or something that this guy, we don't really know if he really believes in god or Islam, whether he's a Muslim or he's a CIA agent or what he is or why he's doing all these things over here. So, three years into my job, I got a call from my director, director of research and development. And he sat me down across the table and said, "We have some complaints about you. And they've come all the way. People have reported you to government authorities." And I said, "What complaints?" "Well, I want to ask you are you a Muslim?" And I said, "What's that got to do with my job?" He said, "Okay, I got my answer. I just want you to know that that's unacceptable." I said, "I do my job. Are you satisfied with my job?" He said, "No, I'm not satisfied with anything you're doing,

particularly what you're doing outside your job because it is causing a disruption. People are listening to you, and we don't want this to happen." I said, "Okay, then I'll resign my job if you're not satisfied. I mean so far, you've promoted me. There must be a reason you promoted me. Now that you've heard things about me which have nothing to do with my job, I'll resign my job." He said, "No, I'm not going to let you resign your job. I'm going to basically impose the essential services act which will never allow you to leave this job for the rest of your life." I thought that was a little harsh. So, luckily, if you remember, I told you I'd gone to this very prestigious high school. So, I looked through the records, and I found one of the people who was a few years ahead of me in high school was a minister. He was a minister of some position but not really in telecommunications, which was the branch that would govern the Telephone Industries of Pakistan. But nevertheless, I went there, and I sent him a little chit saying, "I hope you remember me." And almost immediately he came out because that school had a very tight-knit student community. And he sat me down and said, "What's the matter, Atiq? What brings you here?" And I told him, "You know, I want to resign my job. And he said he's-- my boss said he's going to impose the essential services act." And he said, "Atiq, you know, in high school, you were a troublemaker. You're still a troublemaker. I have never had a single person come to me asking me to get a resignation accepted. Don't you want a job?" I said, "I'll find a job." So, he took the resignation, got it stamped by the minister of telecommunication. And that's how I got free again. And then I went and started as an assistant professor at the same university where I'd done my physics and philosophy in solid state physics. They had just opened a solid state physics section. And I stared teaching over there until I finally came to the U.S.

Fairbairn: And how long did you teach? And what--?

Raza: That took another three and a half years. And what happened is that, along that time, if you guys remember the military overthrew the democratically elected prime minister whose name was Zulfikar Ali Bhutto. Bhutto was well-known around the world. That overthrow was coupled with the invasion of Afghanistan. And the invasion of Afghanistan was supported by U.S. money but by Saudi influence also. And it had caused a rise in an element of Islamic fundamentalists and a particular section of society that was completely marginalized until then. And they descended very heavily armed upon all areas where there were any intellectuals. And the university was targeted. And they started actually going through the application forms of the university professors to see what they had written against their religion. And if they saw somebody had left it blank, they would attack them in their homes. And then they would pull out their albums from when they were studying abroad. And if they saw a woman not wearing proper clothes, or in a bikini, or a swimsuit, they would blow it up and put it on-- it was like a reign of terror had descended upon the university. And I was threatened on one occasion because I had flunked one of the guys in that group. And he wanted me to promote him. And his-- so, they showed up with guns. So, there was a physics professor, interestingly enough, who was-- I knew was involved with them. So, I was an external examiner for the physics department from the Solid State Physics Center of Excellence. And I went and talked to him. He liked me a lot, so I told him about this story. And he basically said, "Okay, you won't have to worry about it." But that told me, I've got to leave Pakistan. I can't stay here any longer. It will put my life in danger and that of my family. So, I basically came for graduate studies mainly to get out of Pakistan.

Fairbairn: So, you-- and then where did you go? Why did you-- how did you pick your landing spot in the United States?

Raza: So, in United States, I basically applied to various universities. I'd never heard of Stanford. I applied to MIT, and I applied to University of Texas, Austin. And I applied to University of Oregon. UT Austin because they had a very good scholarship program. MIT because it was the best known university in technology in Pakistan at least. And University of Oregon because University of Oregon had two professors in physics. Every one of their PhD students used to go straight to Bell Labs. And it was the cheapest place for married housing, eighty dollars per month.

Fairbairn: So, you were married at the time?

Raza: Pardon me?

Fairbairn: You were married at the time?

Raza: Yes, I was. I had a one and a half year old son. So, that accelerated my thinking of leaving Pakistan. So, I arrived over here with my wife, ex-wife, and one and a half year old son and ended up at University of Oregon. But I was there only for one semester and a summer. And my advisor got appointed as director of Argonne National Lab's department of solid state physics. And he basically said, "Atiq, I think you should go to Stanford." And I said, "I can't afford it because my fellowship doesn't even pay for married housing over there." So, he said, "Okay, I'll make a recommendation that they give you a second scholarship." And that's how I ended up at Stanford.

Fairbairn: So, you came to Stanford and studied solid state physics? Or what--

Raza: Yes, I studied mostly solid state physics in the department of material science and engineering. So, material science of engineering, if you are familiar with Stanford, is a confluence of physics, electrical engineering, and metallurgy.

Fairbairn: And you got a master's degree.

Raza: Yes.

Fairbairn: And what year did you go to Stanford?

Raza: So, I went to Stanford in 1979. And I got a master's degree. And at that time basically, I was going to do my PhD because it's easier to basically get a research assistantship if you're doing a PhD. But you know once you've got a PhD, it's harder to get a job. So, while I finished-- once I finished my master's, I started applying for a job because even with my two fellowships, it was hard to go month to month. So, my first job was at Signetics. And from Signetics, I got hired into Trilogy because when Trilogy started, Gene Amdahl started Trilogy, he started looking for bipolar engineers. And I was working on bipolar FPGAs, or FPLAs as they were called at that time, Field Programmable Logic Arrays. So, one of the

senior engineers, who left from Signetics to join Trilogy, recommended me. And then I was interviewed at Trilogy, ended up at Trilogy. And that is how I got to know Gene Amdahl. It was a very interesting story of how I actually got to know Gene because Gene was way above me. I was a project manager. And Gene was the CEO and founder and chairman and a god in computer science. And what happened is that he was getting a lecture by Dan Siewiorek who was a professor at Carnegie Mellon in reliable computing. And Gene had this idea of having a wafer-scale integration, if you remember.

Fairbairn: I do remember.

Kapoor: Yes. Yes.

Raza: And he was using the concept of triple modular redundancy, which is logic blocks from flop to flop will have three flops. And they'll be a voting element on three flops because everything had three copies, and we could have two out of three vote in order to get a complete processor end to end. And what happened is that I was sitting in the same lecture while Dan was talking about how reliable such a computer would be. And I raised my hand, and I said, "It's a great idea, but what if the voting element is hit by a defect? You won't make your way to a reliable computer. You won't even yield." And Gene came unglued at me, screamed at me. "How can that be possible? It's not possible. The Thomas Group has done an analysis." Okay. Well, word of that went all over. And my boss came, my boss's boss, "Atiq, you got yelled at by Gene?" I said, "I asked a simple question, what happens if a defect hits the voting element?" He said, "Okay." So, then I get a call from Gene. I got called to Gene's office, and he says, "Why did you ask the question?" I said, "I asked the question because the voting element is finite in dimensions. And if the defect density is high enough to wipe it out, you're not going to get any yield. And secondly, you haven't had any yield. And thirdly, I have been looking at the whole wafer under a microscope, and I can see cases where it's getting hit." So, Gene said, "Are you serious?" I said, "I'm telling you why I asked the question. You asked me why I asked the question. This is why I asked the question." He said, "Can you prove what you're saying?" I said, "I can either prove or disprove or even tell you what threshold of defect density you require in order to yield." He said, "What do you need?" I said, "I need to hand-pick my team. And I want to basically run a simulation. And I'd like to get access to the computers in order to run the simulation." So, I hand-picked the team. I was given one month to do this analysis. And we did the analysis very simply. I mean we basically made a model of the voting element by its dimensions and made a Monte Carlo analysis of how the defects would land, gathered defect density information from the fab, looked at how various levels were impacted by the defects. And lo and behold, it could never yield. And the day we announced it, the next day, Trilogy was more or less shut down. But during that process, Gene became quite close to me and offered me to stay on to do other things. But I told him that I have to move on and do something else.

Kapoor: So, going back to Signetics, you came from the material science world from Stanford. What was your job like at Signetics? What were you doing?

Raza: That's a very interesting question because I was first hired into failure analysis in Signetics. What happened is that in the failure analysis, there was one failure that was impacting digital equipment. I was the highest revenue make for Signetics logic and memory group. And I was given the task to debug it. I,

for the life of me, couldn't find out what was wrong with it. So, I looked around. And I found there was one person at Signetics who had been doing failure analysis for the longest time. And I just went to him. And I described the symptoms. And he said, "It reminds of something I'd encountered. So, there is a book that I described exactly how I found the problem." And I picked up the book. I read the book. And I followed exactly what he had done to get finally at the root of the problem. And the root of the problem was that there was aluminum migration because the aluminum metal was over silicon dioxide. And aluminum actually was migrating through the silicon dioxide because there was no transition metal layer below the aluminum lines, which happened later on in order to overcome this process. And that was causing a short in all the I/Os. So, if I had not gone to him, I would have been stumped. Well, once I found the problem and I recommended changing the design rules to give more space so that the short would not occur, I became a hero. So, they said, "You have to move to the design group." So, that's how I transitioned there. And they saw that my background was in double E.

Fairbairn: But you hadn't done anything in system design or architecture or anything like that at that point, is that correct?

Raza: Not practically, not practically.

Fairbairn: Okay, so you were at Trilogy. You figured out why they shouldn't be in business <laughs>. Tell me about the next step.

Raza: So, then I went to CDI, where I was there for a short period of time. And CDI kind of--

Fairbairn: California Devices.

Raza: California Devices, which made the first large scale gate arrays. And then basically, I was recruited actually into VLSI to rescue the gate array family because VLSI was really struggling with this gate array family which had second sourced [ph?] out of Fairchild. And so, I came up with a new design for the gate arrays. And it was successful, if you remember.

Fairbairn: That was Sea of Gates?

Raza: That's exactly right.

Fairbairn: And so, at CDI what were you doing there, at California Devices?

Raza: I was head of engineering.

Fairbairn: And what was the state of CDI at the time? And what impact did you attempt to have there?

Raza: Interestingly enough, I developed routing methodologies and congestion analysis software over there in order to get the large arrays that they had already physically designed to route. And we made

them successfully routed. So, that was the first large scale gate array in the industry. It was the largest gate array that had ever been designed in the industry that routed.

Fairbairn: So, you were using software routing at the time?

Raza: Right.

Fairbairn: And so, you came to VLSI Technology. The-- you worked on the gate arrays. Tell me how that evolved and what the next step at VLSI was.

Raza: At VLSI, I don't remember the details. But I ended up then basically made in charge of the design centers. That's when I started again going back and started catching up on computer architecture and computers because there was the Wang project that was the actual, I think, catalyst for my becoming head of the design centers.

Fairbairn: So, tell me about the Wang Project, that's an interesting story.

Raza: So, basically, this was right after the gate array project had been finished because the gate arrays were struggling in the beginning. And the Wang Project had fallen into hard times. The Boston design center was struggling in their interaction with the Wang design team. They were doing the second generation of CISC processor, very simple single scalar CISC processor. And Henri Jarrat, the president of VLSI, asked me to go take a look at what I could do. Could I rescue that project? So, I arrived over there. And the one thing I had was confidence that if I really dug into it, and I figured out what had to be done, I would be able to manage it to conclusion in a systematic manner. And I put in a very expensive program, which I proposed to Wang. There was a business manager by the name of George Jones, who wrote the financial plan. I said, "Try to charge them as much as possible because I don't know how much it will cost to make this successful." So, we made a complete plan of how it would be successful. I went and presented the plan to Ahn Wang himself because, you know, processors were always under the direct guidance of the CEOs of that time in vertically integrated companies. And he listened to me. And he bought in to the chagrin of most of the processor designers at Wang. So, I said, "However, the entire team has to move to San Jose for me to effectively micromanage the project from beginning to end." And when that happened, we moved the team. I borrowed basically the best guys out of the San Jose design center and combined with them the assistance that I needed from the design technology group, which you were heading at that time. And I started studying how the architecture worked, how the processor worked, and learned more and more and more and became very interested in it. And we got the project done on time on schedule. And it was a very big success.

Fairbairn: So, that was your first introduction to processor design in a serious way in semiconductors?

Raza: In semiconductors, yes.

Fairbairn: What previous work had you done outside of semiconductors and processor design?

Raza: The only exposure I had was at the Trilogy Computer, which was a mainframe where Gene Amdahl had told me that economics of computers is a hundred thousand dollars per MIP.

Fairbairn: A hundred thousand?

Raza: A hundred thousand. And you know, how a MIP is calculated in those days, there is a very simple benchmark called Dhrystone. This is a very short piece of software. And you count how many millions of instructions can be processed while running Dhrystone.

Fairbairn: So, you started to develop-- anything else happening in your life at that time? Was there any other-- you were just-- did you have a vision of what you wanted to do? Or what was your personal goal at that time? Or were you just sort of--?

Raza: Well, the one thing I had was much more hubris than I have today. After all the challenges I have gone through, and things that I've done, I thought I could basically undertake anything, learn anything, and I would be able to get a handle on how to get things done. So, I was approached by NexGen where the founder was Thampy Thomas, who actually had related to Ratan Tata and had started a company, not successfully, but-- which was funded by Ratan Tata. So, somebody, I think one of Thampy's engineers, first came and approached me and asked me if I would be open to looking at a company that's trying to take on Intel. And it's not only taking on Intel, it's taking on Intel, Microsoft, and IBM at the same time. I thought that was a little bit beyond even my hubris. But I would take a look at it. And then I met Thampy. And he described his vision of actually building not just a processor, but a full computer with a new operating system based on UNIX. So, I listened to him. And then he said one of my board members is Vinod Khosla. Vinod was the founder of Sun, and he met me. Vinod actually was more inspiring than Thampy was. Thampy is very smart but a relatively shy person. And Vinod and shyness never met. So, Vinod was very aggressive and painted the vision of taking on Intel and challenging Intel with a small team.

Fairbairn: So, Vinod was a venture capitalist?

Raza: Yes, he had just been removed from Sun by one of the board members, which was John Doerr. He was fired from Sun and hired into Kleiner Perkins where John Doerr was the lead venture capitalist.

Fairbairn: <laughs>

Raza: And Vinod-- this was one of his earliest ventures--

Fairbairn: So, he was representing Kleiner Perkins at that time?

Raza: He was representing Kleiner Perkins.

Fairbairn: I see.

Raza: And he attracted me into considering the task of becoming the head of engineering at NexGen.

Fairbairn: How long had you stayed at VLSI Technology?

Raza: I had stayed at VLSI for four and a half years.

Fairbairn: Okay, and most of that time was running the design centers?

Raza: The bulk of the time was running the design centers.

Kapoor: So, just connecting to previous life, so meanwhile your family in Pakistan, were you visiting Pakistan during this time?

Raza: I have gone back-- from the time I have come to the United States, I have gone back only twice back to Pakistan, once to visit family, and the second time when my mother passed away. And the thing is that both of those incidents had something-- when I was at VLSI Technology, I went to Pakistan. And during that time, I had met with several industrial leaders as well as the government. And I offered to open a design center over there. And the result was that nobody was interested in opening a design center. But I was supposed to be going to India next. And they basically said that if I go to India from Pakistan, they are going to make my parents' life miserable. So, for me, it was hard enough when I left Pakistan to see this reign of terror occurring at the universities. Having that situation face me over again, I just decided I'm not going to go back again. I only went back when my mother died. I haven't been back now in close to twenty-eight years.

Kapoor: It will still be a very unfriendly place for you if you did?

Raza: Yes, because since that time, I have remarried. And I have married about eleven years ago with a woman who's a Hindu Brahman and is a very devout Hindu Brahman. And in Islam, that would be-- either it would be apostasy, or it would be something worse. So, that could easily qualify me to be killed just for doing that. <laughs>

Fairbairn: So, interesting side story, thank you. The-- you spent four and a half years at VLSI. What were the years, just to kind of keep track here along the way?

Raza: I think it was-- I joined VLSI in either late '83 or early '84. And I left in December of '88.

Fairbairn: And had you continued to sort of develop an interest or pursue interests in computer architecture and so forth?

Raza: Yes.

Fairbairn: What was--

Raza: That was the reason why basically I got involved at NexGen because here was trying to use some innovations in computer architecture, interestingly enough, doing branch prediction and out of order execution in a single issue machine, single scalar machine. But nevertheless, something that would give you an architectural edge over the Intel processors of that time. When I joined, I discovered that it was extremely disorganized. They had only one computer on which they were running everything. And they were doing gate-level designs. So, it became a very painful experience to actually build the processor. And I knew right away, in about the first three or four months, that this would be a very tough project to pull off. Four months after I joined NexGen, while I was still struggling with building a team, because by the time I arrived, what I didn't know is that Thampy, the CEO of that time, and the previous VP of engineering had a big blowout with the result that almost the entire engineering team had left. And there were only about four guys left. So, I had to rebuild the engineering team. And I was doing all this. And I get a call from one of the expatriates from VLSI Technology, Wes Patterson, who had gone and joined Xilinx. And Xilinx was already quite successful and on its way to having an IPO. And Wes Patterson calls me and says, "Hey, Atiq. I want you to consider coming and joining Xilinx as head of engineering. And you'll get a lot of stock options. And you'll be rich because we're going to have an IPO soon." This is before the days of 409-A. And you can't have low value stock just before an IPO, which all the rules had came later. But I had already given my word and commitment. And I told no to Wes Patterson and stayed at NexGen. And there were times when I wondered if I'd made the right decision between that time and until the project was completed.

Kapoor: So, who was the VP of engineering that was let go?

Raza: Nick Tredennick.

Kapoor: Oh, Tredennick, okay. Yeah.

Fairbairn: So, you came to NexGen in '88?

Raza: End of '88, more like I started in '89, yes.

Fairbairn: And you describe sort of the early process, but how did you turn that around? And what was the-- what were the steps? And you eventually became CEO, is that correct?

Raza: Yes, 1990, I became the CEO by unanimous vote of the board, including Thampy. Thampy became the chairman. And the whole thing was, I mean even as CEO, when you are CEO of a company that's developing a product, you're really head of engineering. So, the one thing I did is I was able to persuade the board that the idea of doing an operating system, a user interface, and a CISC computer all in one is a hopeless idea. So, the processor that we were trying to build was so large that the technology we were using was at Yamaha which was three generations, or two and a half generations, behind Intel technology. So, it took eight chips to build that processor.

Fairbairn: Did you actually build it in eight chips?

Raza: We built it in eight chips. And the reason we built it in eight chips is I couldn't get enough funding to do a single chip processor unless I showed that the first eight chip processor worked and could boot DOS and run some applications. That eight chip processor was extremely difficult to complete. Once I completed it, I got the funding to build a single chip. Now, I decided I'm going to intercept Intel's technology. And there were only two companies in the world that had semiconductor technology coming close to the kind of technology that Intel had. One was Hewlett-Packard. And one was IBM. IBM was not doing, at that time, foundry or processing for any outside company. I went to Hewlett-Packard, and I was able to persuade the head of semiconductors in Hewlett-Packard to build the processor. They gave us their design rules. And we started building a single chip processor. And it was a very, very tough project, but we were able to accomplish it in a very short period of time because we already had the logic working. So, it was mostly a transition to a new technology and integrated it onto a single chip.

Fairbairn: Do you remember what technology that was, NMOS, or CMOS?

Raza: It was CMOS.

Fairbairn: And what kind of--

Kapoor: Device count?

Raza: I think it was half micron technology, which, at that time, was pretty much the state of the art. And so, it becomes very interesting because we built the chip. We got the first chips. They worked, but the yield was extremely low. And Hewlett-Packard, at that time, was very interested in a strategic relationship with us. They were watching us. We were actually being successful in making a chip that ran the operating systems and applications compatible with Intel. We are getting a little bit of a reputation, not widespread yet, but, you know, for those that mattered, we were getting a reputation of building an advanced processor.

Fairbairn: What were you competing-- You were competing against Intel. What was the Intel product of the time?

Raza: Well, Intel was between the 486 and the Pentium. We were faster with that chip than the 486, but not faster than the Pentium. I had in the meantime started a two issue machine with basically an Intel compatible bus for a sixth generation processor that would outdo the Pentium. So while that was under development, I had the fifth generation on Hewlett Packard technology just prototyped. Right at that time there was a change of CEO at Hewlett Packard and the new CEO, one of the first things he did is he shut down the fab and this was my only fab and you can imagine, you know, a complex microprocessor at that time was kind of at the state of the art density, how do you port it so quickly? So I ran into some IBM executives in the semiconductor area. I'd run into them earlier and we had talked about what we were doing and they were interested in knowing what we were doing. I called them and I said, "I need to talk to the head of your semiconductor operation. Somehow you have to put me in front of him." So I went and I talked. At that time, his name was Mike Attardo. Mike Attardo was also the person who inspired the development of the power PC and he, for some reason, he hated Intel. I think it was because originally he

felt that it was IBM's money that allowed Intel to become so powerful that now they were more powerful than IBM themselves. So we met and he listened to my whole story and to my immense surprise, he asked the IBM process team, the fab team, to modify their entire fab flow to mimic the Hewlett Packard process.

Fairbairn: Wow.

Raza: So that our mask set, our data mask database, they would generate a new mask set because they had to use their own fiducials, would be identical so we would not have to change the physical design database. So we did the physical design database. Nobody at NexGen believed it would work because they said we haven't simulated it enough, we haven't checked it out enough. How can it possibly work? But it worked. It came back, it yielded much better than Hewlett Packard and it ran at 100 megahertz which was faster than anything Intel had at that time.

Kapoor: So, a question. Was L.J. Sevin on the board? L.J., Sevin Rosen?

Raza: L.J. Sevin was on the board of Compaq at that time. Compaq had invested in NexGen and L.J. had played a role in the decision for Compaq to invest in NexGen.

Kapoor: The reason I'm asking is he was also on the board of Cypress.

Raza: Yes.

Kapoor: And I think you approached Cypress. I met you at that time.

Raza: Yes.

Kapoor: To look at the process technology.

Raza: Yes. I looked at Cypress process technology because there was a guy by the name of Ross who was trying--

Kapoor: Yes, Roger Ross.

Raza: Roger Ross, who was trying to build a SPARC processor at Cypress and we thought that if, you know, basically, John Doerr said, if Roger Ross thinks he can build a SPARC processor on Cypress technology, you should be able to build. But when I looked at the technology, I mean, I'm not competing against SPARC processors, I'm competing against Intel processors. Cypress technology did not cut it even though, you know, T.J. was very impressive and really a thinker beyond, in semiconductors, a thinker beyond his time, but he was not developing a state of the art technology at pace with Intel's manufacturing technology.

Fairbairn: So you were able to create a single chip and you got IBM to fab it. What happened at that point? What was the--?

Raza: Well, the story is not over. So basically, we brought it to market and as we brought it to market we are developing the next generation, because this is never ending. Once you start a fight with Intel, you can't stop, you know, you keep building the next generation. And our whole team was only 110 people including marketing and, you know, whatever other administrative functions, which were very thin in any case, in our company. So we're doing the sixth generation processor. We're doing the fifth generation and we brought it to market head to head against Pentium. Right at that time, this is 1994, if you remember, Pentium had a divide bug in their floating point calculations.

Fairbairn: Mm-hmm.

Raza: So in the fourth floating point part of the processor, they had a divide bug and, you know, it became a scandal. That was an opening where we got an opening for people to start using our processor and we started getting market momentum. Compaq came back and in early 1995 announced that they were going to use our processor. That is what got the attention all over the industry. I mean, there were headlines in San Jose *Mercury News*, which people read newspapers in those days, talking about what we had accomplished. Nobody expected that we would be able to pull it off.

Fairbairn: You mentioned you only had 125 people, which is small for building a complex processor. How much money had been put into NexGen over that period of time, do you recall?

Raza: Almost $100 million. We were basically spending a million dollars a month and I had kept that spend flat almost throughout that time period. Interestingly enough, one side story is that I used to run out of money sometimes every month and I would somehow raise money for another month and another month and another month. I mean, if you ask Vinod Khosla who was the longest sustaining board member at NexGen, he would say that it was one of the most difficult companies to pull off in the history of Silicon Valley, which is true.

Fairbairn: Yeah. Being in the processor business, it's a major challenge.

Raza: Oh, yes.

Fairbairn: Technically and marketing and every other way.

Raza: In every other way. I mean, Intel basically warned our distributors that if they would pick up our product they would shut them down. And this was happening while 1990-- when 1995 happened as we were going public, now we were very visible and Intel just turned all their guns on us because AMD had flubbed their processor. So they had a processor called the K5 which never really saw the light of day and--

Kapoor: So going back to the architecture--

Raza: Yes.

Kapoor: Of the single chip at NexGen, was that a RISC chip or was it emulating CISC using a RISC chip?

Raza: Well, you can't say it was emulating CISC using RISC, but it had a RISC-like approach in the sense that the data path was a fixed length data path. So what we did is we created pseudo-ops which would break up the long instructions in the Intel instructions set architecture. Because Intel instructions set had the CISC instructions and some of the instructions are extremely long. So we would break it up into regular size pseudo-ops and we would process them. And we had since set out of order of execution pipeline, we would always respect the boundaries of the instructions themselves in getting the execution and we would eliminate any interlocks that would occur before you would write down because you always write in order. So in doing so, some people described it from a marketing point of view as a RISC inside a CISC, but it was really data path regularity because it made the physical design of the data path much more even, much more controlled and you know, we basically had the equivalent of a data path compiler for tiling up the data path because all the critical paths in logic are in the compute data path, in the integer calculation of the results that you are generating whether it's the address calculation or it is the operand calculations.

Kapoor: Did it give you any advantage in chip size, for example?

Raza: Oh, yes.

Kapoor: Okay.

Raza: But what really gave us an advantage in chip size is that we started going for very large caches, so that's what gave us the biggest advantage because a big cache and an efficient cache hides a lot of, you know, issues elsewhere.

Fairbairn: So the chip, the processor itself was smaller but then you added a lot of cache to it so that made it bigger? I mean, what was the ultimate comparison in terms of chip size with the Pentium?

Raza: We had a smaller chip size than the Pentium.

Fairbairn: So, smaller.

Raza: Yes. Despite that.

Fairbairn: And was that-- I mean, was that-- What was your key advantage going to market? What did you sell on?

Raza: Same performance, smaller die size so I could sell for a lower price than Intel. That was the advantage

Fairbairn: And was IBM still the foundry at this point?

Raza: IBM was the foundry. So when I had signed the foundry agreement with IBM, I had put in that in the event of a change of control they would share all their design rules with the acquirer. That saved me because what happened is that when we became quite notorious and well-known, we got a visit from Microsoft engineers. Nathan Myhrvold knew about us. He was interested in one of the things we were doing in multimedia, acceleration, which was different from what Intel was doing. Intel had defined the MMX instructions and architecture. They had talked about it but not described exactly what the MMX architecture was, which was multimedia extensions, that was what MMX stood for. We had developed our own media extension. So the IBM team first came to see the media extensions but when they heard about our sixth generation which was under development, they were totally fascinated with what we were accomplishing in the generation after the one that we were shipping. That took us, they took the news back to Microsoft that these guys at NexGen are the only guys who have a product that could be competitive with Intel. So that's what led to a call from Nathan saying, "Atiq, we need you to come and meet Bill Gates." And it was supposed to be a 45 minute meeting and Nathan said, "You know, Bill has a very short attention span, so if the meeting doesn't last 45, don't be offended, it's very common." We met at a Chinese restaurant. Our meeting lasted four hours. I mean, Bill became completely interested, absorbed and--

Fairbairn: And Microsoft was just interested in getting a competitor to Intel, right?

Raza: Microsoft was interested in getting a competitor of Intel because the theory that I presented to Bill, because I had tried to practice what am I going to say to Bill when I go there to keep his attention past 45 minutes, I said, "I can lower the price of the end product. And if I lower the price of the end product, this is an end product that is a mass market product. The price elasticity of demand is going to pick up volume and you gain by volume. And if I take the price of Intel down also in the desktop," which is the most commonly used platform at that time, "it will be-- it will allow that elasticity of demand to be built such that there'll be more room for software in the total cost or the total price." And that appealed to Bill. And that's when he asked me, okay, this was the most crucial conversation that occurred, he said, "What do you think of AMD's fifth generation processor?" And I said, "It has 300 bugs from what I heard directly from their CTO." So he said, "300 bugs in a processor? Is that a big deal, because there are more than 300 bugs in my operating system."

<laughter>

Raza: So everybody started laughing and Nathan turned to me and said, "Atiq, you're not allowed to talk about it because you can never quote Bill having said that because this is covered by our NDA."

<laughter>

Raza: So now I can say it because the NDA has long expired. So Bill said, "If that's the case that AMD basically is not going to come out with a processor, I can tell you, you cannot compete with Intel. End of story. Just trust me, you can't compete with Intel." I said, "What about an alliance with IBM?" He said,

"You're insane. There's no such thing as an alliance with IBM. I have tried an alliance with IBM on OS/2. Did that work? It can't work. Alliances with IBM don't work but you should basically merge with AMD. Have you ever talked to Jerry Sanders?" I said, "Yes, once. I wouldn't call it I talked to him, we were introduced at an investment banking conference and somebody tried to introduce me to Jerry and Jerry did not hear my full name but, you know, I'm a brown guy and he heard "Raza" so he-- they changed it to "Raja" and then he kept calling me Raja for about an hour while he told me how he was going to crush me."

<laughter>

Raza: So I said, "How do I have a conversation with such a person?" So Bill said, "Well, I can help but I want you to know that Jerry Sanders is very smart. He's very smart. He's also extremely egotistical and the only other problem is he is completely random. So if you can handle that, I'll make the introduction and I'll make the phone call." So Bill did. He made the phone call to Jerry.

Fairbairn: So at this point, did you think that would be a great plan to be bought by AMD or sell to-- I mean, what was the--

Raza: Yes. Why? Because my product had stalled in the channels because the channels were threatened by Intel. And basically, Intel had gone to OEMs, they had gone to Taiwan, they had threatened every single person who was selling my product. I had gone to the Federal Trade Commission and appealed to them for help. Nobody was willing to help. Intel was such a star of the entire U.S. economy. At that time it was a juggernaut, more powerful than any company that you can pick today.

Fairbairn: Okay. So you went to meet with Jerry Sanders. Was it hard getting that meeting set up?

Raza: It wasn't hard once Bill Gates had made the call. The meeting happened very quickly. Jerry Sanders was not convinced that his own product was flubbed, that he was in trouble with his own product. He had already built a fab for $1.5 billion dollars that was empty and it had the ability to have not the state of the art but a few generation, a generation and a half behind Intel. So the one thing that I had done during this time period, I had hired as Chief Operating Officer the former GM of Intel's Pentium group. His name was Vinod Dham. So Vinod Dham actually gave us a lot of credibility because he had left Intel and come to NexGen. And Jerry Sanders was more convinced about our efficacy and reality of the product that was under development-- he was not interested in the one that we were selling, he was more interested in the product that was still under development, which was due to tape out in 1996. It was about seven or eight months from tape out. That's the one he wanted, because that potentially could really challenge and even have an edge over the Intel sixth generation product. So one thing led to another and we were able to come to a conclusion. Jerry found out that his product sucked and it had no chance of competing against Intel and it led to the acquisition of NexGen by AMD.

Kapoor: So what was your meeting with him like, and going back to the--?

Raza: I mean, basically, Bill Gates' characterization of Jerry Sanders could not be more accurate. I very quickly found out that Jerry had one other quality that Bill had not warned me of. Jerry had a photographic memory. I mean, he would just remember everything. And I never underestimated his intelligence. He's very intelligent. The only thing that interferes with his intelligence is the ego. He's extremely egotistical and but we were able to get along. We were able to form a rapport.

Fairbairn: So, you, at what point or when did you merge with or when did that deal close, do you have any idea?

Raza: The definitive agreement we signed in October of 1995 and the deal closed in January of 1996.

Fairbairn: These mergers don't often go well. How did things go with respect to the engineering team and K5 processor?

Kapoor: And Thampy was the chairman still with--?

Raza: No, Thampy actually stopped being chairman in 1992 or '93. So Thampy virtually never came to NexGen after 1992. So I kept him informed, but he completely had walked away from NexGen at that time. So--

Fairbairn: The engineering team and how did the-- how did that merger go?

Raza: So I think it went extremely well. I mean, I cannot imagine a merger of this kind of situation going as well as it did. And the credit I give to Jerry Sanders, that he left me in total control of the sixth generation. He didn't even move the buildings. We stayed in the building in which we were until the processor had gone into production. During this time I was CTO, because I did not know how I would fit in in the AMD corporate culture, so I decided that if it didn't work out I would walk away and do something else. What happened is that as we were ramping the sixth generation processor, now we started blending and we moved into the big building which AMD occupied. But the ramp did not go well. There were issues with the process technology. This process technology was identical to the IBM process technology because the design rules were obtained. AMD was not quite ready to implement that advanced a technology and there was a big yield problem where we were basically building for a massive ramp because the demand for our product after prototypes was gigantic. And there was no yield, virtually zero yield out of anything but the R&D fab. The R&D fab was yielding but the manufacturing fab was not yielding, so I worked day and night during that time with both the teams, and there was a lot of dysfunctionality also in AMD, which is a side thing, but I became kind of the glue between the R&D team in process technology and the process technology in the manufacturing line. And finally, we discovered what the problem was and it was something as unexpected as the liquid that was used to clean after chemical mechanical polishing of the metal layers in order to get planarity of the interconnect. And that was, it was exactly the same chemical composition of the water that was used by the manufacturing fab as the R&D fab, but it was a different manufacturer and that was causing defects to completely kill the yield. And the moment we discovered it, I mean, we were basically going, these layers are built here, these layers are built here, then you exchange and then you keep exchanging going back and forth until

you basically get to the stage where you'll find the problem. We found the problem right as the entire manufacturing line was building the wafers for manufacturing.

Kapoor: And the fabs were here in the Valley?

Raza: No.

Kapoor: Oh.

Raza: The manufacturing fab was in Austin, Texas. The R&D fab was over here.

Kapoor: And you were still building product at IBM?

Raza: No.

Kapoor: No. So that was--?

Raza: That had transitioned away.

Kapoor: Okay.

Raza: By now, AMD had brought up the technology that we had built the design with.

Fairbairn: What was the name of this process or what did you go to market with?

Raza: We called it the K6.

Fairbairn: And that had been completely designed within NexGen.

Raza: The NexGen, yes.

Fairbairn: And what happened to the design team, the processor design team within AMD when you came in with the K6?

Raza: They were working on what they called the K7. And in general, they hated us until the product was successful and then they grudgingly accepted us. Now the K6 was beginning to ramp. We had gained authority of having proven that we could build an Intel compatible processor flawlessly which would succeed in the marketplace and I basically had taken the next step of going to Comdex and I was at Comdex and at COMDEX I was listening to Andy Groves' speech on native signal processing and that was what he was describing what he called MMX as native signal processing. And there was an interesting side story that our floating point performance was not as good as Intel's, although our integer performance had an edge over Intel. That used to bother me a lot. So we wanted to expand outside the market that we were in and I was listening to Andy and I figured out that what he is describing as native

signal processing is not correctly being implemented by MMX, that we have to do a vector floating point engine. And I called from COMDEX to our architects and said that's what we need. And we basically developed it and we brought out what later on was called 3DNow! Technology, which was before the K7 and the seventh generation. I will talk about the seventh generation what we did over there. So this was the follow up to the first sixth generation processor, but in order to do this I had to basically get Microsoft support because for the first time in history there was an Intel compatible processor that had an instruction set extension that was different from Intel's to support 3D. Now 3D games were coming at that time. Now we are talking about 1998. So I went and met Jim Allchin at Microsoft and told him the whole vision of what we were trying to do. And he said, "I'll support you if you do this." So we kept coordinating that they were supporting us, they were supporting us. Our chips came out. They worked perfectly. I called Jim Allchin and he said, "I put the project on hold." And I said, "Why?" He said, "Because I didn't expect that you would have working chips in this time period." I said, "Jim, my entire future depends upon your support. We've been selling this to IBM, to Compaq, to Hewlett Packard, to Acer--" the four big guys at that time in the PC world-- "and you're telling me you're not going to support it?" So I went to Jerry and I said, "Jerry, we have to go see Bill Gates." So we flew, we saw Bill Gates and Jim Allchin and that was a very interesting meeting because Bill said, "You basically broke away from the Intel instruction set. You're extending the Intel instruction set. That takes guts. Why are you doing it? Who is your partner in graphics? Because if you're doing this, there has to be a graphics partner." And you know what happened? I tried to work with Cirrus Logic, Suhas Patil but they declined. I tried to work with S3, they declined. They said that, "If people see you coming into our building, Intel will drop their support. We can't afford it. So stay out of our building." So I found this little company on Arques, on the second floor of Arques that was funded by Sequoia, by the name of Nvidia. And I went and met Jensen and I said, "Jensen, is your product real?" And he said, "Yes, let's try it out." So we tried it out. Its performance was very good. The drivers were not complete but we both collaborated to complete the drivers. I told him, "If you get your product 100 percent ready, I'll put it on every reference design and, you know, I have Microsoft support." I told him I already had Microsoft support even though I did-- I was at that time struggling to get Jim Allchin to support me. Now with this story, I went back to Bill and so when Bill said, "Who is your graphics partner?" I said, "Nvidia." He said, "Who the hell is Nvidia? I never heard of them."

<laughter>

Raza: I said, "No, no, they are the best," and I praised Jensen to high heaven. Good thing. Look at what he has accomplished, you know?

<laughter>

Raza: So he turned to Jim and said, "Jim, why aren't you supporting this? This sounds very promising." And Jim said, "Because all my resources are on NT." If you remember, NT was coming out.

Fairbairn: Yeah, yeah, yeah.

Raza: That was the new technology and--

Fairbairn: Yeah, new operating system.

Raza: For servers. For servers. So Bill said, "So you have a resource shortage." He said, "Yes." So Bill turned to me and said, he said, "Atiq, do you have any resources in software?" I said, "Yes." He said, "Would you give them to Bill-- to Jim?" I said, "Yes. Of course." And he said, "Well, here's Atiq's resources." I had five guys in software, you know. <laughs>

Fairbairn: But you can have them all.

Raza: <laughs> "You can have them all," yeah. <laughs>

Kapoor: So you used to get source code, right, from Microsoft to test out everything?

Raza: Yes. Well, not source code. You didn't need source code, although we had source code access, but basically, object code is enough to test compatibility. I mean, they have to take care of fixing anything.

Kapoor: For source. [ph?]

Raza: Yes, exactly, so--

Fairbairn: Now did you provide your meager resources to--?

Raza: Yes, but they didn't use them much except for testing. So they came in very handy because they were in the same place, we were able to test it out. And the thing is that it just hit the market unbelievably hard. Now 3DNow! is the slogan we used to describe it. Intel was running ads on television on their next generation. We came out and we had plastic placards that we put in all the retail stores. And we went from zero market share in the retail market to 40 percent market share in five months.

Fairbairn: Wow. <laughs>

Raza: I mean, it was unbelievable. Now while this is happening, you know, while the product is ramping and all, my attention is on the seventh generation and I look at the seventh generation development, seventh generation development was very aggressive, six-way superscalar architecture, six issue machine. Way more aggressive than the NexGen architecture except it had thousands of bugs. So I went to Jerry and I said, "Jerry, I want to restart it. I made a mistake in not doing a restart at NexGen on the 586 when I came in. I should have done a single chip from the beginning. It took me much longer than I should have taken for the first one. This time I'm not going to make the mistake. I'm going to restart it and I don't need as many people as you have on that program. I'm going to lay off 100 people and I'm going to reformat the disc with any part of that design and we're going to start from scratch." So we did that. Jerry first thought that I was insane. I still remember, we had a discussion at some restaurant in Palo Alto about it and finally he said, "Okay, do it." Because now I had done a couple of processors successfully and taken them to market--

Kapoor: So your title is still CTO?

Raza: I think by now he had actually made me--

Kapoor: Maybe COO?

Raza: Yes.

Kapoor: Okay.

Fairbairn: So what was your goal in restarting it? Was the methodology flawed? Or what, it was too cobbled together? What was the--?

Raza: The second one. It was too cobbled together. They had thrown every micro architectural trick in the book and they did not have a systematic way of doing the design and debug of a relatively complex, more complex than any chip that had been done at that time.

Fairbairn: And this is mainly your NexGen team that you had come over with, right?

Raza: No. This is not the NexGen team. This is now 100 percent old AMD team headed by Mike Johnson. Mike Johnson is already a well-known person who wrote the book on superscalar architecture. He wrote the first book on superscalar architecture. Second most important book in computer architecture after the Hennessey and Patterson book in computer architecture. Very well-known person, brilliant guy, but not a guy you want to have heading your processor development team.

Fairbairn: <laughs>

Raza: So I also basically hand-picked a guy, ex-Digital guy, Dirk Meyer, to head the processor development, and made a co-processor development head from NexGen. We said we will do the floating point engine in NexGen, with the NexGen team. The integer engine and the rest of the processor will be done in AMD. So now we are doing the development and we are on a crash program to do the development from scratch. For a while, people wanted to kill me because there were so many people laid off, and I took out the core of the architectural team and put them in a separate group and their job was to validate the microarchitecture at a higher level abstraction than doing the RTL, because I wanted the microarchitecture to be validated before we started doing the design work. And that turned out to be an extremely successful development. As the development is going and we are doing the architectural evaluation we find that we can't match the Intel architecture that is expected to come out. And where we were losing--

Kapoor: In terms of performance--

Raza: In performance.

Kapoor: Yeah.

Raza: In architectural performance.

Kapoor: Yeah.

Raza: And where we were losing was that if we had a miss in the highest level cache, which was we at that time had two levels of cache, and the second level cache when we had a miss the penalty of our cache miss was too high. So basically, I decided that we'll break from the Intel bus and we'll do our own bus, and we were already doing our own memory bus, but I would have the memory directly accessed from the processor itself because that would reduce the latency. I wouldn't have to go through a chip set and go to an external memory. I would just go directly to main memory and do a fetch. Suddenly, we are at a 20 percent advantage over-- and 20 percent, trust me, in a fight with Intel is a huge advantage-- 20 percent advantage architecturally at what Intel was claiming.

Kapoor: So you were comparing performance by, you know, emulating the Intel architecture and then comparing?

Raza: No. We never emulated the Intel architecture.

Kapoor: Okay.

Raza: We just took Intel on their word on what they were projecting--

Kapoor: Okay. What the performance was.

Fairbairn: What the performance was going to be.

Raza: On performance.

Fairbairn: Yeah.

Kapoor: Okay.

Raza: I mean, that would have been too much work to emulate their whole architecture and do our own architecture evaluation. So we took them on their word and they were pretty close to what they said. But that represented the goal that we had to hit or exceed. So when we came out with a seventh generation, which we called the Athlon, we were faster than Intel. So now the seventh generation, Intel was reeling at that time. I mean, the stock had gone from $100 dollars to $20 dollars or whatever, you know, and we were ascendant at that time. So now the next problem was they were coming up with this thing called the Itanium where they had a 64-bit extension that was not compatible with x86. So we approached Intel and asked for an early look at the architecture, because, you know, you have to pick the architecture that you're going to build a 64-bit extension on well ahead from when it comes out, and Intel refused. They

had carved out in the cross license Itanium instruction set architecture. So I was stumped and I basically had internal discussion and brainstorming sessions. Everybody said we're going to get screwed. Itanium is going to take over the world. So I said, "Okay. I find it very weird that basically they have abandoned the x86 and are doing a different instruction set for 64-bit. We should also consider doing a different instruction set if that's the case." But I didn't like that idea, but I said, "Let's try it out. Well, we have a lot of digital people, let's go do it with Alpha." So we actually, there we both emulated and built a prototype model of an Alpha and an x86 processor to see how software would run on it. It ran quite well, actually. Because Alpha had already developed an emulation capability of 32-bit x86 called FX32. But not good enough. It was very kludgy and at that time, Jim Keller was already the person I just described who joined Intel as SVP of their entire processor group. Actually, he's going to work on the Inference engine, I suspect, you know, for AI, not on their processors. So I went to Jim and I said, "Jim, life and death for AMD. We do an x86 extension to 64-bit. You have to write the spec and you have to do it with very little time." And Jim basically started working on it day and night and, "Nothing else, Jim, you can do. There's only one other project that you'll do and please, the bus through port and support both the synchronous and asynchronous transport." That was Jim's job. And he came through with it. I mean, he did a phenomenal job in extending it to 64-bit and Itanium was--

Fairbairn: And that's what you built and Itanium died.

Raza: Itanium was dead.

<laughter>

Kapoor: Itanium died, yeah.

Raza: And it got adopted, the 64-bit extension.

Kapoor: It was all titanium until then.

Fairbairn: So Intel adopted your 64-bit.

Raza: Exactly.

Kapoor: So going back to the Athlon, then a lot of market share, I guess you captured with that and--

Raza: We started capturing market share in the server world.

Kapoor: Right. So, like--

Raza: Before, so far it was desktop.

Kapoor: Like Bechtolsheim's company and all that Sun is required, right?

Raza: You're talking about Afara? Or which one?

Kapoor: No, the--

Raza: Oh, Granite?

Kapoor: No. What was the name of the company?

Raza: Oh, yeah, he-- That was much later Andy did that company, you know. Andy in the meantime had dropped out of Sun. He was doing Granite, which was a switch, which was acquired by Cisco, yes.

Fairbairn: Okay. But let's get back to this. So you did the 64-bit extension and that also was successful. So you were on a roll. You had three processor generations.

Raza: But there was a problem developing between me and Jerry. Then Jerry had promoted me to be President, but he was working around me and giving direction to my staff without my knowledge sometimes and on one critical issue we had a disagreement. He was building a fab in Germany faster than we really needed it, a year or a year and a half, and that was, that would have consumed, you know, a huge amount of cash. So I sat down with Jerry, I got him to say, "Okay, I will keep you in the loop. I won't approve anything without you. Go ahead." I put a lot of expense on hold, but he went around me and he approved it. And that's when basically I told Jerry, "Jerry, if you do this, I can't really run the company. I can't be Chief Operating Officer and President of the company if you basically undercut my authority by approving $800 million of expenses without my knowing about it."

Kapoor: So that's when you left?

Raza: That's when I left.

Kapoor: Okay.

Fairbairn: And what was the state of processor development at that point?

Raza: It was going very well at that time.

Fairbairn: But where was it in terms of which--

Raza: We hadn't brought the 64-bit extensions to Silicon. Athlon was ramping very successfully. The 64-bit had been defined. The next generation had been completely defined.

Fairbairn: Before we move on from AMD, tell me about working with Jerry and how that went. Obviously, things sort of split at the end, but what was it like leading up to that point? What were the signs of those sorts of problems if they did exist? And why do you think Jerry made the decision that he did? What was driving him to do that when it was clearly going to be a major-- it wasn't required?

Raza: That's where Jerry's ego and irrationality comes in. I asked him that question and he repeated a statement that he used to make in public and that was, "Real men have fabs."

Fairbairn: <laughs> I was just thinking the same thing. I thought, wow. <laughs>

Raza: And that was such a staggeringly ridiculous answer from an intelligent guy like Jerry. It gives me great satisfaction that Lisa Su is running AMD today, you know.

<laughter>

Kapoor: But I think you see his lineage. He came from Fairchild and--

Raza: That is true. But, you know, you can't-- I mean, the other guys at Fairchild were both smart and they were not, you know, male chauvinists, because that's embedded in that statement. But nevertheless, I couldn't fully understand why he wanted to spend money on the fab and the only explanation he gave is that, "I have given my word to the Governor of Saxony." But, you know, you asked a different question, how was your working relationship with, because most of the people from companies that AMD acquired didn't last more than six months. I was there for 4-1/2 years. The entire NexGen to AMD duration was almost 11-- over 11 years. And Jerry, I very quickly found out, had this issue with ego, that if you basically just expressed an opinion which was not, "Yes, Jerry, you are completely right," while there other people around, he would get annoyed. And on a few occasions he got really mad at me and insulted me, you know, completely unnecessarily and, you know, I got pissed at him on one occasion and he took me aside and said, "Atiq, you can disagree with me, but not in front of others. We have to disagree, when you want to express your opinion which is not in agreement with me, let's do it behind closed doors." I said, "Okay, Jerry. Then we have to meet once a week." So from that day till this last incident where he signed off large amounts of money without my knowledge, Jerry and I used to meet once a week and that process really helped us work together for a very long period of time very successfully.

Fairbairn: So besides the ego, what were his strengths and weaknesses? What made him successful to the extent that he was and what other Achilles heels did he have from your perspective?

Raza: He had a very, very powerful intellectual capability. He was able to see through the haze of marketing confusion very clearly. He came up with very, very good ideas of how to market products. He was very good also as an individual sales guy on how to incent sales guys, almost Machiavellian in how he incented sales guys and made sure that they spent most of their money, gave them high amounts of commission for just meeting the bookings and revenue goals, and that they are completely beholden to that cycle of earning and spending, earning and spending. Gave them fancy cars. So I thought that he had an engine running that for the culture of AMD worked.

Fairbairn: And how did that work running engineering? I mean, it'd be--

Raza: It didn't. It didn't work running engineering. Jerry for the most part used autonomous people to run engineering and then they lived and died on the results. If they were successful with the results, Jerry let

the business go on, left them alone. And if they didn't, then he would either do an acquisition or chop their heads off and get somebody else to run it.

Fairbairn: So were people across the country-- across the company, mainly afraid of him? I mean, were they-- did they respect him? What was the--?

Raza: All of the above. They were afraid of him because he was egotistical, didn't like disagreements. They respected him also because he had brought AMD quite a distance against odds, competing against Intel. They also liked certain aspects of him. He was a good speaker and used to have huge parties every time AMD had a good profit quarter or a good profit year. So it became part of AMD's culture. I think during my tenure there I changed that culture quite a bit and it used to bother Jerry a little bit. I made it a lot more geeky. I made it a lot more intense. I fired people for incompetence. There were a lot of incompetent people in various corners. There was somebody running IT who was sitting in Oregon who knew nothing about IT. I fired him. I fired the guy who was supposed to be doing corporate development because he only came four hours a day for work and was doing hardly any corporate development. So--

Fairbairn: Now did he hang onto marketing and sales while you were COO? Or did--

Raza: It was joint. It was joint. Marketing reported completely to me. Sales was both. It reported to me as well as him. Because Jerry was in Beverly Hills on Mondays and Fridays, so he came only three days to work over here. He was available but he had a very rigid thing, you know, 9:00-4:30. Don't talk to me. I was frequently calling at 7:00 in the morning and at 8:00 at night. That used to bother him, but I told him, "You'd better get used to it while I'm here, Jerry."

<laughter>

Raza: "That I'm not going to stop. If there's something urgent, you're going to find out, because I don't want you later on to tell me I didn't tell you." So we were able to work out reasonably well during this time.

Fairbairn: So you had this disagreement. You said, "I can't work this way." You left AMD. What, did you have a plan at that point?

Raza: No, I didn't, actually. I was just going to--

Fairbairn: You were leaving AMD but you weren't going to something?

Raza: I wasn't going to anything at that time. But almost immediately as people found out that I had resigned from AMD people started approaching me to do all kinds of things. I told them I hadn't made up my mind what I was going to do. But interesting opportunities were placed in front of me. And I think I barely got the opportunity to even decide what I was going to do. There were so many opportunities. Vinod called me. Vinod Khosla called me. He wanted me to join the board of a company that he was working on which eventually got acquired by Redback Networks. Then I became acting CEO of a DSP

company and that company was also-- it was acquired by Intel, ironically. And then I also started thinking about what I would do myself.

Fairbairn: So where you-- did you resolve that you wanted to be the CEO or run the show at this point? What drove you? Was it technology? Was it management? Was it control? At this point in your career what was driving you?

Raza: I think it wasn't directly any of those things. But it was just the desire to do something that is impactful. That was driving me. I think over time I felt that I preferred to hold the steering wheel of any development, of a company building operation. But I was not consciously looking for just being the leader or just being the CEO or just being in control. But that was implicit that, you know, if I'm just on the board my influence is not as great in the final result of what I am involved with than if I am the CEO.

Fairbairn: And were there other things you were 10 or 11 years in the world of competing with Intel and x86 architecture. And the level of detail and understanding and so forth associated with that I'm sure it was quite significant. Had you even had a chance to look at what else was going on or look at what major developments were going on? And did anything particularly strike you at that point?

Raza: Yes. The importance of data connectivity was really-- I was getting exposed to it because AMD had a fairly sizable communication and networking group. At one time it was the leading group in the industry in semiconductors. And our 10-megabit switches and adapters they were the leader in the industry. They lost it to Intel at 100 meg but until that time they were the leader. So it was a competent group. I got the understanding I wanted to basically acquire a company which actually-- called Maverick, which got acquired by Broadcom. Maverick was ready to sell to AMD. And Jerry told me he won't let me acquire it because he doesn't want me to take my eye off the processor fight. But I was fascinated by the fact that the next boundary is how do you have a universal connectivity that is high-bandwidth conductivity? And all the problems associated with high-bandwidth conductivity arise out of how do you go from one place to another? How do you resolve and a routing path? How do you have prioritization within routing? These are the things that have to be resolved. How do you resolve it? The way people were doing it they were building data path processors and control path processors. Control path processors are just like microprocessors except cheaper or simpler. Data path processors were just moving data forward and comparing it against routing tables of how to move it forward. But there were two different kinds of silicon. And I was thinking of combining them into one where you use a standard processor technology but which has a significant data path capability. And that became the heart of what became RMI later on but there were other companies that I got involved with funding along the way. But the one that I really, again, became CEO of was RMI.

Kapoor: They were also in graphics at one point.

Raza: While I was basically-- before I started RMI I was doing effectively the equivalent of incubator/venture fund. During that time, I was approached by Scott McNealy. And Scott said, Our SPARC processor development is a disaster right now. What do I do? Can you help? If you come on my board I will even be willing to acquire AMD." I said Scott, the DNA of semiconductor company is so

different from the DNA of a systems and software company which is what you are don't acquire AMD. You won't know how to digest them and compete with Intel. So, he said, “Okay. So how can you help.” I said I don't need to get on your board. I will look at developing a SPARC processor. Around that time Doug Leone at Sequoia called me and said, “You’ve got to meet this professor at Stanford Kunle Olukotun. He has a weird idea. See if you want to do anything with him.” So I met Kunle and that became the start of Afara. Kunle, I figured out, didn't know how to do a processor, how to build a processor. So I needed a processor team with a real micro architect. But the good idea that Kunle had of doing hardware multithreading I needed somebody to think through how do you build a state of the art processor with hardware multithreading supporting? The whole idea of hardware multithreading is that if you have multithreaded processes running and you have basically a cache miss and that creates basically a bubble in the sequence of processing that is going on by having hardware multithreading you can start processing the next thread which fills that gap.

Fairbairn: So let's back up. You said after you left AMD is that when you did the Raza Foundries?

Raza: I hadn't started the Raza Foundries. I first did VxTel which was a DSP company. And then did Afara

Fairbairn: And that so Afara was in there. And what was the mission of Afara?

Raza: To build a state-of-the-art SPARC processor.

Kapoor: So Les Kohn was hired.

Raza: Les Kohn I hired basically to be my pro architect of Afara. Afara is what became Niagara that saved, actually, the hardware business at Sun. If that hadn't happened Sun was in deep shit with hardware.

Kapoor: And, actually, later it even affected other companies to adopt multithreading.

Raza: Multithreading is now everywhere.

Kapoor: Yeah.

Fairbairn: So that became the SPARC processor.

Raza: The leading-edge SPARC processor.

Fairbairn: I see. I didn't realize that. Okay. Good. So you sold that to Sun, Afara. And then you went on to something else yourself?

Raza: Then Raza Foundries at the same time was starting.

Fairbairn: So tell us about Raza Foundries and what motivated you and what the idea was.

Raza: So the idea was if I can work with entrepreneurs in more than one company then I can have two or three companies or four companies, a small number of companies that I can be involved with actively, not as a CEO, but as a chairman or an executive chairman and cultivate them and assist them. So it's not quite holding the steering wheel but it's kind of working with an entrepreneur that you can teach to hold the steering wheel better. And it was reasonably successful. But then the downturn in the tech and the communication industry came. We were able to build more than one company that was acquired or became successful.

Fairbairn: And were these all communications companies?

Raza: Two of them were definitely communications companies. One which made fabric architecture. And the second one was making a cable modem termination system. The third one was a cybersecurity company which basically developed a method of doing intrusion prevention and intrusion detection. It was called IntruVert. Very, very capable set of people. They were not getting funded actually. And one of their board members knew me and he came to me. And I looked at it and I decided to fund it. And it became the first company to do intrusion prevention and detection. And was acquired by McAfee and became basically the bulk of McAfee's business over time.

Kapoor: So you were now almost like a venture capitalist now?

Raza: It was like a venture capitalist/incubator because I had people on my team who were technical. I had people on my team who were also marketing guys. And we were able to support the companies that we were building at more than just money dimension. And be more active rather than have a board meeting once in six weeks. We were basically having weekly reviews of the product development.

Fairbairn: So it was a hands-on venture capitalist.

Raza: A hands on venture capitalist which is what an incubation is.

Fairbairn: Okay. Were you supplying most of the funding yourself? Or were you partnering with other VCs?

Raza: Partners with other VCs.

Fairbairn: And you were putting in some of your own funds so you would have skin in the game.

Raza: Yes, exactly. So the VCs loved it because we were providing much closer guidance to the companies we were involved with. So it was working. But it was a corporation. And that structure ran into a problem because there was another company before us that completely tanked after going to one billion in value then completely tanked. And our ability raise a follow-on capital round as a C Corp. became virtually impossible. So at that point what I did is there was one company that was going to develop

exactly the processor that I described which combined data path and control path processing. And I basically took that company and called it RMI and started running it myself.

Fairbairn: So that was Raza Microelectronics?

Raza: Yes.

Fairbairn: So tell us about that company and how that worked out.

Raza: Well, for the investors it worked out very well. And for the employees also it worked out very well. It was eventually successful in its growth. It had a first year set of customers. It does not have the market demand that a microprocessor of x86 class has. But we were able to ramp up to over 100 million in revenue. And it was acquired by NetLogic. Broadcom and Cavium also were looking at acquiring it but it eventually got acquired by NetLogic. And it was acquired on the basis of a stock exchange, preferred stock being given. And after NetLogic acquired NetLogic stock quadrupled. So by the time anybody could liquidate their stock they had gotten 6X their investment or 10X their investment depending upon when they sold. So it was a very good return for everybody.

Fairbairn: And who were the customers of RMI?

Raza: Cisco. Juniper, Huawei, ZT, all the big…

Fairbairn: All the majors?

Raza: All the majors.

Fairbairn: And it was a critical component in building whatever communications devices they were…

Raza: It was a critical component in building routers and switches.

Fairbairn: And did anything else like it exist at the time?

Raza: Cavium had a product similar to it. Ours outperformed the product by almost 2X. But they were bigger than us. So they had their market share. But today, actually, they have acquired from Broadcom because NetLogic, in return, got acquired by Broadcom. And Cavium has since then acquired that team as well as the product and is now the flagship product of Cavium.

Fairbairn: They acquired team and were able recreate that product?

Raza: No. They actually acquired the product and the team from Avago because of Avago didn't want to invest in anything more or less. That's why they lost the ability to acquire Qualcomm because Qualcomm said, "Look at every company they've required they cut off the R&D." So that's exactly what they did with Broadcom. Broadcom had a processor group which was leading-edge processor in the industry for

servers. Cavium had that but they didn't have anything that competed with Intel. Broadcom had that. So Cavium went and acquired it from Broadcom. Team and product.

Kapoor: So along the way you have been on the boards of many companies.

Raza: Yes.

Kapoor: A numerous companies eASIC and several others. So this is while you were forming RMI or was it post?

Raza: Yes. All of the above.

<group laughter>

Kapoor: Okay. You must've been very busy.

Fairbairn: So once RMI-- we'll come back to those in a moment. Once you completed RMI then you sold it to NetLogic. And you did not stay with the company for any length of time?

Raza: No. I took a break. At all time I had gone through divorce. And I took a break, not a very long break but still a break. And I remarried. And then I got, again, attracted to something quite unusual which was one of the funds where I was an investor approached me and asked me to do a turnaround. Now, I had never done a turnaround of a company that had been around for eight, nine years. And I didn't find it interesting to begin with. But I was an investor in the fund. This was one of two companies that were left in the fund that had some life. And the interesting thing is that one of their customers was Google. So I got involved. And it kind of brought me back in the game. It was a very difficult company to turn around because it was in Santa Barbara, not in Silicon Valley. And all of the guys who worked over there had been there for nine years without getting any revenue.

Fairbairn: This is one of the companies you're currently still…

Raza: Correct.

Fairbairn: CEO of or whatever. Right?

Raza: Yes.

Fairbairn: And the name of the company is…?

Raza: CALIENT.

Kapoor: CALIENT Technologies.

Fairbairn: So how long have you been-- when did you join in?

Raza: Five years.

Fairbairn: Okay. So you've been with them quite some time. And what was the problem that you were challenged with? Why were they not being successful?

Raza: Two reasons. One, the product did not really have a use model that was important at the time they brought it out. It was a pure optical switch light-in, light-out, no processing in the middle, which would be very useful if you were-- if you had the need to have software defined networking control that switch and you are using it to redirect traffic or you were using it to reconfigure connectivity across it. But there was no software defined networking at that time. And then the product that they were shipping was very clunky. It was half a rack in size. And they were selling it for $0.5 million. And where such a product could be attractive would be around $50,000, 10X less than that. And you had to have the market develop so that software defined networking and software defined connectivity was important because you needed that upward layer of software to be able to use this capability of an all optical transport that is reconfigurable. And that was emerging. And it's still emerging. But it's now gathering momentum. So the product was redesigned in order to have your cost structure that would allow it to sold for 50,000. And it has all of that now. And it is basically at the threshold of ramping several places.

Fairbairn: And what was the venture firm that was funding it?

Raza: TeleSoft. So TeleSoft invested mostly in software and telecommunications companies.

Fairbairn: And they were the ones putting money in over all of these years…

Raza: And others, the co-investors. But they were the lead investor.

Fairbairn: Mm-Hm. So there had been a CEO in place during that whole period and you replaced that person?

Raza: No. There was a CEO in place and then the CEO had been fired because he couldn't get the company off the ground. And the venture capitalist himself had stepped in as acting CEO.

Fairbairn: I see. He asked you to come in and take over.

Raza: Yes, exactly.

Fairbairn: And how would you characterize the team there in Goleta?

Raza: Very bright team. Not quite used to the idea of building something and having a manufacturing line to basically manufacture it in volume. Not quite in tune with what the rigor that is required for something to

be built in volume, not quite understanding the concept of fast turnaround time, all the things that are necessary for something to have any kind of volume.

Fairbairn: A little bit more of an R&D kind of research-oriented kind of activity?

Raza: Very much. All PhDs, about, I think almost 20 percent of the people were PhDs.

Fairbairn: And from UC Santa Barbara?

Raza: From UC Santa Barbara, from Cornell, two the places that help grow strong optics background. UC Santa Barbara has, I think, seven people who have optics background and Nobel prizes in that. I think it's probably the strongest university in the world in that area.

Kapoor: So you've been looking at diverse areas like biometrics and then also the lithium-ion technology and so on.

Raza: Yes. I mean I think that just, in general, intellectual curiosity is something all of us have. So in my case for lithium ion technology I was really interested because here was something that was going to replace gasoline, something that can store energy to the extent that it can have cars running around instead of the big humongous internal combustion engine with a little motor like a go-kart. And what is holding up that thing? And what is holding up is energy density, how much can you store safely in a battery? And how much can you get out of it when you're trying to reuse that energy? So that's power density so I came across this company that we know that invested in called Seeo. And that's basically Vinod asked me to step in as acting CEO. So I stepped in as acting CEO. The technology came from UC Berkeley and Lawrence Berkeley labs. That company had a successful exit with Bosch. It was a very tough, tough project because they were using a solid electrolyte, a polymer-based solid electrolyte. And the thing is, the thing you like about lithium is because it's very light. And it has very good transport properties because it's light. Because you are comparing it against the other kind of storage which is your lead acid batteries on the one hand and a capacitor on the other. A capacitor basically stores electrons. The disadvantage of capacitors is all of the storage is on the plates. There's nothing in the bulk. In a battery you have storage also in the bulk. But then in order to pull ions back and forth you have to thousand times the size of these fat ions so you take the lightest through the fatties which is lithium. The trouble is that if you bring them to close together as you're increasing the density it becomes volatile, especially, if it's going through liquid. And hence the big fear of lithium-ion.

Fairbairn: One of the problems associated with it. Right?

Raza: So here we're doing solid electrolyte, completely solid.

Fairbairn: Is this a company you're currently CEO of?

Raza: No, no, no. I can't do that many companies.

<group laughter>

Fairbairn: Okay. I'm trying to get this. I'm trying to bring some order back here. I forget. Was it RMI that we had just finished up with?

Kapoor: CALIENT.

Raza: Yes. RMI basically was in the process of getting acquired. And I basically was-- Vinod asked me to take a look at some of his portfolio companies. And I got involved with eASIC and I got involved with Seeo. eASIC as a coach and board member to the CEO and acting CEO at Seeo which was the lithium-ion company. And that's where I was. This was before I got involved with…

Fairbairn: Where you a limited partner with Vinod?

Raza: No, I am not a limited partner in Vinod's because his investment style at that time I felt was too aggressive in clean energy. And in my back of the envelope calculation I couldn't understand some of the investments that he had made. He has since moved away from clean energy. But I think he did a very good job in at least raising the awareness of the risks associated with not investing in clean energy. And he was a catalyst in a lot of clean energy investment from not just him but others also.

Fairbairn: So this company Seeo, S-E-E-O.

Raza: Yes.

Fairbairn: What was the distinguishing technology? It was still using lithium-ion.

Raza: Solid electrolyte. Polymer solid electrolyte. No liquid at all. So electrolytes, solid polymers are used as a separator but they're doused in a liquid electrolyte. So most of the transport happens through the liquid electrolyte. In this case it was doing site hopping between polymer sites. So fundamentally going through the long chain polymer sites and hopping through it. So it was challenged on the power density side. And in terms of energy density it set world records. But power density was very slow.

Fairbairn: And that company was sold to Bosch and continues on in development?

Raza: Yes. It continues on in development but Bosch has basically spun it out again.

Fairbairn: So these were a couple of companies that Vinod had linked you up with. What was the next hop in your career direction?

Raza: Well, this all happened eight years or nine-- no, more like eleven years ago that Vinod got involved with trying to get me to look at some of the companies in his portfolio. I also invested in another company called QuantumScape which is actually still doing a next generation lithium-ion battery and has some of

the ex-Seeo people working over there. And that's when I got to all with CALIENT. CALIENT I got involved about five-and-a-half years ago.

Fairbairn: So just bring us along the next step if you can remember.

Raza: So one of the people who I have co-invested within the past lives on the East Coast in Boston. You know, the last few of the venture capitalists from the Route 128 entrepreneurial activities.

Fairbairn: Who is that?

Raza: His name is David Furneaux. He's 10 years younger than me, actually. He sent me a company which is a cybersecurity company that I'm now running. And he asked me to take a look at it because he knew that I was involved with IntruVert which is intrusion prevention. So the founder of this company which is Virsec came and described what he was trying to do. And he described mostly how he was trying to identify a cyber-attack on software that is written in compile code. So what he was doing was fascinating because what he did is that when an application is loaded, object code is loaded into memory he created a map of that object code. And the particular relevant portion of the map is the source address and the target address through the entire software. And, also, any manipulation of the stack pointers. With that information he would effectively have the characteristics of the underlying source code captured, the critical characteristics because any intent to now deviate away from the original intent of the source code you'd have to modify, effectively, the target address. Sometimes. The source address, also, if you're trying to modify like U.S. did with Stuxnet when they went and screwed around with the Iranian centrifuges. So we track both. So he basically showed how he did the tracking. And I felt that if he can do it then for compile code it is virtually unbreakable. It is a flawless approach. But I decided I'd show it to my chief architect at RMI, who was at that time at Broadcom. So I sent him to Broadcom and he called me and he said, "You're absolutely right. This is like the Holy Grail. If it is, I want to invest. And so should you." So I thought, okay, let me get yet another opinion. I sent him to be Cavium's chief architect and my former nemesis. He also said, "Atiq…"-- the great thing is in the processor world if you fight a good fight against your competitor you get a very good reputation. For instance even today I can reach anybody at Intel from the CEO down to any level of management I will be able to connect with them. And they help with Virsec. So I became an investor. He asked me to also join the board. From there he asked me then to become the exec chair of the board and help the company raise money from an institutional round also. So the seed round had already occurred. It was getting oversubscribed after I got involved. I sent them to a few VCs that are doing _Series A investment and one of them called me back and they said, "We are ready to make the investment but we have a condition." And I said what? "That you step in and be the CEO." And I said don't you know I'm running CALIENT? I'm not insane. That's a tough enough thing to do. They said, "No that's what has to happen." So by now I had become really interested in this whole approach that I described because they had extended that to creating a true table for interpreted code. And the interpreted code approach they have is different. But it still is deterministic. And if you know how interpreted code is written it basically has an interpretive language semantic. And the semantic basically has some modifiable portions in the code part, not in the payload, but in the code part, the equivalent of the instructions. And that basically has only certain sections that are modifiable which you can call wildcard for the purposes of just this discussion. And if you basically go through the entire

semantic of all languages that you're going to cover you can basically make a determination if somebody screws around with the wildcard portion of the languages after you have created the equivalent of a map. Except now these are very long strings that you have to compare. And to do such a long string compares between the truth and any deviation from the truth takes a Regex engine. And if you run regular expression searches, long string searches on Intel, normal instruction head architecture with C++ code or something like that it sucks. It doesn't run fast enough to be able to respond fast enough. So this company had a hardware accelerator. Virsec had a hardware accelerator. So the hardware accelerator this doesn't make any sense. I mean how are we going to go into a cloud environment where you can't go plugging in hardware cards. So I approached Intel, my former nemesis. I went to Diane Bryant who was at that time running data centers. She is now at Google.

Fairbairn: She's at Google?

Raza: She's at Google. She's chief operating officer of Google cloud running under Diane Greene who is basically CEO. It just boggles my mind. Diane is such a great person and towering intellect. The sweetest person. I can't imagine her being CEO of anything. You know? <laughs> But she got the right person as a right-hand man because Diane Bryant is hardcore operations person. She won't let anything out of control. Anyhow. I went to Diane Bryant and I told her the story. Your Regex engine sucks. I'm having to use a card. And guess who the card is from? The card is from Cavium. And Cavium is developing this Thunder product trying to take ARM architecture against x86 so in places where binary compatibility is not important you're going to lose because long string searches are going to be very important. So she said, "Well I think we have a group in Australia that have been talking about Regex acceleration. We don't know what they're doing. Are you willing to work with them?" I said absolutely. So we started working with them. They had created an assembly language macro for doing regular expression searches. We started working with them and experimenting with them. And within two or three months we were able to get it to run 10 times faster than the Cavium hardware accelerator for Regex. So out went the hardware. We had to redo part of the architecture in order to run it in all software. And now we had a full software solution. So from then we started making it cloud-worthy and scalable and everything else. But we came out with the product and announced it at RSA 2018 four weeks ago. And we got the first position in the announcement of the new products against many, many large companies as well as some small companies. And then shortly thereafter Raytheon, which is the largest supplier of cybersecurity solutions to the government over here and among our allies, they formed an alliance with us to distribute our product. And gave us a big order. We don't even have it in GA yet.

Fairbairn: What is the name of this company?

Raza: Virsec. V-I-R-S-E-C.

Fairbairn: And where is it located?

Raza: San Jose. Only 15 or 20 minutes from here.

Kapoor: Are you the CEO then?

Raza: I am the CEO.

Kapoor: Okay. So you are running both CALIENT and…

Raza: Yes. Which is very tough. I don't know how people do it because I remarried and I have a 16-year-old stepdaughter who is as close to me as any of my biological kids. And spend more time with her than I did with any of my biological kids.

Fairbairn: So does that bring us up to the present?

Raza: Yes.

Fairbairn: What is the most rewarding of all of those adventures?

Raza: Doug, I don't try to compare. I don't try to compare because the sense of excitement that I feel when I'm involved in any one adventure is still a very high. I don't have perhaps the energy of youth that I had when I left VLSI to go to NexGen. I mean at NexGen there were periods for years when I never got more than four hours or five hours of sleep. I still am a bit of a micromanager. Now, I don't make as many mistakes particularly in business decision and management decisions as I did when I was younger. So it is easier to do things. And because of having had some degree of success in my past it's easier to get people to listen to me and not to challenge every one of my decisions. But I know how to stitch a very smart team together. And when I am involved with an extremely smart team working together with them I am very excited.

Kapoor: So in terms of your background in philosophy, looking back, do you think that the effect that had on you is there a different perspective?

Raza: Oh yes. Absolutely. I mean basically I started with Western philosophy. I actually went into philosophy from being exposed to Hinduism. From there I actually started Western philosophy because I got influenced by both Bertrand Russell and then I went all the way to Anaximander and all the way through Asia Minor and Greek philosophy. So I was steeped in the Western philosophy tradition. And Western philosophy is all about epistemology, what is the cause? What is the effect? How do you have a model of how things work? And just bearing down the linguistic aspects of logic all the way to mathematical logic. Eastern philosophy, which I have come back to, is different. It's experiential. It's looking beyond the boundaries of logic. You know, recently, I was listening to television and on CNN somebody basically mentioned a book by Carlo Rovelli, “The Nine Lessons of Modern Physics” or something. So I picked up the book. It's a 100-page book. And I have an original degree in physics but I was amazed at how much progress physics has made from when I did my degree until now. In physics. You're not talking about computer architecture and cellphones. I decided to pick up another book, 500-page book by Carlo Rovelli. Carlo Rovelli is a theoretical physicist, Italian theoretical physicist and writes as well as Feynman used to write when he tried to popularize the latest discoveries of physics. And I find that the boundaries of physics are now beginning to look like the boundaries of philosophy. And what can we explain by logic? And where transitions over into what lies beyond logic or when you go into

consciousness and things that can't easily be explained by logic. So, yes, I still dabble in it. I still read these books. And that's kind of an escape from technology, I suppose, or keeps me sane or allows me to sleep at night.

Kapoor: So we were maybe talking earlier about your fear about the new dimensions of artificial intelligence and other domains that we are encountering and how they will affect society. Would you like to comment on that?

Raza: Oh, yes. We have come a long ways from when artificial intelligence people started thinking about artificial intelligence. You know, what Alan Turing said, “Artificial intelligence is truly there when you can't tell the difference between a human and the artificial intelligence source.” The thing is we are getting close to it. And much faster than people expect. Today's AI machine learning is an extension which owes itself to chance and brilliance of some of the AI pioneers that it combines a statistical interpolation with rules. But now adding learning to the rules and using statistical interpolation and extending it to extrapolation and then forming the links back itself in an unsupervised manner that's what human beings do. So if machines are able to do that to the point where there are no constraints what does it mean? And it starts feeling like they will easily become far more powerful in all areas that you can think of than human beings. What is the consequence? Do we become dependent on them? Or does it get to a point where machines develop a direction of their own and we are kind of irrelevant as a species at that point?

Kapoor: So should we be putting constraints on things?

Raza: It's hard to put constraints on purely unsupervised machines. It will only take somebody who doesn't put constraints on it and it will happen. By definition it will happen.

Fairbairn: Yeah. I don't understand it nearly to the depth that you do but my understanding is that for so long what computers did was only exactly what we told them to do in writing a program. With the machine learning it is-- we’ve sort of crossed that boundary of its learning itself. And we don't know in which ways it's developing, if you will.

Raza: Well, supervised learning still you have control. You're guiding it. Unsupervised learning is the beginning of basically setting the machine free to learn on its own. That's the dangerous direction. That's the direction where now the gap between what we do and what the machine does-- the hazard is even in unsupervised learning. When you basically have an inference engine that in its concept looks like a neural network you are getting there. You are basically creating a basis for drawing conclusions very similar to how we draw conclusions behind our eyes which is the ability for us to use our eyes and be able to take a look at the entire plethora of what we see and be able to know what we are looking at. That was the magic of being a human being. That plus consciousness and other things. If machines are getting to the point where their ability to detect that and distinguish it is getting there now the next boundary is independent learning.

Kapoor: And then if you combine that with biology and the DNA it's very dangerous.

Raza: That is another very dangerous direction completely orthogonal but very dangerous. We will have species that will be different from one another. You will have people basically the wealthy buying themselves more intellect and more physical attributes.

Kapoor: And looks.

Raza: And looks and everything.

Fairbairn: So what do you tell your 16-year-old adopted daughter, stepdaughter?

Raza: So I tell my 16-year-old that you have to be in STEM to be relevant going forward. Which field in STEM? Computers is like a given. You have to know computer science. You have to know computer languages. You have to know programming. You have to know the basic structure of how computers work. That's a given. There is no way around it no matter what you do. But do something in STEM because if you don't do something in STEM you'll be irrelevant faster than others. But what I can't tell her is that even if she does that will she become irrelevant? And I don't have the answer but I still push her to STEM. <laughs> And she's a STEM girl by nature.

Kapoor: So in the domain of philanthropy are you looking at any foundations and any specific ideas?

Raza: So the person who leads the philanthropic part in our family is my wife. And I have had the same orientation but she basically has made her goal basically spending money to educate the poorest members of society whether it's in the U.S. or in India or anywhere. She was even contributing to Pakistan before she met me even though she comes from India and her father basically was almost killed in a major massacre of a train as it was crossing from Pakistan to India. He was so traumatized that he could not speak for one year. She's the daughter of that man. And before I met her she was basically contributing to the education of girls in Pakistan.

Fairbairn: Because that's the way you get away from that? Right?

Raza: I mean, you know, her wanting to marry me and defying the wishes of her parents. Eventually, her parents now are as close to me as they are to her because we have been together 11 years. And it's been phenomenal. So that's where most of the philanthropic focus is almost entirely. Whatever we give away that's where it's going. And the intent is eventually we'll give most of what we have made away except for what we leave to our kids. And they're well taken care of. My biological kids have almost already without even my ex-wife who has half of everything that I had made until then they already have on top of it a fourth. So I was left with only about a quarter of what I made. But that's okay. I'm still doing well.

<group laughter>

Fairbairn: You're still all right?

Raza: Yeah, I'm still all right. Exactly. I'm still all right.

Fairbairn: All right. Thank you Atiq. I very much appreciate your spending the time. It was very interesting and informative. Great contribution.

Kapoor: Thank you.

Raza: Thank you.

END OF THE INTERVIEW

