Oral History of William David “Bill” Mensch, Jr.

Interviewed by:
Stephen Diamond

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Stephen Diamond: OK, it's November 10, 2014, here at the Computer History Museum. I'm Steve Diamond, and we're doing in oral history of Bill Mensch. Thanks, Bill, for joining us.

William David “Bill” Mensch: Well, thank you.

Diamond: We'll be talking about a variety of subjects and your perceptions of what's happened in the past and, perhaps, where things are going in the future. Why don't we start out by talking about your youth and your education, and then we'll follow that up into your transition into the semiconductor world?

Mensch: All right. Well, thanks for inviting me. It's an honor to be here right now, and I will enjoy telling you what I know about my life, how I got here. And we'll start, then, with my growing up on a farm in Pennsylvania, Bucks County, about 35 miles north of Philadelphia, very rural. The dairy farm had like 26 head of cattle, and I was a middle child of eight children I grew up with. And as a result, I got to explore because it was more fun being outside of the house rather than inside the house.

When I was probably about 10 years old, we may have gotten a TV. We had a radio, liked to listen to the Lone Ranger. Soon as the cow's milking was done for the evening, we'd run in and try to get a good spot in front of this tall radio, and so I started out what you would call, I call, pleasant poverty. So the dairy farm to support eight children, that's the source of income, 26 cattle. So my father was a small businessman, and the farm was his business.

He was given that farm by his father, and so there's a lot of history associated with that happening. I found out, later in life, that my father wanted to be an engineer and wanted to go to Drexel. He wanted to be an electrical engineer. So when you look at my past, I don't think there's many indications that I'd be sitting here talking to you. I don't know what, actually, was the path and what the guide posts were because it was like I was following something, but I didn't know what it was.

Diamond: When is the first time you thought of yourself as possibly an engineer?

Mensch: It was probably when I was about-- when I was an engineer. In other words, the reason why I went to college was because I took the academic classes in my high school, and I really didn't know, even, what that meant. So therefore, I took the classes that I was interested in, I suppose, math and science. But for me, I never thought I was going to be an engineer. I thought I was going to be a laborer because that's what you do on a farm.

So you learn how to do things that you're told to do. We need this project done. We need to plow that field.

We need to cut that hay. We need bale the hay. We need to bring it into the farm. We need to milk the cows in the morning and the evening. And all these things you were doing, and you're expected to be.

So hard work was what I knew, and I enjoyed that. I enjoyed being outdoors. So for me to think that I was going to be in an office environment, that's nothing I ever thought I would do.

So maybe when I was 18, and the guidance counselor said, well, you've prepared yourself to go to college, I'm thinking this is a mistake because I wanted to get out of class. I didn't like English, didn't like history, and didn’t like social studies. I just liked math and science because you could get real answers.

If somebody asked me what did this poem mean, I'd go why do you ask a poet? I mean, really-- I mean, what did I get from it? That wasn't what I remembered the question to be. So to me, going to college was not expected. None of my family ever went to college.

Diamond: So you find yourself studying engineering?

Mensch: Yes, and I think I studied engineering because my dad had engineering magazines. Maybe IEEE maga-- well, I don't know IEEE was around. Maybe it--

Diamond: Oh, it was.

Mensch: It was around, but some of these magazines, like Spectrum, started 50 years ago, and this was-- well, maybe that was something. But what I'm getting at here is he had some electronic magazines, and also he equipped the farm with a generator that, when the Philadelphia Electric Company power went out, we needed to keep the milk cold. So then he had a big circuit breaker from a ship, I think, and he installed that and then started the tractor and started generators, so to keep the milk cold. So that's electronics, so I suppose I got that from my dad.

Diamond: Do you remember what classes interested you most?

Mensch: In college, or--

Diamond: In electronics, in engineering?

Mensch: Ah, no. Well, Temple was engineering technology, so it's more like learning how to use equipment technology, not the theory and the physics. And so therefore, the classes that I took were just to get my degree, get out, get a job as a technician, thinking I'd be able to make more money as a technician than as a laborer, so I was rudely awakened when I'm working for Henkels & McCoy making about $150 a week with overtime and then working for $85 a week. It didn't make sense after I got my degree. So I needed to make some changes, and I decided to be an engineer to pay my mom back.

Diamond: So what was your first job after college?

Mensch: OK, I worked for-- and I very seldom tell people this. But for three months, I worked for a company called Polyphase Corporation in Bridgeport, which is across the Susquehanna-- Susquehanna? The Schuylkill River from Norristown, and it was an old manufacturing community, and it was in an old factory that this Polyphase was. It was depressing situation for me. That I didn't start until-- it would have been in the spring of 1967, and I first went into the army for National Guard training. And that's why I did not interview right out of college. So it was after that that I got a recommendation from a friend of mine that found a job there, and he got $100 because I took the job. So then I decided this wasn't for me, so I quit without another job. Then I worked for Philco Ford, and that's where I was introduced to semiconductors.

Diamond: So tell us about that.

Mensch: Well, at Philco Ford-- now Ford bought Philco, and I think it was for the electronics that was going into automobiles. And then Ford-- or I don't know if was Ford or Philco-- acquired GME, which was the first MOS manufacturer of semiconductor products. And in fact, they had a 1024-bit ROM back in probably '67, something like that, because there was a jet engine controller that was built out of these with eight 1024-bit ROMs. Of course, there would've been memory in there-- I mean, RAM in there.

So that is where I learned about semiconductors, and then I studied the physical characteristics of semiconductors, for instance you want to know the f tau of an amplifier and the frequency, and then the thermal coefficients of materials. So if you put a semiconductor, a regulator, solid-state regulator, on a heat sink, what's the thermal coefficient from the surface of the semiconductor to the actual heat sink? And so these kind of basic characteristics of semiconductors is what I worked on as a technician, so then I was interested in their characteristics.

I went to Villanova night school. Took four different engineering classes to see if I could be an engineer, and then I did well in those four courses. Then I wanted to transfer my credits from Temple. I had like 109 credits from Temple-- you need about 130, 135 to be an engineer-- thinking I could finish in one or two years. They didn't accept my credits.

That's when I came to Arizona because I had a fraternity brother that came to Arizona. And he went to ASU, and I went to the U of A, interestingly enough. I never saw him again. But that's how I got into semiconductors is through Philco Ford.

Diamond: And how did you get from there to Motorola?

Mensch: Well, good question. At Philco Ford, being in the radio business, television business-- [CLEARS HIS THROAT] excuse me. Motorola was a leader in those circuits, so Philco Ford was trying to figure out-- or Philco was trying to figure out how Motorola was developing some of their high voltage circuits. So the breakdown voltage and other things, characteristics, of the circuitries in TVs and radios, is what Philco was looking at.

So then I knew who was the leader because we wouldn't be trying to figure out what the follower was doing. We're trying to figure out what the leader's doing, so I knew then Motorola was the leader. So I wanted to work for a leader, and so my whole goal was set on working for Motorola after I got my engineering degree.

Diamond: So how did that happen?

Mensch: Well, that's another interesting question. That was kind of bizarre, actually. In my senior year-- so it took me two years to get my engineering degree at the University of Arizona. Very good school back in those days. The professors were writing the textbooks.

And actually, I took a course, and it could've been one of his first courses or early course because Temple-- Temple-- University of Arizona professor started systems engineering. I didn't know that until recently. But I took a course from him, and I did very well in that course.

So what happens was, when you have businesses coming to interview the students, it was clearly stated that if you're not graduating you-- if you're graduating in the spring, you interview in the spring. So if you graduate in the fall, you interview in the fall. Well, for whatever reason, I really wanted to get interviewed at Motorola, so I went to the fall interviews and found that there was nobody signed up. And Motorola was looking for someone with over a 3.3 grade point average, and so I'm thinking, hey, there's nobody signed up. I'll sign up because I have a 3.3 grade point average.

So the head of college recruiting came. His name was Jerry Fulton. And Jerry interviewed me, and we had a wonderful conversation.

As it turned out, Jack Haenichen. Jack Haenichen? Yeah, Jack Haenichen was a manager from Philco that went to-- no, I'm sorry, it wasn't Jack Haenichen, it was another name. Right now, I can't think of his name.

He was at Philco Ford. He was like two levels above my boss at Philco Ford. He was at Motorola, so I had something in common. There was somebody I knew. Oh, I almost had his name. [It was John Ekiss.]

So what happened was I'm talking to Jerry Fulton, and Jerry and I get along really good. He says we've got a job for you, partner, because I had two years’ experience in, and so I had this engineering technology background and an engineering degree. So they were looking for people with experience like that.

So when the spring semester came, I didn't do very well in that area, and I found out later why. But I don't need to get into that right now. It just didn't work, and I left in the middle of the interview thinking I already talked to the boss.

And so that spring, when you get your responses back, I got an employment offer from Martin Marietta in Denver. I promptly put it back in the mail, thanks but no thanks. Got one from NCR in California working for a computer company. Both of them were computer. I promptly put that in the mail, thanks but no thanks, waiting for the Motorola.

Motorola gets a letter signed by Jerry Fulton, said thanks for interviewing, but I'm sorry. We don't have a position for you. I wanted to jump in the mailbox to get back those other letters.

So instead I called Jerry and say, hey, Jerry, this is Bill at the University of Arizona. He goes right. I said, well, I got this turn down letter, and I thought you wanted to hire me. Oh, Bill, there's a mistake. Throw that away.

I said, Jerry, you signed it. He said that's a mistake. Throw it away. There's another letter coming. That's how I got the job.

Diamond: What was the job that you were hired to do at Motorola?

Mensch: Well, at Motorola--

Diamond: Presumably what interested them when they interviewed you?

Mensch: Well, you know, Motorola is an awesome company. Was an awesome company? It's kind of fractured right now.

But Motorola had a training program, and you spent three months in four different areas of the company on that training program. You were treated like royalty. Everybody wanted a trainee working for them. The reason why is the training department paid your salary, so you're free labor for the department that you're working for.

So I thought about it, and I thought, well, why don't I learn Motorola. So my first one, first three months, they called them rotations, was in the applications department which is part of marketing. So I worked on the modem, 6860 modem, working with a consultant. I think his name was either Anderson or Jacobsen.

There was Anderson-Jacobsen was the name of the modem of manufacturer at the time. Well, they wanted to do an integrated circuit modem, low speed, 300 baud and so I got to flowchart that and look at some of the circuits that were needed to make the modem what it needed to be. So then the next three months I spent in the design group, designing what I specified in the first one. Then I wanted to get into MOS processing because I wanted MOS because I knew MOS was the future.

Diamond: And how did you know that?

Mensch: Again, it was about some basic characteristics that I learned at the University of Arizona and saw at Philco-Ford, that the bipolar process was slower switching if you go to the-- the highest performing circuits were going to be voltage controlled, which is the FET. And so therefore, the analog, or the bipolar, was current controlled, so it's slower. But at the time, it was the fastest, but you knew in the future, it was going to switch from bipolar to MOS field effect transistors. So what happens is I know that I want to be in MOS. I knew that was a future.

I was working for a leader in a business. I wanted to be in process design next, so then I would manufacture what I designed, so to speak. Not really, but that's the idea. And so that wasn't available to me. There wasn't an MOS spot available as a trainee, so I worked for a bipolar part of Motorola that was doing emitter couple logic, which was the fastest switching circuits in the world at the time.

And so that ECL-- Motorola called them MECL, Motorola ECL. And so I designed a triple diffused process -- we called it MECL-N, which was the end of the line, so to speak, and I was defusing into a bulk background the collector. Then next was the base and then the emitter, and that was really hard to do. Nobody had done it before. So I decided I'm going to create a program model so I could change times and temperatures, and then I would be able to see the diffusion of the ions into the background and into the collector by the base and then the emitter into the base.

So if you punch through the emitter through the base, you've got a diode. Or you've got a short, really, because they're the same type of material. So that's what I did, and so then I could get all the design characteristics with five different programs that I wrote. And there was a guy named Jim Dunkley that had a cookbook for bipolar processing, so what I did was automated his cookbook.

So then the next rotation was marketing. So then I wanted to see how you sell these things, and so I worked on data sheets. And then there was a quote needed for IBM for various size memories and various volumes of memories.

So it's a learning curve over a seven-year period, like seven different-- all I remember is 7 7 7, like seven different volumes, seven different years, and seven different densities, and so there's seven pages of numbers. So I didn't think the secretary would type up the numbers very accurately, so I decided I would write a FORTRAN program. And all I did-- it was a spreadsheet I wrote -- so you plug in the numbers, and you print it out. It was a FORTRAN program on a Silent 700, which was a terminal at the time. And then I copied on a--

Diamond: From TI.

Mensch: Yeah. So then I copied it on regular paper because that rolled thermal paper wasn't fun to handle. So then I did that within a couple of days, and then onto the next project. But marketing is how I was forced by the marketing people into the logic group because there wasn't an opening for me in the microprocessor group, which I wanted to be in.

Diamond: So why did you want to be in the microprocessor group? You got to Motorola. You worked on designing the modem chip. You worked on the processing for the bipolar chips. How did you decide that microprocessors were where you wanted to be?

Mensch: It wasn't really microprocessors at the time. I was focusing on the fact that I love the design characteristics of MOS, but as it turns out, I got four offers. In every department that I worked in, they gave me an offer. The fourth one-- the fifth one actually, I'm sorry, would bring out five offers.

The fifth one came from the high voltage bipolar organization that had the TV circuits. They wanted me because I could model the junctions, and so we could figure out what the breakdown voltages were, which was a very important characteristic. The reason why I didn't take the job is because, when I was told by Jerry, hey, Bill, you need to get off an extra month on this, and you need to pick, and so I needed to pick.

Well, I wanted to work for the bipolar group. I sent them a letter. Never got a response. This was when you have interoffice memos sent around. We didn't have email, and so what happens is I never got a response.

And so then the marketing group, the MOS marketing group, said we haven't really gotten circuits to work out of that MOS logic group, so we want you to work there. So they're the ones that said you need to take Bill. Well, meanwhile, I never got a response from the bipolar group. So then after I'm working for a week, I get this call from the head of the bipolar group that wanted me to work there. He says, Bill, where are you?

I said in the logic group. Oh, he says, well, we want you to work here. We told you that.

I said, yeah, but you didn't respond to my letter, my memo. And I thought, because you didn't respond, you didn't want me. So that's why I'm in the logic group. Now, I made a commitment. I'm here.

He said, Bill, did you see the TV last week or the week before, when that tornado set down in North Scottsdale? Well, maybe. He says that was my house.

I was putting my house back together. That's why I didn't respond to you. And I'm thinking a tornado changed my path.

Diamond: So what did you do?

Mensch: I worked in the logic group, and then what I did there was something that-- another one of these opportunities. Nobody wanted to design just logic gates. Motorola had a local logic, I called it loco logic, in Boston for some of the computer companies, and so you could design your own custom circuit with a standard cell library. So it was the job that I took over from somebody else that probably didn't really want to do it because it wasn't that much fun. But you had to put in the capacitances on the inputs and outputs.

You have to have the drive capability and the performance. If you remember the old logic libraries that had their various characteristics that you had to have in a sheet that described the performance of the various logic gates. So I designed the local logic library for PMOS metal gate, PMOS silicon gate, CMOS metal gate, CMOS silicon gate, NMOS metal gate, NMOS silicon gate. So I learned all the processes, so it was kind of like, wow, now I know how it all works.

So then because I did that, then they wanted me to design the process control monitor that monitored all of the wafers for the memory products and for the microprocessor products that ran on the NMOS enhancement load process that we designed our chips on. So then I designed the process control monitor that was stepped into the wafer in five different locations. Then you probe that to get to know whether the process was in spec or not, so then I designed that.

Then I was asked to join the microprocessor design group, and that's why I worked on that. But then all the engineers were working on that, and then they needed somebody to do the peripheral interface adapter, so I was pulled off the microprocessor to design the peripheral interface adapter, which connected the microprocessing element, the memory elements, to the real world, driving solenoids, driving just reading external switches. And the PIA was used, also, for a keyboard interface so that you could drive some of the-- with some of the pins, you drive the rows, and then you sense which key is depressed. So I got a wonderful introduction to the whole system by doing that keep peripheral interface adapter.

Diamond: So on PIA, what did you do? How did that project start, and what were your contributions to it? And take us through the--

Mensch: OK, so at Motorola, they had a-- like that applications department. They specify things. The marketing specified what they thought the industry wanted, and so as a result then, you would take that spec that was created in combination with the design group, but mostly dominated by the marketing group. So in some cases, that's a good thing. Some cases, that's a bad thing.

The 6800 microprocessor was thrown together by a lot of contributors, so therefore the design group didn't really have much of the say about what went into it. And if a sales guy came back and said, hey, we need this instruction, so they added another instruction, whether-- whatever. So it was kind of a random thing, but it was built on the specification of the PDP 8, the 6800. The 6502 came later and was modeled on the PDP 11, better architecture.

And now going back to my contribution on the PIA, somebody picked the numbers. I didn't pick the numbers. They said it was supposed to be 135 mils by 135 mils. So that was my challenge. So then I think--

Diamond: And what was the feature size?

Mensch: Oh, it was 0.8 micron-- 800 nanometers? So it was 0.8 mic-- that means 4/10 of a micro-- I mean, 0.4 mils-- 0.4 mil? I got the number system right.

The line width, metal line width, was 0.4. The spacing was 0.4. So it was 0.8 mil centers, so that was large compared to the future, where we are now.

So we knew what those characteristics are, and so how they came up with 135 by 135, I don't know.

Diamond: Maybe that was the cavity or something.

Mensch: I think sales said we needed that to make money, and so-- no, it wasn't the cavity because the same package accepted to 217 by 210 mill, 6800.

Diamond: So you got the outline of the die, the size of the die.

Mensch: Size of the die.

Diamond: And they tell you--

Mensch: Basically--

Diamond: Do they give you a pin out?

Mensch: I don't know if I was given a pin out, or I chose the pin out, right now. But when you design a chip, on one side is the data bus because you're going to latch in information from the microprocessor. Then you're going to have I/O, so across the chip, you have a data path. That data path kind of tells you where you want to put things, so I don't know if I actually defined the pin out. I could have because I knew I wanted the flexibility to define where things were.

Actually, maybe I did do the pin out because I got a patent on it. It was the first patent for the layout of an IC. Lawyers have called me from time to time, not recently, but they say how'd you get that patent?

Well, my patent lawyer, Charley Hoffman, he put that together. But he thought it was worthy of a patent, and so I got a patent. The patent is that I place things that, if you changed it, it would be a bigger chip. I convinced the patent office that it was unique, and if anybody copied it they were violating our patent.

So a patent was created-- the patent office was created in 1800-- well, 1800 is when Thomas Jefferson was president. He was the first head of the patent office, and I do have a patent-- the very first patent is on potash in my office. Charlie gave me that copy, but he made it look real.

So going back to that is what a patent is about. It's about teaching someone what you know and what you've invented, so you get the monopoly. That's the word that's on the patent. You get a monopoly if you're willing to teach someone. So I was teaching them how to do a Peripheral Interface Adapter, so I got a patent on it.

So that device, I chose every transistor on there. I taught the mask designer how to design integrated circuits, and when he said he couldn't do this one part, I stayed up-- after a party, I stayed up on a Friday night and finished the chip. He didn't have the advantage of knowing what he could do with the actual transistors and the resistors to make it work, so I figured it out. And I took it in on Monday and say I think we're done with the chip. Now, we just need to check it.

Diamond: So what tools did you use to design this?

Mensch: OK, so back in those days, there was no LVS, no layout versus schematic, so you had to check those things. And it was with Rubylith, so you actually had a flat bed with a knife on it and cut it out, and then somebody had to peel off the Rubylith from the places where you want a light to shine through. So those patterns were driven by a Calma-- it was the original Calma I system-- could drive a plotter, or it could drive a Rubylith cutter on a flatbed.

So the simulation of it-- I was one that liked computers. So I was given, by a friend of my aunt back when I was at Temple-- he was an IBM supervisor, and when my aunt-- my father had passed away, and so my aunt said maybe this friend of mine, George Rogers was his name, maybe he knows what you could do after you graduate from Temple. And his one comment that-- I don't remember anything else. I don't even remember hello or goodbye or anything-- get into computers.

So that's why, every chance I got, I used a computer because I had one piece of advice, get into computers. So that's what I did. So that means that, when I'm designing an integrated circuit, I want to use simulation because I knew the computer could help me figure out whether it was going to work or not.

So I had to prove out that the PC control-- or the wafer-- the process control monitor matched up with the actual characteristics in the simulation program, so I knew whether that was accurate or not. We had to make some changes to model because of things I found. And I found that narrow transistors had a higher voltage threshold then a short one, and these are things that the memory product guys didn't use. And so they had to change their design because of what I found on the process control monitor. I put very narrow transistors, very wide transistors, very large transistors, and very short transistors, so I knew the characteristics and what the actual sizing might have an effect on.

So I did that, and then I matched it up. So then I simulated everything. So I simulated everything, and I knew it was going to work.

Diamond: What software did you use to do the simulation?

Mensch: Motorola-- there was an engineer there. His name was Frank Jenkins. He, I think, graduated from Stanford, but I'm not sure if it's Stanford or Berkeley. One of those two. And so Frank wrote a program called TIME, T-I-M-E, stood for Transient, something, integrated, whatever, microelectronics or something like that, circuit analysis.

So when he went to Motorola from Stanford or Berkeley, he wrote MTIME, so he just put the M front of it. And so that MTIME-- Frank and I became friends. I was taking the data in the lab. He was writing the software, then I'd tell him when the model had to change.

We only had like less than 10 characteristics that we plugged into that model. It was very empirical. So I got to know everything about the transistors, what worked, what didn't work.

Diamond: How complex was this chip? How many transistors or gates or what's were there?

Mensch: In the PIA? I'd say 1,000 or 1,500, not that many. We still supply it, by the way. We're still getting orders for a compatible version with the original design.

Diamond: And how many I/O lines did it have?

Mensch: OK, it had 20 I/O lines. It had eight individually programmable ports on one write, so when you write with an 8-bit processor, you store your accumulator into a register. We had bi-directional control, so we had a data direction register and a data register. Intel I don't think ever had that, so we actually were selling PIAs with 8080 processors from Intel because they had eight bits out and eight bits in, but not individually selectable. So that really benefits if you only have a couple of bits, but you have more outputs or inputs or whatever so you can mix and match.

NCR bought-- I don't know. They were a big purchaser of PIAs. Motorola would force them to buy a 6800.

They were buying Intel processors but buying my PIAs, so Intel marketing thought, hey, for every 10 PIAs, you've got to buy one microprocessor. So I don't know what they did with the 6800s, but I think they tried to find a home for them, sell them or something. But they used my PIA with the Intel processor.

So the other two-- so there's two handshake pins on a port, so the handshake-- on two different ports. So now we have two 8-bit ports that would be 16 pins, then two handshake pins per port. So when you wrote to the output, let's say, when you wrote to the output, you wanted to tell the rest of the world I wrote to the output buffer. Now, it's your turn to take it, so it's handshaking.

And so then when that peripheral took the value of the pins, it would tell you that it read the pins, so then you can go back and forth. It's interrupt-driven or polling. You can see that this transfer had occurred, so that's basically a PIA. The other side of it is the interface to the microprocessor, eight data pins and register addressing, and then you have read, write, and phase two, and power supply. That's the 40-pin part.

Diamond: What other chips did you do at Motorola?

Mensch: Well, my patents-- I designed the buffers that were used on all of the parts.

Diamond: I/O buffers?

Mensch: I/O buffers. Clock generators-- I designed all the clock generators. And so the individual circuits-- because of my work with the standard cell library, I knew how to pick the transistor sizing because you look at the loading that you're going to have on a data path or a wire, you can calculate the capacitive loading. If there's resistance in it, you can put that in the model, simulating it. So all of that, I knew, and that's what I-- all of the chips at Motorola used some of my circuits.

Diamond: So you were kind of the analog guy in the digital group? You understood the dynamic issues with the cells.

Mensch: Yeah. In fact, much later after when I started my company, to survive, I taught Xerox how to design microprocessors, and that was a big part of what they were missing. They didn't know how to really put a microprocessor together. I showed them how to do that.

Because you have to use some basic physics-- what capacitive loading do you have on it? And if you don't know what the capacitive loading is, you don't know what transistor sizes will be required to switch in a certain timeframe. So, yeah, I knew the characteristics of the transistors.

Diamond: So after the PIA, what did you do next?

Mensch: Well, my next chip was to design a peripheral-- I mean a programmable timer unit. But it was in the middle of that that Chuck came a 'calling and said, Bill, do you really want to go to Austin, Texas? No, I don't really want to go to Texas. So he says, hey, how about if we get a group together, and we design the microprocessor we really want to do.

And you know that the 6800 isn't the right one. It's too big. Right, Chuck, I know it's too big.

So Chuck said who do we need to be successful? Who can we take out of Motorola to be successful? I'm going to look for some place that we can land, and we'll design the microprocessor. And that's what started my thinking “Motorola isn't going to be the place I'm going to retire at”

But another thing happened. At Motorola, I made a bet with the Operations Manager of the MOS group, Otis Wilkins. Otis ended up at GTE heading up their semiconductor operations later, but Otis said-- was it Otis? Maybe I have the wrong guy.

But anyhow, we had a party for releasing the microprocessor and the PIA at the same time to manufacturing, get the samples first. And so what I said, I'll bet-- now, this is after a glass of wine or two or three at a favorite restaurant. Everybody's celebrating. I'm saying my chip will work the first time, and he says that's an easy bet. No chip has ever worked the first time.

So what's the bet? And I said how about dinner? What do you think? You and your wife, me and my wife, dinner. He says, OK, where?

I said, well, for me, the Wharf in San Francisco. We're in Phoenix. He says, well, I know a restaurant in Scottsdale with a $100 bottle of wine. I go, OK, you're on.

My chip came out and worked. Well, why did it work? We didn't have LVS [layout vs. schematic]. What I did was I checked it five times. You make a bet, you better back it up.

I wasn't wanting to buy him a $100 bottle of wine anyway. Well, he never paid off. So when somebody doesn't pay off, then you go is this the right place for me?

And then another thing was said to me in a meeting with AMI, which was our second source. They said if Bill's chip works the first time, we're going to give him the “first” engineering bonus. Whoa! And John Buchanan, he's passed away now, John's like what? What about me? He was the guy that was in charge of the project leader of the 6800 in this meeting, so he wasn't happy with that because he thought probably that he deserves a bonus just because he held the team together to get the project done.

Chip came out. Worked the first time. Never paid off on the bonus.

Diamond: So at that point you were skeptical about how successful the 6800 was going to be?

Mensch: No, no, I thought that would be successful. No, it was the fact that I needed to leave because, not one, but two promises were broken. That was powerful. So who do you think I meet in the hall at 52nd Street? Jerry Fulton.

Bill, I heard you're leaving. I said, yeah, Jerry. I've got to go.

Diamond: So then what happened?

Mensch: Went to MOS Technology, so now I'm fueled by “we need to make this successful”.

Diamond: So what was MOS technology like when you showed up?

Mensch: Oh, my gosh. That's a good question. It was run by calculator people out of Texas Instruments. And so the operations guy-- I forget what his name was, but he was a very successful Texas Instruments production manager. So he was like vice president of production.

And the people that were designing the calculator chips, they were PMOS metal gate. That's what I think TI had at the time. And so they were very successful in the calculator business, and in fact, the-- oh, almost had his name. His first name was Don.

But he came up with a thing called “spot knocking” the masks. So they had perfect masks, but nobody else had perfect masks. So they had a great manufacturing team from a TI background and had a great logic team designing calculators that were really significant. They're scientific and everything, so they know what they were doing.

So Don McLaughlin was the vice president of engineering. He was one of the founders. So what happened when we got there, they didn't want us there. They were saying, well, how could John Pavinen and the founding president, how could he hire this group out of the west?

They don't know what they're doing, and we know what we can do. Why aren't we doing it? So they weren't happy that John Pavinen had brought in a team to do a microprocessor.

Now, the actual 65 where’d that come from? I guess it's a lower number than 68. I don't know where the 65 came from. And then of course, you start at 00, then 01, 02, like that, but 00 isn't too interesting. So the first microprocessor was the 6501.

Diamond: And how big was the team that came over with you?

Mensch: Eight of us, and then we hired one. I think we hired one back there. So we had two mask designers. We hired one mask designer, so we had three mask designers on the project, Harry Bawcum and Mike Janes, J-A-N-E-S I think. And then Terry Holt was the operations guy.

And then we had Chuck Peddle was the marketing, and he was the ringleader. He was the business guy. He was the guy that said, if we do this, we can create a good business opportunity. So Chuck was the marketing guy, and he kind of controlled the opportunity, so to speak. He put together the package for MOS to the contract.

And so then there's myself, Ray Hirt and then-- how many do I have there? Cid Holt was one that we hired that was back there. So there's a picture in EETimes of the group that designed the microprocessor and the product.

Diamond: Did they have an MOS process when you joined?

Mensch: No, so we had to bring up an MOS process, which-- going back to Motorola days, which was another reason why I left Motorola, is when you want to make a difference, and somebody stands in the way for no apparent reason, you kind of say what's going on here? It's confusing. So what happened was, because I had the process control monitor responsibility, I decided that I would have a line with the same lattice structure and everything. If you know a little bit about the physics of the lattice, the mobility can change depending on which way it's oriented subtly. And so I had depletion load process and enhancement load process on the same process control monitor, so all you had to do is use the depletion mask so that you could implant for the depletion thresholds for the load device.

It was a much faster process, much easier process, less transistors. It was the way to go. Well, Chuck saw what I was doing, so when we went to MOS technology, we specified what we wanted. It's what I wanted at Motorola, which Motorola didn't want to do.

Diamond: How many masks was that processor?

Mensch: Oh, wasn't very many, seven or eight, something like that. Wasn't very many.

Diamond: And what was the wafer size at that point?

Mensch: Well, the first wafers that I worked on a Motorola, they were like 2 and 1/2 inch wafers. But I think we probably were three, I don't know if they had three and a half, but I don't think they were four inch wafers. But what Ed Armstrong, the process guy that was the head of process at Motorola for the NMOS process at Motorola, he grew a long beard waiting for 10 good die-per-wafer, and we were getting like 100 good die-per-wafer on the 6502. We had at least 10 times the yield per wafer, and it was because of their “spot knocking”..

Diamond: And what is that, “spot knocking”?

Mensch: Well, when you build a mask, you have flaws sometimes in the material that's used--

Diamond: Now, are these contact masks at this point?

Mensch: Well, no, that's another thing. The contact mask meant that you would wear out your mask after using it a few times, so these were projection-- proximity, so it was proximity if I got it right. And so that means it didn't touch the wafer-- so if you've got a good mask, you had a good mask that you could use for hundreds of wafers as long as you didn't damage it.

So the “spot knocking” meant that if you compared two, you're not going to have a hole in the same place on both masks. So then if you went in and put little ink or something to cover the hole up, you could create a perfect mask. That's what we had.

Diamond: So you retouched the masks.

Mensch: Yeah, yeah. Motorola wasn't doing that, so we had the advantages in the manufacturing. So when we sold a $20 6501 and a $25 6502, we were making money.

Diamond: So your team went to MOS to build a microprocessor. Who came up with the architecture of the processor?

Mensch: Well, it would be Chuck, I would say. I'm a semiconductor engineer, so I'm building what Chuck wants built. When I did step in and started defining things is when I realized there were some basic things here that could make a big difference. Motorola 6800 had a clock generator that they sold for $69 on top of a $375 microprocessor, so if you add the two together, you got over $400.

Diamond: Without any I/O even.

Mensch: Right. So then the idea here is that if you design a clock generator, and it's run on one wafer, and the microprocessor's on a different wafer, then the characteristics between the clock generator wafer and the microprocessor wafer, one could be fast, and one could be slow. So if you have a slow clock and a fast microprocessor, it could have some race conditions that would cause it to fail. So while Chuck's off on a marketing visit someplace, I'm talking to Rod, and I say, hey, Rod, why don't we just build a clock generator right into the 6501?

Well, why do you want to do that? I said because then you don't need a clock generator chip. Just put a resistor and a capacitor on it, or a crystal and a resistor on it, and you're good to go. You don't have to worry about it. And so Rod's saying, well, whatever.

And so then Chuck comes back. I tell Chuck, hey, this isn't going to cost you anything. He says, well, as long as it doesn't cost anything, and you can put it in there.

I said it's a metal option. If you want it, you have it. It's the same chip.

6501 and 6502 is exactly the same except the metal layer. You just connect up the clock generator the way it's designed. So Rod and I have a bet where Rod doesn't think the clock generator's necessarily a good idea because it differentiates it from the pin out of the 6800. Rod says we're going to sell a ton more 6501s than 6502s, so we make a little friendly bet while we're waiting for the die to come out.

Diamond: And 6501 had the same pin out as the 6800.

Mensch: Yes.

Diamond: 6502 is different.

Mensch: Different.

Diamond: So you made a bet as to the relative volume of the--

Mensch: Yeah, yeah, I'm saying I think technology wins over marketing. Rod says marketing wins over technology. OK, well, when Motorola sued us, and then they required as part of the settlement to drop the

6501, I won the bet that day. Well, Rod was probably not happy with me, whatever. But Rod and I were friends always.

Diamond: Tell us about that suit. When did you hear about that? What was your thinking? What did you decide to do? How did you make the decisions?

Mensch: Well, I never thought about being sued by anybody, but it doesn't mean that you don't get sued. But I didn't spend any time thinking about that. I figured we were doing something totally different. Motorola didn't want to do depletion load, totally new process, totally new everything, totally new instruction set. None of the op codes from the 6800 would run on 6502 or 6501, and so therefore what's their claim?

Well, as it turns out they were claiming patent infringement. Well, yeah, a 6520 chip is exactly the same as a 6820 chip. Yeah, we violated your patent.

Oh, OK, but then they tried to get us on trade secrets. Then one of the parties, one of the mask designer, brought the schematics, and you go, oh, that's not good. And then under deposition, these are revealed. Well, this is not good.

But we didn't need the schematics. It wasn't the same. There wasn't anything the same. All the circuits were different because the enhancement load process, all the critical performance, was on bootstrap circuits to get the high drive for the power supply, and depletion mode got those automatically because of the depletion loads. So we didn't have any reason to have a schematic.

And so then this mask designer was-- Chuck may have mentioned that in his interview. I don't know, but Chuck always had a problem with-- I won't mention who it was. So what happens is, when push got to shove, then the settlement was on patent violations, and the trade secret thing was given up.

And so they defined the terms, and it was to drop the 6501. But the 6502, then, was now the only one. So I won the bet. Technology won out over marketing.

Diamond: So the 6502 onboard clock generator, different pin out, different architecture, about more than an order of magnitude less expensive than the 6800-- how was that, at that point, going with your customer design-in process?

Mensch: You know, I wasn't involved with that. Chuck was. So Chuck would make the customer visits, and then Wil Mathys-- there were four inventors listed for the one patent on the 6502. The one patent is on decimal correct. Motorola-- the 6800, I don't think, had decimal correct. That means that you set a bit in the status and the mode register, which is the P register. You set a bit to define whether it's binary math or binary coded decimal math. That was a big deal for whatever reason. I needed to write a FORTRAN simulator of that to make sure that all the combinations were correct. So actually I did that design, but because we all worked on it, all four of us are on the patent-- Chuck, myself, Rod, and Will Mathys. They're the four inventors for binary coded decimal feature of the microprocessor. So I don't know. Did I answer your question?

Diamond: Did folks, customers, use that BCD feature that you're aware of, maybe building calculators around the chip?

Mensch: Atari used it because they used it in their Asteroids game, and I found this out because, when I designed a CMOS version, I had to do it with one more cycle. So I didn't use my patent. That one more cycle made the Asteroids break up because they updated the score on the retrace, on the screen retrace. So because it took an extra cycle, it messed up their-- the code was timed to the screen.

So now, going back to it, the reason why MOS Technology basically couldn't make a go of it is because the microprocessor industry was very young. So where are you going to get the volume? And then with Synertek and Rockwell picking up big orders in California, MOS is going out of business.

That's what Jack Tramiel saw. He saw blood in the water, and he bought up, I think, six months or a year worth of calculators thinking they're going to staff up their, maybe, 200 employees. And then what happened was Jack said I don't need any more calculator chips. Well, they're gasping because the microprocessor industry didn't build at the speed at which Chuck told them it would, or indicated, and so that's when Jack came along and acquired MOS technology. And that, I was gone by then.

Diamond: So the revenue growth didn't happen fast enough to keep MOS Technology in business. Jack came in and acquired it. And when did you leave?

Mensch: I left about March of 1977, and so the microprocessor came out in the summer of 1975. We left and dropped the-- we were dropped from the payroll of Motorola on the 19th of August. We were picked up on the payroll for MOS technology on the 19th of August, 1974. So within a year, we brought up a process, a new processor, and marketing was started in September of that….'75 is when we had a wonderful reception at the Moscone Center.

Diamond: Mm-hmm. I remember that.

Mensch: Remember that? That was an awesome party. There were so many people who wanted a chip, so many people. I remember--

Diamond: I could only afford the manuals, so--

Mensch: Is that right?

Diamond: I got the manuals, but not the chip.

Mensch: Yeah, there was a mason jar, maybe about that tall, of chips in it. This is Chuck. This is classic Chuck. Chuck is the showman.

And Rod and I were there, and so we had a lot of beers. It was in the Saint Francis hotel, and we had beers and talked with people. And a lot of people interested in what we created.

Diamond: So before you left MOS, who had designed the 6502 into systems?

Mensch: Well, I really don't know. I know, apparently, Wozniak bought one of the chips. Various people bought the chips. I would work the floor, and you would take one of their cards that they gave you. You swipe it and give them a data sheet, and this is what we did for hours at a time.

You could look down from the second floor and look down. Who are all these people around our little booth, knocking over a pinball-- not a pinball? What do you call it? A pachinko machine or something like that, with little balls. Our neighbors were not happy with us because they were getting trampled trying to get a data sheet, so it was just the funnest time an engineer could possibly have.

Diamond: Were people skeptical that you could build and ship a microprocessor at a 10th, or less than a 10th, of the price than Motorola? Did you have a lot of people questioning you about that?

Mensch: Well, see, again, I'm a design engineer at the time, so I don't see what's going on in the market. Chuck sees what's going on the market. And Chuck had his way that, I think, Chuck could cause some people to doubt because he tends to manipulate the information a little bit where I'd say, hey, this is the reason why we can do what we're doing.

The process yields 10 times as much, and we got the same size wafers. And here's what the cost could be, and here's what we're selling for. We're making money, and so if you have any question about it, hey, we'll be happy to show you the schematics or anything you need to see that we know what we're doing.

They're very successful at building bigger chips in the calculator market. They were selling bigger chips than we were doing in the calculator business at a lower price, so all the experience was there. We know what we're doing. The guy that's running the operations is the guy from TI. TI knows what they're doing, And we have their best people.

So if you had a question, now, what Chuck actually told them, I don't know. But I wasn't in those meetings for the most part. I was back designing chips. I designed a VIA without any computer assistance.

That VIA is why I knew I could start my own company. I would be making money off of just not even to have to use a simulator. By this time, I knew the transistor sizing, see. I knew what it took, so I could design chips without a computer.

Diamond: So how did the VIA differ from the PIA?

Mensch: Well, with Chuck, I can still see the Arby's restaurant there in Norristown. And he comes back from one of his meetings and say, hey, we need a timer. We need a timer. OK. We need a serial port.

OK, so what are you saying, Chuck? Well, let's go to lunch. So on a napkin-- the old classic napkin, lunch napkin, there I am saying, OK, you're going to have PIA plus a timer plus a serial port.

Wow, that's more registers. OK, so we're going to have to keep it to 16 registers, OK? Because I need 16-- I can do that. So that's Chuck and Will and I have lunch, and they say, the application guy, Chuck, OK. So then I go back to the MOS, and now I have to design it.

So I designed it, and Chuck says, no, we have to have whatever, more compatibility. So then I had to redesign it, and so I designed it twice with a different pin out. I don't know what the first one was. But then I said what about the serial port? He says just any serial port.

That serial port was used as the mouse interface on the original Macintosh, and so it's a weird serial port. It's eight bits in, eight bits out. It's synchronous, not asynchronous.

If I had to do all over again, I'd say, Chuck, we need a UART, plus the timer plus the I/O pins, and we got a really good product. But that serial port is being used in different interesting things, but it's kind of weird. Nobody ever duplicated it, and I don't think anybody ever would. But it's a serial port.

Diamond: Were you thinking, at that point, about applications for this chipset? Did you consider what it might be used for, what software might be needed to make it a unit for a future system?

Mensch: Well, not really because I kind of had my boundaries pretty fixed. Chuck, you're doing the marketing. That's your job. You tell us what we need. We'll make it happen.

And Wil, he was somebody Chuck found in the neighborhood, so to speak, that really knew applications very well. Wil did the Hardware Manual. Chuck did the Software Manual.

So we had our focus, so that's how we thought we'd be successful. You focus on that. You focus on this.

And so coming back to your questions, some of these questions, I wasn't involved with. However, I did help get the Pong chip-- I think the Pong chip was manufactured, part of it, part of the volume was manufactured by MOS Technology, or another Atari chip. So I actually worked through some of the details of getting that figured out, and so that and the Vic 20, I worked with the design engineers on the Vic 20.

Now, Chuck was completely opposed to what I think was the Vic 20 and the Commodore 64. He was PET. That's industrial strength stuff, if you know about the PET versus the Commodore 64. The PET had a Hewlett Packard 485 bus on it, and this is industrial.

This is real engineering. This is a real computer. And then of course, it had the chicklet keyboard, which was Jack's mistake, but Chuck had to put up with Jack. But anyhow, if it had a full size keyboard, it would've done much better at the beginning. It got a bad image from the chicklet keyboard.

But going back to the Commodore 64, from what I remember, the design engineer Al Charpentier, and he was the guy that was behind some of the sprites and things you could do to make these video games and other things. So that wasn't my creation. That was these other guys. So I was more into just straight laced I/O, processor. Do what you can with it.

But I did do something Chuck thought was impossible. I took that serial port, and I drove the composite video on a TV, and I made a barn- storming game out of it. I did it in two weeks. Chuck says you can't do that. I go, yeah, I can.

I figured out the timing. I'd be running it at four megahertz. That's another part that the industry really doesn't really know about. We were running two to four times faster than Intel or Motorola, so not only where we a 10th of the cost, we were twice as fast.

Anytime you're twice as fast, twice as low a cost-- and we were lower power because of a depletion load process. So we were lower power, higher speed, lower cost, and lower power. We had everything-- oh, it was easier to use if you know the coding of it.

So we were easier to use, lower power, lower cost, and twice as fast. You got a winner! Any one of those things, you got a winner. All four of them-- slam dunk!

Diamond: So at that point, did you have, in your mind or in your dreams, what would ultimately turn into huge, huge volume for the 6502 architecture?

Mensch: I didn't know what the volumes would be. All I know is that, when you design something that is so right, what is possible might happen. There were no bets.

It was like . . . DEC, I think, going MOS Technology, small company, even though it looks like its PP-11 in some ways, they have to go with-- Motorola? Oh, wait a minute, there's these guys that know how to do marketing, and they know how to manufacture these things. We're going to go with Intel. So you go really? That architecture wins out over ours?

It's not about whether the architecture's better. It's do you know what you're doing in manufacturing? Will you support your customers' needs, like you were saying about Bob Schreiner and saying what's going to make it work for you? Let me know what it takes. Put together a deal.

And see, MOS Technology guys didn't know how to do that, I don't think. So I wasn't in the middle of that. I wasn't capable of being in the middle of that. I was too much of a semiconductor engineer.

Diamond: Did you have problems with the integrated clock generator on the 6502?

Mensch: No, no, it worked the first time. I never changed it. No, that worked great.

Diamond: So that could be because of your analog experience. You were really aware of what it would take to make that work.

Mensch: Right, I was a clock generator guy at Motorola at the time. Now, since then, I'd probably change some of my concepts, but I also redesigned a cardiac pacemaker oscillator that was 10 kilohertz, Statek 10 kilohertz crystal. Wouldn't start up right, so then they wanted to change it to a 32 kilohertz oscillator while I'm at ICE. So I do that design.

That's the only chip I ever designed in my life I never saw. It's a pacemaker chip. They called me on a Saturday and said, Bill, your oscillator works great.

Well, wonderful. Am I going to see it? Well, no, it just works fine. I never saw it. That was the last I heard of them.

I guess they had to recall pacemaker chips-- pacemakers. That's painful. Literally, to replace it with my oscillator. So I was an oscillator guy, but the truth be known that David Gray that's here, he got my oscillators to work really good on my 134 and 265 chips recently.

He found an article, and I go oh, wow. So I thought I knew what I was talking about before, but now I've been just reintroduced to the whole thing. And I realize there's some characteristics that I wasn't aware of that we put into our circuits that work like a champ. Anyhow, so my designs were successful.

Diamond: You mentioned that you'd left MOS at that point. What motivated you to do that?

Mensch: I wanted to design microprocessors, and I wanted to design commercial products or industrial products, game products. I didn't have a calculator at home. My son got his first game system from Nintendo. It was a Famicom 16-bit, but it had Japanese captions and Japanese characters.

And Ricoh, who supplied them their chips-- Ricoh supplied the Nintendo. It's the only exclusive agreement I ever gave anyone, exclusively for Ricoh to supply Nintendo 8/16-bit chips for their Super Nintendo. Well, my son got a Super Famicom. He was popular on the street because, what's that? So anyhow, I'm digressing here.

Diamond: OK, so let's talk about your transition from MOS.

Mensch: OK, well, when we saw the situation changing because of the business climate, they we’re looking like they were going to go out of business. And Chuck was moving from a microprocessor team leader to a systems person, so he aligned himself with California in the process of the acquisition by Commodore. I'm not sure what the timing looked like there, but I left soon after or in the process of Commodore acquiring MOS Technology in a depressed situation, or a fire sale.

Diamond: So do you know what year this would be?

Mensch: 1977.

Diamond: OK.

Mensch: So about the introduction, I think, of the Apple II and what was going on there. And so what happened was I wanted to work for a real company, not a game company. I'm not a game guy. I like the industrial, high quality-- I only want to design something that goes into high volume production used by many.

And so looking at feeding the game or calculator consumer products, that wasn't my cup of tea. That's not what I wanted to do. But then what are my options? So I ended up-- I interviewed at Xerox. They were going to double my salary, go to El Segundo.

And Bob Markel, if I got his name right, he flew me out while I'm an employee at MOS, and he wants to double my salary. And I go OK. So why would you do this? Because it's hard to find microprocessor designers. You're one.

So what would I be doing here? Well, you'll be designing-- we're a research lab, so you design something. Then we transfer it into production, then they redesign it for their production manufacturing.

Oh, Bob, you're in the wrong place. My designs don't get redesigned. They go into volume production right away, or why didn't I do it right in the first place?

So I'm not a research guy. I'm somebody that wants to make things happen, and how I know I'm making them happen is they go into volume production. They're used by people. We don't throw away designs. We just do it right the first time.

So, Bob, it was nice meeting you. Thank you. I'm going back to Pennsylvania. I need to find out my other thing I want to do, and I don't know what that is.

So that's when Glen Madland, ICE-- he's in the seminar business. He's teaching integrated circuit design-- or integrated circuit usage, and he was the first. Glenn was the first design manager at Motorola in Phoenix. And so when these integrated circuits started happening, he said, you know, Motorola, you're going to need somebody teaching the world how to use because integrated circuit is so much different than resistors and transistors. Now, you have a new way of doing things, and in order to get this out into the market, you're going to need somebody to teach integrated circuit engineering.

That's the name of his company. So he hires me realizing he could use a microprocessor guy to teach the world microprocessors. So then he asked me to put together a seminar called Microprocessors for Management, so I put that together.

He hired me straight across the board, no raise. I'm going to Arizona. Feels right to me. I have two children under the age of four. Now, I'm going back to Arizona.

I'm not designing anymore. I'm talking about designs, and I get a migraine headache. I'm talking to 50 people.

He charged a good price for attending the seminars, and I get a migraine headache. And it's like-- I don't know if it was a two-day thing, but within an hour of the first one, it's like I got a migraine headache and nobody can back me up. I got to do the whole thing.

Diamond: Are you teaching people to design microprocessors or to design systems with microprocessors?

Mensch: Actually, I don't remember what I taught.

Diamond: You remember the headache, though.

Mensch: I remember the headache. But I remember it's Microprocessors for Management, and it's about these microprocessors are going to change the world. And so it's not about designing systems. It's about knowing what to do because now microprocessors are replacing other forms of logic.

And I didn't have it then, but it's embedding intelligence into products. So you need to be aware of what that would change. Now, that's what I'd say today. It's not what I said then, and so it was one of those things where I was probably getting a migraine headache because it wasn't, maybe, that good. But it was the best I could do knowing what I knew at the time.

And then I would be the microprocessor guy in a weeklong seminar. So I don't know exactly how many different hours I taught, but I know that, at the end of the review, they reviewed each of the consultants that were teaching. And then you fill out what's your grade? I was getting failing grades.

It's like this is so painful, Glen. I don't know what I'm doing. And the other guys that were doing this, I didn't feel like they knew what they were doing. But they were getting the A's, and I was getting failing grades. If I got a C, that was really good for me.

And so I'm thinking, Glen, I don't understand. How can Howard do that and me, and he gets A's. He says, Bill, you haven't figured it out yet. We're in the entertainment business. I go, Glen-- he says you're trying to give them too much information.

I go, well, they're paying for it. Don't they get the best? Well, they're coming here to Arizona because it's cold wherever they were, and you want them to leave thinking that they know something. But you're giving them too-- they can't digest what you're giving them, so it's painful for them. OK, well, that's a mismatch because I'm giving them the good information, but they can't use it.

And so I don't know how-- so then I dumbed down what I have to say, and then my grades go up. And I'm thinking this doesn't feel right at all, so I can't do this. So that's when I asked Glen, so what's it all about? That famous question that's been asked and probably never answered, but Glen, at the coffee shop, at the coffee bar outside of his office-- and my office was next door to his. Glen, what's it all about?

Glen answered it. He said, for me, it's about doing what you want to do, living where you want to live, and you're comfortable. Whoa, thank you, Glen. Went back into my office.

I'm not doing what I want to do. I'm living where I want to live, but my son was just born on a credit card, so I'm not comfortable because you didn't have maternity benefits. So here I am, not comfortable with my debts, enjoying where I'm living, but not doing what I want to do.

Denny McClain, I think, pitched 30 winning-- he had a 30-win season, which hasn’t been duplicated, I don't think. Maybe, but I don't know. And that's what I feel. I feel like I'm Denny McClain. I just pitched a no-hitter, wins 30 games, and I'm out of the business.

I need to get back in the business. So my transition from MOS to consulting-- that's when I got to reverse engineer all of the popular, valuable, industrial microprocessors for $5,000 per processor, which means that I had to set up a little factory line, assembly line. So bipolar-- I had a bipolar consultant that he could help you with the bipolar, and then I had to put it together in the registers and what was going on.

Shell Oil Company had the first patents on dynamic RAMs, and they were chasing down Mostek so I had to reverse engineer Mostek and show them that Bob Proebsting used the same circuits he had at Shell. He was a designer at Shell and went to Mostek and I'd just say, well, he's got balanced bit lines Hey, he's got sense amps…. So I had to do this kind of stuff because I knew what the transistors were doing.

So I wanted to get back, and so I transitioned to ICE. A year later, I'm starting my own company because Jack Tramiel wanted me to design CMOS calculator chips because they're lower power. And so there's Frontier, whatever it was, semiconductor, Southern California. Was it Frontier or Pioneer? (It was Frontier.)

I don't know. It was something like that. I think it was Frontier, like the airlines I think, but I'm not sure. But anyhow, that was the CMOS manufacturing for Commodore for CMOS calculator chips. That's how I got started in my own business.

Diamond: So that's Western Design Center. So did that happen before you left ICE, or did you leave ICE and then start WDC?

Mensch: Well, what happened was I was doing all this is talking about design, and then I actually trained NCR engineers how to design microprocessors. They were using emitter-- I don't know if it was injection logic or emitter coupled logic. It was bipolar, and that wasn't fun for me to teach somebody about designing microprocessors that I didn't think was a good idea. But I did what I needed to do. They had the process, and I-- whatever.

So NCR, and then I forget who else-- but anyhow, it was just consulting, so answering questions or giving them my best. I gave them my best. But what happened was I went to Glen and said I want to build up a design capability here. To do that, I need a circuit simulator and a logic simulator, so we found a logic simulator and a circuit simulator that was out Bowmar. ICE had been part of Bowmar, the calculator company.

And so Frank Jenkins is the same guy that was at Motorola. He did the circuit simulator and logic simulator. I'm thinking that's good stuff. That works. So I knew Frank, but Frank left Motorola selling logic simulators and circuit simulators back before for Verilog.

And so what happened was that was running on an accounting firm's Prime 300. Prime was virtual memory, and so it could handle any size logic circuit because of the virtual memory. And then I got that to work, and then I wanted to sell logic simulators and circuit simulators through ICE.

So I was building up the base for designing chips for ICE when Glen says, you know, there's a problem with designing integrated circuits. They don't always work. Yeah, but if you know how to do them, they work. Yeah, but there's a risk involved there, and you can risk our goodwill, our relationship we have. So I can't really take that risk.

And I'm thinking, oh, my god. [SIGHS HEAVILY] Well, how am I going to do this? And so then out of the blue, Chuck calls me. Jack wants you to design calculator chips for him.

Oh, OK, well, I need a customer. I'll go to Glen. Go to Glen. Hey, Glen, I got a possibility of designing calculator chips for Commodore.

Glen says, no, Jack ripped me off. Jack owes me money. It's not good. I never want to do anything with Jack ever again.

But this is an opportunity for me to design chips again. That ain't going to happen here. OK, Glen.

So then I go back, and I'm thinking is this a two-way street or a one-way street? Go back, say to Chuck, Chuck, I want to design calculator chips working here at ICE. What do you think? I got everything set up. I got circuit simulators, logic simulators, we can get mask design done and all that.

Nope, Jack doesn't want to have anything to do with Glen. Glen's a good guy. What do you mean? No, Glen ripped him off.

I'm thinking how can you both rip each other off. So that's when I decided, well, I can't do it here. Start my own company. So that's when, on Mother's Day weekend, in 1978-- I think Mother's Day was maybe the 13th of May that year. I don't know.

But anyhow, I visited Jack and Chuck at a casino in Las Vegas, and Jack's down $10,000 when I arrive. Then, he turns around winning $17,000. That's what I remember. He says, well, you brought me luck. Let's go talk.

Go up to his room. Chuck's sitting here. Jack's sitting where you are. I'm sitting over here on a sofa. Jack says so what do you want to do, Bill?

I said, well, I'd like to design integrated circuits for you. OK, how are we going to do that? I'll give you a department within Commodore. I'll make you vice president of Commodore, a whole division. I'll pay you more than I pay Chuck.

Chuck is like what? Where's that coming from? So Chuck wasn't too happy with that statement from what I recall.

I said, well, I thought about it, Jack. I want my own company. How will that work? I said, well, we'll have an agreement. I've been writing agreements with ICE.

We'll write agreement. We'll put milestones in it. I get paid, and I'll break even. And the design will work.

And how you know it'll work is I get a royalty off of each chip, so I don't make anything if it doesn't go into volume production. I believe in what I do. I believe what I do will produce volumes. That's where I'll make the profit. I'll break even, and that's how it works.

Diamond: So the idea was he'd pay you enough so that you had your costs covered for that design, and all of the upside in future was on a royalty basis based on a percentage of--

Mensch: OK, now, we go back to what happened at MOS Technology, and why was everybody not happy, why did everybody leave. There was a learning opportunity. Chuck put together the deal. Guess what it is? A percentage of *profits*.

Well, you get to looking at who's cooking what books, and you go when will there ever be profits here? Well, you know, it's how you do your accounting, what do you assign to this and that and the other thing. So there were some really unhappy folks.

Now, Chuck and I, we're friends. Now, Chuck's hard to live with sometimes, but it's that, whatever you call it, the synergy of two different styles. But would I call Chuck a friend? I would, but there are some saying really? I am.

I'm a friend of Chuck's, but I understand Chuck in a way that very few people probably understand him. But I know he's a winner. There's a winner there someplace.

It's like that story about the pony and all the crap. There's got to be a pony around here with all this crap. And so I think Chuck can put together some interesting deals that only Chuck can put together. He's just like a Steve Jobs in a way, and so if you know him that way, life is exciting, so to speak, opportunities.

Diamond: So what was the deal that you negotiate with Jack?

Mensch: Oh, yeah, it's per unit.

Diamond: Per unit?

Mensch: Yeah, it's per unit. So you sell it, you get a percentage of the sale price. I don't care if you make a profit or not. That's your problem. But I'm getting a percentage of whatever you sell it for.

Diamond: And was he going to use some of those chips for internal use as well?

Mensch: Yeah, yeah.

Diamond: And how did you get compensated for those?

Mensch: Oh, he never manufactured anything I did, ever, which is interesting. What he did was, when I duplicated the LC5K3 chip out of Toshiba-- that was some interesting design. It was a serial processor, and it's hard to reverse engineer an LCD implanted resistors. You can't see them on the surface, so you go how is that happening? And you have these nodes that aren't connected up to anything.

Well, they've implanted resistors in there you couldn't see, so I had to figure that out. It makes you use your imagination more when you-- wow, that doesn't make any sense. That doesn't make any-- then they also embed into it some circuits that are phantom circuits that would confuse somebody trying to reverse engineer it. So all these tricks these guys use-- well, I got it to work.

But guess what Jack wanted to do? He wanted to get the Japanese price, which was half of the American price, so he wasn't going to buy any chips. He wasn't going to build any of my chips. He wanted the chip, the design, so he could go back as a negotiating. OK, well, we can--

Diamond: Did he have that idea from the very beginning?

Mensch: I don't know. Jack was shrewd. He may not have. I don't know, but he was a gambler. He was a gambler, so if he's going to gamble-- and he's saying, well, can we build this any less expensive than buying it from Toshiba?

He's making the business decision. It wasn't about my design running in a factory. It was about can he make more money off of getting a better price from Toshiba.

Diamond: OK, so we were talking about the Toshiba calculator chip that you did for Jack, and you mentioned that you did the design, but he didn't use your chip.

Mensch: No, and actually I designed a 4-bit microprocessor parallel. Now, the Toshiba chip was serial, but in order to get that to-- scientific calculator, now. Now, we're going after the scientific business. The other one was five function, and that's a low end. Then we're going to go to scientific.

In order to do the scientific, I said we needed to do parallel, not serial. And so you'd think can we do the 6502? The 6502 would not have been good because it's floating point, 64-bit. We have to do 64-bit math, but sometimes, we might not do 64-bit. We might do 24-bit, like the mantissa and the exponent, on a single precision.

So I have to be able to change from 32-bit to 64-bit and/or other, whatever the math, we need it, would work. So Chuck had a coding-- guy that programmed it. His name was Shirah And so Shirah I don't know if he was in India, or he was in northern California.

So Shirah and I worked out what we were going to do. I don't know how much Chuck was involved with it. He didn't seem to be involved with it. And I wanted Wil to help me with this because I'm a semiconductor guy. I'm not a processor guy, really, if you think about it.

I had to add on the microprocessor functionality working with the market, like what we've talked about. So as it turns out, a 4-bit RISC processor, it had 16 instructions, but what I had was a field, a 4-bit field, that would tell you how many nibbles. So if I wanted to do a 64-bit, I'd have 16 4-bit nibbles. So it's a cool processor, and it also helped with the LCD interface. So I had the LCD interface also would be supported by this 4-bit RISC processor that could do 64-- any four, eight, 12, 16, all the way to 64-bit.

I could do that, and so I had this new instruction set. And the 6502 wouldn't have been good at that and keep the size down. But then another thing that was the Achilles heel that I didn't know about at the time, because Sam Tramiel, Jack's son in Japan, knew the characteristics of what was going on in the calculator industry, and one microamp of standby is a lot. So you couldn't even have one microamp standby, but I didn't know that. And I should have known that, but I didn't.

And so what I designed into this is a single transistor dynamic RAM using what Proebsting did …what I learned at ICE. So I had a single transistor non self-aligned metal gate dynamic RAM on the chip so I could save space on it because everything else had to be static. So here I am, thinking the semiconductor technology that I knew, and I got it to work, and it works fine. But--

Diamond: Too much power?

Mensch: You had to refresh it, so I had to have the refresh cycle in there. So I had to refresh the memory, and that was over a microamp. So that wasn't a good design.

Diamond: How did you get involved at the Western Design Center and the 65C02? How did that project start?

Mensch: OK, so Xerox-- I have to say the first customer after Commodore-- now, Commodore didn't want the CMOS 6502. The NMOS was low power enough for things like the PET, and these other things. It was already lower power than anything Intel or Motorola had, so they weren't interested in the CMOS version.

So after Jack was fired-- I thought he quit because he made a billion dollars or something like that. Commodore sales was over a billion dollars, which is a big deal for Commodore. But apparently Jack was kicked out by Irving Gould, and I didn't know that until the book was published about-- On the Edge, that book. You're familiar with that, right?

So what happens is they pull up stakes. They brought a truck, whatever, a truck by the office, took all their equipment, and take off with all the equipment that they felt was theirs from an office that I had a $50,000 note due on in six months. I just purchased this thinking we're going to do well, and then they didn't want to do anymore.

I didn't have any other customers. That's one thing Jack said, exclusive. You don't work for anybody else. You work for me. You don't work for anybody else.

What I translated is I can't even talk to anybody else, like sales. I can't set up a next opportunity. So when Jack pulled up with his truck, so to speak-- it's the guy from California, the CMOS, the design manager there, he took everything he thought they owned and left that day. And so then what I'm doing is saying, oh, wow, three kids under the age of six, one customer gone, now what am I going to do?

I call up Bob Markel at Xerox. Hey, Bob, I'm available. So this must have been near Christmas. Can you come over--

Diamond: And what year?

Mensch: 1980. He goes can you come over? Yeah, I need to talk to you. Sure, I'll be over on the next flight. So bank accounts, probably on a credit card, and all this other stuff.

So then I go over and meet with Bob, and I said so, Bob, so what do you have in mind? He says, well, Bill, now that I have you, I couldn't hire you, and I took you in. Their vice president of Commodore-- Xerox is going to give them their most advanced process just to have a part of my time.

And Bud Frye was their vice president at the time, who was managing me. We met at Xerox, and Bud Frye listened to them. No, no, we want 100% of Bill, sorry. So then when they pulled up stakes, then I go back to Bob. Now, Bob's saying come on over and let's talk.

He said what happened? I said, well, I don't have any business exclusive for Commodore. Commodore left. I don't have anything to do. OK.

Talks to his secretary. We had secretaries back then. [COUGHS] Excuse me. She leaves. Comes back with an envelope.

Bob hands the envelope to me. I open it, $25,000 check. Bob, what's this about? He goes you have a nice holiday. I said but what are we going to do?

We'll figure it out after the holiday. Yeah, but why would you just give me $25,000 without any contract or anything? He says, Bill, when a microprocessor design engineer becomes available, you lock him down. I want to talk to you after the holiday. We'll figure it out.

Well, thank you, Bob. Came back. Want you to teach my guys how to design microprocessors. That's when I hired Dianne and trained her in five weeks to help me make good on my contract, so I taught her design.

But anyhow, that whole process is so random that you go how does that figure into anything? You go, well, it's the way it worked. It's the way it happened.

Diamond: So how did you get from teaching Xerox to design microprocessors to restarting the 6502 legend?

Mensch: OK, so the 65C02 came out of the fact that GTE-- while I was at ICE, I gave a seminar on Microprocessors for Management--

Diamond: So they were one of your students at ICE?

Mensch: Not GTE, EM&M Semi. Remember, we were talking about that earlier? Well, EM&M Semi was there, and Fran Krch-- who has no vowel in his last name. I think it's C-R-- K-R-C-H.

Fran Krch was the marketing guy for EM&M Semi, and he, I guess, was convinced by Glen that this would be a good investment on EM&M Semi to hear this seminar, or whatever. Not exactly sure what happened there? But Fran knows me.

Doctor Desmond Sheahan got his PhD from Stanford. Got his undergraduate in Scotland, I think. He is the vice president of technology. He was the vice president of technology at the Lenkurt division up here, and he was the one that proposed semiconductor operation to GTE Corporate. So he needs to make this work, and his career is attached, now, to getting technology into the factory because he's convinced corporate they need to be in the semiconductor business.

And so Fran Krch is a marketing guy, and so Fran knows me. Introduces me to Des. Des and I hit it off. Des says I need to send you to the ATEA division of GTE in Lemkurt-- no, not Lenkurt-- outside of Antwerp, Belgium.

So first international flight, I've got to get this. And so I'm going over there, and they have a 6802 based key system for telephones. So they're telling me what they need for the 6802-- serendipitously, Mitel had a unipolar doped poly silicon, which they were the first to do that. And its oxide isolated, so it's lower capacitance.

So I know that oxide isolated unipolar doped CMOS is a winner. That's what we need. GTE figures this out on their own, but serendipitously, I have my secretary call the sales office for Mitel where GTE got their process. I didn't know they got that.

So they got licensed on the 6802 and the process from Mitel. I have my secretary call the sales office in California. I get online with him. He says can we meet in Chicago on Sunday?

This is a Friday. What? Yeah, I want to meet in Chicago-- or where it was, or Montreal, or someplace.

Diamond: That's where Mitel Semi was, in Montreal-

Mensch: No, no, Ottawa. So we have to meet at this airport because you can't fly directly into Ottawa. And so it's like minus 30 degrees. It's 70 degrees in Arizona. It's in whatever, February.

And so I go there, and they're saying we fired our guys that were in Lake Tahoe designing the 6802, and it only runs at 250 kilohertz. And we need it to run-- the original spec was 5 megahertz. I said if it's so far off, I think I can get it to a megahertz or two megahertz, but not five. I don't think I can do five.

It'll have to be totally redone, and I don't think you want me to do that. But I think I can get it to run at one to two megahertz if that would work for you because that's what the original one worked at anyway. So you'd be matching up with the NMOS, but you're not doing everything you could have done had those guys known what they were doing. Well, we fired them because they were, apparently, two forms of snow, and they were not really working too hard and enjoying themselves on the slopes and otherwise.

And so you go how serendipitous is this? So I said, well, basically, I'll do this for $15,000. They give me a check just like Xerox did. Now, I got the wolf away from my door for another whatever, another month maybe, or two.

And so then, now, it's CMOS unipolar doped poly, good. Oxide isolated, wow, this'll be good. I started my own process model rules called OXI-CMOS for oxide isolated CMOS. So I had my own design rules and everything.

And so then Des sends me to Belgium. OK, so I go to Belgium. Listen to these guys. 6802, they're using the NMOS version, and we want to add this and that and the modem features and dialing features and all that. So I brought back the spec. That's what Des asked me to do.

So then I put together two proposals. We could either do the 6802 version or the 6502 version. So Otis Wolkins at GTE now running-- he's the operation vice president running-- GTE vice president running their operation out of Motorola. He's got Motorola people all around him, and they're not happy with the 6502 because I left Motorola. And the 6502 stole some of their thunder. Right?

So here, they're all Motorola, and I got GTE vice president Des is there. We're having a meeting.Otis Wolkins in his office, and I, at some point-- so I present it. 6802, two-chip version; 6502, one-chip version; so presented that.

Otis looks at Des and me, says I'll be back in a little bit. So I thought he had to go the bathroom, but what he did was talk to Fran Krch. And Fran Krch says to him, hey, it's been my experience that the smallest chip wins every time.

He comes back, says to Des, it's your call, Des. You're the man. You make the choice. Des says the 6502 base. I got emotional, but I had to wait until I got in my car. Wow.

Diamond: That surprised you?

Mensch: It was the right decision. Sometimes in big corporations, the right decision isn't made. Des was the one. He knew technology, and when it was his turn, he picked the one that he believed in. I designed every chip that they had at GTE.

All the chips that I design, they were a licensee of. So that's how the 6502 came about. And then Rockwell licensed it like the same week or whatever. I always think GTE was first and Rockwell was second, but I think that's the way it was. But anyhow, the 65C02 was it. Rockwell put it in billions of modem chips because it used the CMOS 6502 in their modems that they were selling.

Diamond: So how many 65xxCxx instances do you think there are in the world?

Mensch: Well, there have been estimates. Actual number, I've been saying 5 to 10 billion for the last 15 years. And we sell about 100 million a year.

So you know these little video games that you get at Walmart for $15? They have my 816 in them. Those chips are sold for, I don't know, $0.25. Full system on a chip, $0.25-- I mean, I don't know what the margins are, but they're very small.

Diamond: Course, Apple used the processor

Mensch: Yeah, Apple-- they used it in the Apple IIc and the Apple IIe, but if you add up all the Apple products-- how many millions did they sell? Five million? I don't know what the number is. 10 million, maybe? Commodore sold maybe 50 million. But the 6502 used in floppy disk controllers and modems and game systems that you never heard of, they're billions.

Diamond: So why do you think that is, Bill? What is it about the architecture that has attracted so much usage?

Mensch: Right, well, I think we talked about this earlier. The architecture was never labeled properly ever. So when you look at the architecture, and you look at how it was used for Apple, Commodore, Atari, Nintendo, what you'll find is that the architecture provides for a powerful solutions based upon addressing registers effectively. So we had zero page as an example, three cycle accesses, and so we could actually access memory registers, addressable registers, in memory to do floating point faster than you could do on a 6800 or anything out of Intel.

I have this on my website, and I didn't do it. I didn't do the benchmarks, instruction level benchmark. GTE did it, and they come back when they did this. They go, Bill, did you know how awesome your microprocessor is in comparison to like the Z80 and the 6800 and the 8080? I go really?

Well, what that tells me is that they didn't do it as well as they could have because I'm doing it as good as you can. So that means that they didn't. It's not like they could have, but why didn't they? I don't know.

But addressable register architecture provides the resources to do anything with this little processor. That's why it was used effectively in these early systems. It just is two to four times better than the other guy.

And did Wozniak know that? I don't know. He was maybe buying it for its price, but then that would mean that he fell into something that really was effective.

But I'm saying when you do it the best you can do it, and nobody can do it better, you know that. But does the other person know that? No. They will use what the marketing guys sell them, and if it matches up, they have a match. They make money.

That's the end of the day or the end of the conversation. But for me, the architecture is the best it can at eight bits, and the pipelining and what we did there was to minimize the number of transistors. So we did it the best possible. That's what we know.

Diamond: I think it could be said that you invented the idea of a microprocessor IP as a business.

Mensch: Right.

Diamond: Did you have that idea and then pursue it, or did you find yourself doing it and then realized what you were doing? How did that come about?

Mensch: OK, Glen Madland again-- Glen Madland told me, taught me, that if, in the consulting business, you can get somebody to pay for a study, you paid for it that way, then you give a seminar on it, then you sell the book. You can sell it three ways, and everybody's happy. There's nobody complaining about that. The original guy got what he wanted. The next guy get what he wanted.

They all get what they-- so if you can sell it three times-- so I'm thinking, hey, if I design a 65C02, and I license it 10 times, that is better than what Glen was doing. But the idea, Glen started in my head. So then I'm thinking a microprocessor can be used for so many different things, and really, applying the microprocessor to an application, an application-specific requirement, is better left up to the guy who knows the market opportunity. So for me, licensing a microprocessor fulfilled Glen's business concepts. And I could design just the building blocks, and somebody else can enhance them for their market separation, their market needs.

And so to me, so I've licensed it, not 10 times, but over 60 times throughout the years. And so what was happening at the time that I licensed it was everybody was looking at, well, I have a factory that needs a second source. AMI was a second source to Motorola at the time. So what people were trading designs so that their customer was supported if they went out of business.

Now, companies like Intel might have, I don't know how many factories, 20 factories that could run the same design, so it's not the second sourcing anymore. So what I was doing is licensing for a fee, then I could do what I wanted to do, and actually collecting royalties. I get a quarterly fee, I get royalties, and I used to get, sometimes, the NRE for the startup of the whole thing.

I still do that, but I'm very flexible. I meet the needs of my customer, so you need this, you need that, I'll mix and match to get the opportunity because it's getting to know one another and what's the right form. So what I'm doing with Chuck right now is the right form of things, which could be the most lucrative thing I've ever done, working with Chuck again. But he has to make good on his marketing, and so there you go.

So I think it's the idea that I needed to change the equation, and for me, changing equation is licensing for a fee at first, and then for a fee and royalties. And then just to prove that they had an accounting system early on, I have a quarterly fee, and it starts with a fee. And so now I have qualified that they know how to communicate financially, and now good luck with your market. So I cheer. I'm a cheerleader, so I cheer for people.

Diamond: Do you have a favorite to application of the C02 that's come over the years?

Mensch: I have favorites in various categories-- how's that?-- because I can't pick one. I just can't pick one. The defibrillator, pacemaker one, I actually did all the life tests and everything and supplied defibrillator chips to a company, so I knew the testing cost was over $100 per unit just to test to make sure that they were not what they called infant deaths, or whatever it's called. So that you don't want to embed a chip that's going to die in the first year. But if it passes that test, then from your own experience, that'll last for a long time, and so I needed to go through all of that learning experience.

But then I needed to find somebody that would manufacture life grade tests, and how that happened was nobody-- Motorola got out of business. Harris got out of the business. Intersil if they were a combination. RCA 1802-- who would use an 1802 in a pacemaker? I don't know, but a company I licensed, ELA

Medical, part of L'Oreal Pharmaceuticals, was the first to embed a microprocessor in a human body for life support.

So these kind of people look for me for two years because I had a clause in all of my agreements, still there, that you can't tell anybody about your license. So my licensees couldn't tell anybody where they got it. Wow, that sounds like negative marketing.

Well, this medical company out of Australia said they looked for me for two years. Somebody must've not honored my agreement because they told because they said we went to GTE. They have the same instruction set. They went to Rockwell. They have the same instruction set, and they all said it's their microprocessor.

But somebody, but I don't know who was, told them who it was, me. So we're back to why are you picking me? Because we can do business. The other guys are getting out of it for one reason-- lawyers. So if they have a problem, they're going to sue you, and they don't want any part of that.

I said, OK, well, in my agreement, you're going to have to agree to indemnify me against everything. And we want to be real understanding that I'm giving you everything I know, so when the judge asks the question what was your part in this, I'm saying I gave them everything I know. You've got all the source, all the information. So I'm probably one of the few companies that are indemnified by my customers, so that's just-- I needed to solve the problem. The problem is that you cannot not use the world's best microprocessors to save lives.

Diamond: So you've evolved the architecture over the years.

Mensch: Somewhat.

Diamond: Tell us about what changes you've made and why.

Mensch: Well, listening to your customers is a good thing. GTE-- the original packet switching, I think for the DARPANET, was out of a company called Telenet, packet switching. And so GTE, Des, sent me to Virginia and said we need to see what they want in this microprocessor we're going to design, so they used a 6502.

They said there's no other microprocessor available that can outperform the 6502 for packet switching. If we could have memory lock, that would mean one processor working on a piece of information wouldn't be interfered with if it's doing a read modify write back into memory. So if you could hold off on that, put memory block on there, and if you could do some bit manipulation-- I forget what it was that they asked me. So there were just a few features that they asked me for, and I put them in. So those were why the enhancements.

Then Rockwell wanted the bit manipulation instructions put in, which I put in, but it conflicts with my 816 op code. But they want to be able to set memory bit, reset memory bit, or clear memory bit and branch on bit set and branch on bit clear, those four. So Rockwell wanted those, so I put those in. So I don't know-- NCR is a licensee of mine-- was a licensee of mine, and so I don't think they asked me for anything. But I listen to them, and that's where the enhancements come from.

Diamond: How did you get to the 16-bit architecture first?

Mensch: Well, nobody wanted it, but I wanted it. And I figured that if I could do the 16-bit and make it compatible completely with the 8-bit, I could get 16-bit accepted. [CLEARS HIS THROAT] Excuse me. So what happened is I went to Apple-- Apple came to me, and they said, well, this is what we'd like. So they gave me these features that they'd like, but they said we're not going to use it.

So why are you telling me what you would like then? And I don't know factually if this is correct, but I was told that Wozniak came back to Apple to do the Apple IIx, it was called, then Apple II GS, graphics and sound. So they gave me some features that they wanted for 16-bit, but they never said they wanted to make it compatible with the 8-bit, run the old code. But I figured, wait a minute, if you run the old code-- and I had an 802, which was an 816 that was pin compatible, so you could plug it right into the old Apple II socket. Learned that from Motorola.

So if you plug it into the old socket, you've got a customer. So mine was the first processor to emulate the previous generation, so I did that. But I remember visiting Apple for the last design review, and they said, Bill, you know we're not going to use it. We have our own 16-bit microprocessor.

Really? What's that? 68000. OK, so you're not going to use it? Right.

So I came back, addressed my team with tears in my eye. This is the right thing to do. Somebody'll want it. So we finished it up.

My sister actually did all the layout on the original design. I wanted a brother and sister to design the only 16-bit microprocessor in the world, and if it became popular, that would be an added bonus. That's what we did.

So because I designed it at home-- so I'm a double entrepreneur. I've got my little company, but I need to do this because I know it's the right thing to do. I did it at home on a game table. Brought it in. My sister was the only layout designer because everybody else had to do the projects they were on.

So it's got an interesting history. But Newsweek, they called it-- there's a mythological figure that looks forward and backward at the same time, and the article-- it's a short article-- they had that 816 is that. So then they came back, and actually, Apple used it in the Apple II GS. I went to Apple, and Dan Helman-- was it Dan Helman? I think he was the project leader on the printed circuit board design of the Apple II GS.

He invited me up. I said what's going on? He said I just want you to come up. Came up to his office.

He had the other designers of the Apple II GS there. And I don't know if they gasp, but it seemed like they may have because Dan hands me the first PCB that was fully stuffed. He says, Bill, I want you to hold this.

Diamond: And that's when you found out about it?

Mensch: That's when I found that.

Diamond: That must've been very emotional.

Mensch: Yeah, I'm an emotional guy. That was emotional. And then the other guys are like how the hell does he get to hold it first? Dan's a good guy. And Wendell Sanders is another name, and he was one that visited me. Do you know Wendell?

Diamond: I met him, I think, during the Apple III.

Mensch: Yeah, he was the Apple III guy. And Wendell's son was the head of the iPod division of Apple recently, and then he went on sabbatical. I don't know if he came back or not. But Wendell was the guy that came down and told me what they might be interested in.

Wendell and I-- I call us friends. I went to his big home that he was building up the mountains. And I found out recently-- about two years ago, we talked again because he wanted a white ceramic 6502 for his Apple I.

He's got an Apple I. Did you know that? He's got a website of an Apple I, and he wanted-- something happened, and so we're trying to get him a white ceramic 6502.

I have a couple of white ceramic-- no, I think they're white ceramic. Maybe they're the purple one or whatever-- 6501. People want 6501s. I've get three of them.

Diamond: I only have plastic 6502s from that era.

Mensch: Oh, yeah, I have--

Diamond: You probably have a lot of those.

Mensch: I don't know if I have a lot, but I have a few.

Diamond: I think at Synertek, we didn't-- I may be wrong, but I don't remember selling ceramics.

Mensch: No, I think it came out of the original--

Diamond: MOS.

Mensch: MOS because-- yeah.

Diamond: Because that's easy for prototyping. You can assemble it.

Mensch: You take the lids off and probe them when you could. Now, you can't, but yeah. But also the plastic is lower cost, and that's what you were going for.

Diamond: We were shipping in volume, and I don't think we had military customers or anybody who would be willing to pay the extra freight for a ceramic package. In addition to evolving the 6502 architecture and evolving business model creating this microprocessor IP business, you've also been pioneering at Western Design Center in other areas like education for example.

Mensch: Right.

Diamond: Tell us about your vision there.

Mensch: Well, on the way to education? Can I make a--

Diamond: You can make any numbers of detours that you want.

Mensch: I want to make a detour to another important business model that I've pioneered, the Fabless Semiconductor business model. I have a meeting. GTE's in the meeting. They're a licensee of my 816.

Wozniak's in the meeting. Couple of the guys from Apple are in the meeting. It's at Apple's headquarters, I think, if I recall.

NCR's invited to the meeting. They're a licensee if my 65C02. Rockwell and NCR got together for a CMOS version of the 6500/1 one-chip microcomputer. NCR called it the Austin chip, codename.

Bob Jones, NCR, is there out of Fort Collins. He knows what the meetings about. Bob Jones is sitting right here. Des sitting over here.

This is a who's in and who's out on supplying Apple with 816 chips. GTE-- Des says GTE's in. We're licensed. We're ready go. NCR-- we're not in.

What? Oh, I have to think on my feet. You need two sources, right? OK, AMI, don't they build your custom chips, Synertek maybe, whoever? Somebody?

Yeah. I said you control the quality of those custom chips you put in your systems, right? Yeah. OK, I can retarget my design for that process so they can build based upon your spec, your quality standards, the 816.

I'll be the second source. GTE's the first source. We don't need NCR. That was the birth of the fabless semiconductor model.

And so then Sanyo, a licensee of mine, they are the best ever, quality, great quality. They were supplying wafers, and I don't even think I had to pay for some of them because they were a licensee. They wanted to see that it would run on their foundry, so they were testing, packaging, everything based upon being licensed. So I had a complete second source in Sanyo-- I mean, a complete fabless business model with them.

And so when the fabless Semiconductor Association was started, they wanted me to be on the board of the original charter board. And I said thanks for the invitation, but I can't do it. The reason why is because I don't want Sanyo to even ever think I needed anybody else for my fabless model. So you figure it out, and I'll enjoy seeing your progress.

So I wasn't on the board. I was a member for a while, and I still get their emails and stuff like that. But yeah, I started that, and that was in 1984 I think, about 10 years before the fabless Semiconductor Association was started.

Now, your question, education-- so when you do these things, and you know you want more engineers to be creative, applying the sciences, practical application, engineering is the-- [COUGHS] excuse me. Engineering is the practical application of science and math. Electrical engineers all about electronics, and as a semiconductor engineer, you want to know the physics of the semiconducting materials and how to take best advantage of electron movement in those semiconductor materials. And so knowing that, you'd say, well, wait a minute. If a learner, someone that wants to learn about these things, has the opportunity to use my technology in all of its forms, IP form, we have hardware description language, Verilog hardware description language versions of all of our chips, and then we have the chips themselves.

And now, we just introduced, in October, a board level product that would make it convenient for someone to get started with a USB port from your favorite PC, Macintosh, smartphone-- I call them smart things. Something with a microprocessor I call a smart thing. So I don't want to keep repeating all the different things, so just a smart thing with a USB port, you can power and use as a terminal for our small computers. So we have small computer boards, and we're looking for this “maker revolution”.

I was in a presentation where Wozniak was the original maker, so yeah. Could I go along with that? Probably, but there are lot of people that make their own things just because they want the joy of seeing something they did work. I may be one of those in a specific category called embedded intelligence technology.

There's only one reason you design a microprocessor, and that one reason is to embed intelligence into things. The intelligence is completed when you hook onto it sensors and actuators that will do something with that intelligence and the software, the coding, of what you wanted to do. Whoever is your coder, if that's yourself, making something work, then that's the reason why you design microprocessors, or we just have big boxes sitting on floors with air conditioning units and everything. But the microprocessor is what changed everything for embedding intelligence into things.

So I'm saying in order to learn about this, just like Glen Madland found out that you need to teach about integrated circuits, I have started a foundation, called The Bill and Dianne Mensch Foundation, to support learning about embedded intelligence. So now, I want to say think about it. We all have an embedded intelligence to do what we do as humans, and every living thing has an embedded intelligence. So just that message alone can help the learner figure out what do they want to learn about?

You don't have a USB port. You don't have a port that downloads the information. Maybe someday you might, but right now you don't, and I think you would enjoy picking and choosing from this wonderful world of information that we have at our fingertips with the smart things we have right now. So to me, education has got to be the way of the future for humanity, and if we're in the Information Age, then I think that's to support the Age of Understanding. So I'm all about education. I've been supporting education financially for more than 25 years.

Diamond: Do you see this becoming more and more of the future role of Western Design Center?

Mensch: Well, yeah, I think it's pretty obvious that if we have a young engineer or a young learner, like in fifth grade-- actually, I'm going for the nursery. I want the mother of their baby to relate to the nursery rhyme called Old MacDonald Had a Farm, and I came up with this four years ago in April, four and a half years ago, at an advisory meeting of Notre Dame at Stanford in Palo Alto. I couldn't sleep one night, thinking about Old Man Stanford had a farm, and on that farm, they built a university. And at that university, they learned about embedded intelligence, and with that embedded intelligence, they created exciting or engineering innovations with opportunity for all, E I E I O.

So when the mother knows and the father knows their baby has a wonderful embedded intelligence, what will you do with that? But if they never related to it that way, then there may be a missed opportunity here and there. So that's how far back, that's how deep, this interest runs. So I think that just knowing that, when you program yourself with information, and then what you're going to do with that, processing that information, then the first person that benefits is yourself. And when you get good at something, you'll have more left over for someone else.

Diamond: So when you started this journey that's taken you-- 40 years ago, something like that.

Mensch: Right, 43 years ago.

Diamond: Did you have any idea where we would be today?

Mensch: No, no, no. I knew, working on the microprocessor, 6800, PIA like I said before, I knew this was changing the equation. And I knew, with the 6502 and with Chuck picking the instructions and what our goals were for it-- our goal was to be price competitive with the 4040 chipset, so I designed the 6530. It had ROM, RAM, I/O, and timer on it, and so that was used in the KIM board, keyboard input monitor.

So the code of the 6530 had the key-- it's really machine code monitor's what they say on Wikipedia. So it's a monitor that used the keyboard, so that's why so many people picked up about 50,000 of them, I think, were sold of the KIM I. Very popular single board computer. Probably the most popular. It's probably the most endeared single board computer of all time.

Well, there was also a TIM, teletype input monitor, and that's what I used on the original tester for all of the microprocessors for that first two and a half years and I/O chips. I had little load boards and all this--

Diamond: For testing?

Mensch: Yeah, and a paper tape, and that's why I was talking to the guy that cranks the Babbage machine. He knows all about terminals, and so I want to get a terminal hooked up to my old tester that I have. But anyhow, the point is--

Diamond: And we did a SIM at Synertek.

Mensch: Yeah, you did a SIM.

Diamond: [INAUDIBLE].

Mensch: Right, and so that was a two-chip system. It was a 6530 plus a 6502 was going to compete with the 4040. I don't know that we ever really competed with a 4040 or even tried to. I wasn't in the marketing. That was Chuck and his team. So to me, that was our goal, so we way overshot our goal, way overshot it. So you asked a question, what did I know? I knew what we were doing was seminal. I knew Rod and I had the conversation, at MOS technology in their conference room on the second floor. Rod said if this works as good as we think it's going to work, in his words, we can go to the happy hunting ground-- that's Indian saying for Heaven-- knowing we did something very special with our lives. So that was Rod and me. We knew what we were doing. We didn't know specifics, but we knew what we were doing. And I, in that 1973 December when my first child was about to be born, is when I said to Chuck we could build a home computer out of these chips, and so I knew we could do that. Now, the Apple II, Atari computer, and Commodore 64, VIC 20, the Beeb out of UK-- the Beeb is where ARM came from, so the designers of the original Acorn used a 6502. They're the only people that ever asked me about the Abort feature on my 816 to this day.

Diamond: Well, you'll have to tell us about that.

Mensch: Pardon?

Diamond: You'll have to tell us about-- I'm asking you.

Mensch: What's that?

Diamond: Tell us about the Abort feature.

Mensch: The Abort feature? I had a Prime 500, so I went from the 300 to the 500. That's a virtual memory, and what that means is that if you make a memory fetch, and there's no physical memory there, then you have to abort that fetch and then repair the location. You could either move memory around in the system physically-- it's really a memory management issue with the address bus-- and then retry.

So I figured, well, why don't I just build an abort so if I go, and something says I'm not there, then I don't want to change anything inside of the processor, and then I go off to an interrupt routine that says there's been an error detected. And then I repair the error, whatever that means, and then I retry. That's how I did it, so ARM put it into their processors.

I've never chased them down because they didn't duplicate my 816. They used my idea, but I never pursued them. I talked to some lawyers in Philadelphia because I was an expert witness for Samsung, and they wanted to pursue ARM. And we had a conversation, but whatever.

So this was a long time ago. But anyhow, the idea of putting in some of these features and doing some of these things, it just felt right, and so I wanted to do it. And I did it.

Diamond: So what's next?

Mensch: Well, these boards that we introduced to you at lunch are what, I think for me, is the most exciting thing I've ever worked on, and the reason why is next year, right now, I no longer have to say Apple, Atari, Commodore, Nintendo. We have our own boards now, so now we can work directly with kids, people that want to make a difference. But before, I would always indirectly feel good about the Apple II and how teachers would plug in boards into their… professors control things that they wanted total control. And when you're working with a PC, you've got an asynchronous bus, and you don't have the synchronicity that some people want.

So now, we have that, and we have the I/O to support sensing, processing, communicating as with the USB port on your smart thing, and then actuating, turning on lights, making motors move, and do things you want to do. So it's sensing, processing, communicating, and actuating. That's what we're about. We have an X for our Xcelr8r, we call it X-C-E-L-R-8-R, Xcelr8r. So our Xcelr8r series has-- that X has these letters in the corner of each of the X's.

So we're doing little things because we're proud of what we're doing, and we're going to directly connect with people now. So then I won't be, yeah, the Apple was a great product. Jobs killed it because he wanted to make space for the Macintosh in education. That was a major disappointment for me. I've heard from the teachers and the professors that was a loss for them, and the Commodore didn't replace it, and the Atari never really replaced it.

So now, we're doing it, but we're doing it with one small board at a time. But you're using your smart thing, so we're not trying to duplicate what the smart thing has. We're trying to add to the smart thing. So we want to work with all smart things, not just one or the other.

So we don't need a high-resolution display. That already comes with your smart thing. We don't need to have HD audio or HD video or anything. That comes with your smart thing. What your smart thing needs a way to interface with the real world other than the various wireless connectivity, and so we think we've got the right product at the right time, and we're happy to be there.

And so we're not trying to out-do ARM at anything. We think of ARM as our prodigal son. Got to do what they got to do, and it's not something I want to do, but I'm proud of them. They started with my technology, and I wish them well. I buy their products that have ARMs in them, and that's what we're doing.

Right now, what we're doing is the most exciting time in my career because we can connect with all levels of engineers, people that want to be engineers, people that are engineers, and our technology, because of our various boards we have, can service the kindergarten through post doc, doing something with advanced technology using programmable logic devices. And then when they want to retarget to an ASIC, then they can retarget to an ASIC because of what we've done. So we’ve opened the doors to creativity, one opportunity at a time. But we embrace the category of microprocessors, so that means that we know what it is like to be a leader, and we also know what it's like to be a follower, although I'd say we probably aren't following anybody because we're doing it our way.

And the things like Arduino and Raspberry Pi and Launchpad from TI and some of these other things, they're wonderful. They've got great features. They're very useful. They are used in education. We hope ours are, too.

Diamond: Do you see the maker movement you talked about, and we've talked about previously, as a follow-on to the beginnings of the computer, personal home computer, wave that you started with the 6502?

Mensch: Do I-- what-- the ques--

Diamond: Do you see the wave that you started back in the day as really leading into this new world that we're seeing today?

Mensch: I think so. Did I start it? I don't know if I'd go that far.

I think the technology was available for people that saw that, that wanted to be part of that. That's why Wozniak is somebody that's referred to in this category, because he did something very visible, and out of that grew the world's most valuable company and the most valuable brand. It's no longer the most valuable, market cap-wise, but I think it's still the most valuable brand.

So can things grow that way? Yeah. How many of them? I think only got one of those, but one of them's better than none.

But do I see the Maker-- I think what I'm amazed by is what people do with their creativity. I mean, right now, these smart things that we have, 16 gigabytes on a small thin-- it's like really? I can't wrap my head around that. And so that's an example of saying did I ever think that? No.

Larry, who is my mentor and someone that wrote the code for my terminal interface on my small computers-- when I was designing four UARTs on my 265 chip, he says one UART, two UARTs, maybe three UARTs, but why four? Well, look at what we've got. I said to him you want to interface to a PC, you want interface to a printer, you want to interface to a modem, and you want to interface to a keyboard. Those are the reasons, and that's what I had him design into my Mensch Computer.

So to me, this maker thing-- I'm a maker, too, if you think of my Mensch Computer. I just wanted to have a reference design on how you could do some of these things, so we built that. I only built 100 of them.

But this Maker Movement is very important, and I think it synergizes, or energizes, humanity in a way that's never been done before. And part of it, a big part of it, is the maker movement encoding the smart thing, doing things that you go that plus this equals this, and that's what creativity is. And so opening up the doors to creativity is what we're doing our way, and it's a simple elegance. You add to it. We're not successful until you're successful.

Diamond: Bill, what would you like people to know about Bill Mensch or Western Design Center? And in particular, what is it that we might not know that this would be an opportunity to go on the record?

Mensch: Wow, wow. I've tried to tell you everything in my answers. Well, one thing that has never been talked about-- in 1984, Wall Street Journal, if you know the second first page-- there's two sections-- there used to be two sections. They call it the second first page. In the left-hand column was a technology article.

I got a call one day out of Wall Street Journal, he said I understand you're doing something with Apple or whatever. And I go, well, they use my microprocessors. But what are you talking about? And so I didn't know what he was interviewing me for. And so it was because they were introducing to the market the Apple IIc.

It was timed to the Apple IIc. I knew what the Apple IIc was. The Apple IIe then was retrofitted, or whatever, with the 65C02 because Wozniak said it was 20% faster to do some of the things that they were doing BASIC because of some of the improvements that I made. I didn’t know if it was or it wasn't, but they must have benchmarked it or something. So it was a minor improvement.

So what happened was they, the Wall Street Journal, closed with a paragraph about me, quoting me or saying Apple could build notebook sized computers using our CMOS technology we have in place today. They didn't do that. Nobody was talking about notebook computers back in 1984. They were talking about laptops. They were talking about big boxes, the Osborne or whatever you want to say.

I'm saying but I've said there would be a notebook for schools. That didn't happen. Now, it happens. They call it Macintoshes, but at the time, you can see that power was a big deal. But performing and doing things that the kids could use in a notebook for education-- so I'm quoted in there.

Well, rumor has it that Apple was unhappy with me because that first column was reserved for Apple, but Bill gets his last thing in. And so based upon that, there were professors at ASU and other people saying who's this guy in Mesa? Who is this guy that's getting this-- and I couldn't believe how many more people read the Wall Street Journal. All of a sudden, I'm known.

Prudential Bache calls me and says we want to take you public. I go really? Yeah, could you meet with us at Gold Street, which is right off of Wall Street I think? And so I met with them, and that was probably '84, '85, because of that article. And they want to take me public.

I can still see the front of their building. And I go you really don't know what I'm doing. I don't think anybody knows what I'm doing, actually. But I certainly don't know what you're doing, and so we're like two ships passing in the night. So thanks for the invitation, thanks for the opportunity to talk to you about this, but no, thank you.

I'm happy doing what I'm doing. And I don't know what it would look like if we did what you're thinking because it would change everything for me. I have it made. I'm doing exactly what I want to do. I didn't say, "and I don't need your money," but basically, that's what I was saying.

So when I see ARM do what they do-- people come up to me at conferences and say they stole your ideas. I say what? What are you talking about? Well, they're doing what you were doing.

I go, yeah, but I gave them the idea. I already knew I didn't want to do that, so I don't know what they're going to do with it. But when I had-- at this conference, they had just gone public, and their market cap was $10 billion. Well, how do you feel about that? I go I think it's wonderful.

I mean, I don't want to do that, but the fact that they did it, and the fact that that may have made these smart things that we have in our pocket, the engine for these smart things, then you see the power of the business model. And so I couldn't be more happy about they did it, and I passed on it. I didn't want to do it. I don't need the money. I'm happy.

Diamond: Bill, thank you very, very much.

Mensch: You're welcome.

Diamond: It's been a pleasure.

Mensch: Mine, too.

END OF INTERVIEW

