Interview with Federico Faggin

Silicon Genesis:

Oral Histories of Semiconductor Industry Pioneers

Interview with Federico Faggin

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[Start of Tape: 0:00]

[House tour omitted. Approximately 3 minutes.]

[Start of Interview: 3:12]

RW: This is Rob Walker. Weíre here today with Federico Faggin. Thanks for having us... doing this interview.

FF: Thank you.

RW: So you designed your first computer at 19, can you tell us about that?

FF: Yes. I had... I finished technical high school when I was eighteen years old and I was hired by Olivetti in Borgolombardo, near Milano, in Italy, to a... as a technician. Actually, ëassistant engineer,í I think was the title. I went through some training, about two months worth of schooling at Olivetti to learn about transistors and digital electronics and so on, advanced digital electronics because what I had at school was, sort of, lower level. And then I took on the job of another engineer that was leaving and this engineer was building a small computer and my job was to continue his work.

And basically I ended up learning on the job, my boss was teaching me a bit, and over the course of a year I was able to not only to build the thing but also to do most of the design. In this first computer was a computer with 4,000 bytes of memory and it was a big rack of electronics with many printed circuit boards. As a matter of fact, I have one of the printer circuit boards that we were using in those days. [Holding circuit board]. This is two flip-flops and it has four transistors and all discrete components. And my computer had something like several hundred of these boards in it. Of course, the function of that computer now is in one chip... actually not now, now itís in a *corner* of one chip.

RW: Itís a cell.

FF: Thatís right. Itís a little cell. But this was my first acquaintance with computers and then I went back to university. I went to Padua, University of Padua, and I studied physics because I wanted to really learn more about mathematics and basic physics. I felt that that grounding would be much more useful to me than doing more engineering. And so I did that and then I went back to work again.

RW: Well now when did you go to Fairchild?

FF: Ah, Fairchild was in ... was in early ë68. But before that I was working in Italy for SGS/Fairchild. Which was partly owned by Fairchild. Thatís, in fact, how I got in this country. I got here because I was sent here for supposedly a period of six months and thirty-six years later, Iím still here. Ah, and the... at SGS/Fairchild, I worked on MOS technology. I basically developed their first MOS process technology, manufacturing process technology, in ë67. And I designed two commercial circuits for SGS and then they sent me over here to come at Fairchild R&D as an exchange program and one of the engineers of Fairchild went to Milan, Des Vigell, you probably remember him. He used to be an engineer working in the physics department in R&D of Fairchild.

So we had this exchange program and I started in February, as a matter of fact, working in Palo Alto, not too far from my home now.

RW: Yes, I was over there. I started at R&D in 1966 doing ASICs, what we call ASICs, but when you think about the work that came out of Fairchild R&D... is the seminal work...

FF: Oh, absolutely.

RW: ... of the industry today.

FF: That was the company to beat and certainly, you know, the prime was probably in the mid-60s but even in ë68 it was still the company to beat. I was really very happy to be here, I was happy to be in this area and, in fact, I just had married six months before so we were really, really very happy to be free from, you know, parents and... we were both very young and in love and we were just, you know, having a ball here.

RW: Well now, you developed the silicon gate, the first practical...

FF: Yes.

RW: ...usable silicon gate process.

FF: Thatís correct. Yeah, that was the first project. In fact, when I joined the lab, I was given the choice of two things to do. One was a circuit design, a shift register using metal-gate technology. I think it was a hundred or two-hundred bit shift register. And the other alternative that I had was to develop a process technology using polysilicon as the gate electrode of the transistors. And I recognized immediately the advantages of using polysilicon and I decided... I picked *that* one, even if my heart was leaning more and more, even in those days, toward design.

And so, so I picked that and Tom Klein had done some prior work to show that, in fact, the work function between the polysilicon and silicon would work out in such a way that the threshold voltage would be lower, which was a big advantage in those days because we could not control Qss as well as we can today. But there was there was no way of doing it... in fact, even etching polysilicon... it was not understood how to do it. And so I started from scratch. I started from the basic idea that how, you know, how could one make an integrated circuit using polysilicon. I developed the basic architectural process. I started doing the... I developed the etching solution for etching reliably polysilicon and, using some existing test patterns that were there, showed that, in fact, we could produce workable transistors within a few months... them we started it.

I also invented the buried... what is called the buried contact, which is the polysilicon to silicon contact which was, in fact, later on was the one that allowed us to make the microprocessor so quickly, so soon. Because it would allow to have much more dense circuitry than was possible with metal gate. So, by April we had the basic process technology worked out and then I designed the first integrated circuit to use the silicon gate technology, which was the 3708. It was an 8-bit analog multiplexer using decoding logic. It was housed in a 16-pin package and it was a product that was particularly difficult to do in manufacturing. There was already a product called the 3705, it was in the catalog of products of Fairchild. It was sold mostly to military applications.

And because the ëoní resistance of these transistors had to be very low, they had to be fast, and the leakage had to be extremely low. It was very difficult to make and so we picked that device as a test bed for the technology and eventually, in ë69, we were in production with that in the lab so that became the first, the first commercial silicon-gate technology product, integrated circuit.

RW: And today, essentially every integrated circuit use silicon gate.

FF: Today, itís basically 90% of all semiconductors use silicon-gate technology, derivatives, of course, of silicon-gate technology. About $90 billion last year worth of business.

RW: Now did you get a patent on that?

FF: Yes. Tom Klein and I got a patent on that. I donít really know how... see the idea... the basic idea was, I think, Hughes and then AT&T had done some work also, although nobody has really been able to make workable circuits with that idea. I didnít know anything of that. In fact, I was... I found out later that there had been some prior work and when I joined the labs I was told: ëHey, why donít you, you know, why donít you do a process using polysilicon and then thatís all... and then I started from that basic information, with no more information than that. So I found out later there was some prior art but nobody had really been able to do it, to do it right, to do it, you know, in a workable manner, and itís really this... itís the difference between an idea and something that works.

RW: Had Gordon Moore and Bob Noyce started Intel yet?

FF: No, no. They started, they started as a matter of fact, after I had proven that it was working... we had the 3708 was, you know... came out already and basically they knew that the technology was working. In fact, I suspected they were going to use silicon-gate technology at Intel and I told... I told Bob Sees [?] I remember, in those days, I said: 'Hey, I had a hunch they were going to use silicon-gate technology.' And Bob Sees said: ëWell, if they do that weíre going to sue them.í

RW: Which they didnít do.

FF: Yeah, which they didnít do but I remember that I was a boy from Italy, I didnít understand the ways of the States, so suing was something very strange for me in those days.

[Laughs.]

RW: Well I went to an IEEE meeting after Intel was a little over a year old where Andy Grove was talking about their products. And he made the statement that this proved you could move a process from Palo Alto to Mountain View in less than a year! Which was always what we spoke about...

FF: Yeah.

RW: ... from Fairchild R&D in Palo Alto to Fairchild production in Mountain View but he was referring to *Intel*...

FF: ...to Mountain View Intel...

RW: ... in Mountain View. So I think it was pretty clear that they did take some intellectual property.

FF: Oh absolutely. Thereís no question about that. Of course, you know, the... now Intel would sue you if you even whiffed something... but in the origin of Intel, I mean, itís very clear that the silicon-gate technology, where it came from... and thereís no question about that. As a matter of fact, later on when Des patented the idea of polysilicon to silicon contact--which was my idea at Fairchild--and I found out in ë74 that he actually had patented that idea as Intel. [Laughs.]

RW: But then... so you decided rather than fight ëem, to join ëem, so in 1970 you went to Intel.

FF: Yeah, in 1970 I decided that I had enough of Fairchild. With Noyce and Moore leaving, the new management team coming in, Fairchild was beginning to really have a slow but steady decline. And also my interest was more toward... toward design and I was, you know, getting less and less interested in process technology, although I managed to develop in ë69, n-channel polysilicon devices. I also developed bipolar and MOS in a single... what now is called BiCMOS... we had... I had early BiCMOS devices built in those days, just the beginning of it.

And I also managed to make thin-film transistors using polysilicon material and so... I ... it was a very... particularly creative period of my time and I enjoyed Fairchild Labs but it was time for me to move on.

And so I went to my old boss, which was Vadez, he was my boss at Fairchild as well and he had joined Intel in, basically soon after the... Intel was founded, and I called him up and I asked him if he had a job for me because I wanted to develop in silicon-gate. Fairchild was... was very... you know, still did not have a good silicon-gate technology in production that I could use and so I decided to leave.

And Vadez... Vadez hired me and my first job was to design the first microprocessor.

RW: Yeah, you were doing the circuit design and Ted Hoff did the architecture and...

FF: Ted Hoff did the architecture and I did everything else. The logic circuit, the whole... and also finish off the architecture because the architecture had still some few... few things that were not.... that were not... you know, it was not possibly complete... but it was 95% done.

So when I picked up the project--I did not work for Ted Hoff, I worked for Vadez and Ted Hoff used, in those days to work for Gordon Moore, he was application research.

RW: Right.

FF: So Ted Hoffís job was finished with basically having developed, having proposed the architecture of the 4000 family--what became known as the 4000 family--in those days, it was called the ëBUSICOM set,í the ëBUSICOM chipset,í I mean there was a... there was the... you know, it had no names yet, when I joined Intel. But after having finished the prop... after having proposed the idea and working with Te... with Matsotoshi Shima which was the engineer from BUSICOM, and also working with Stan Mazur, they had developed the basic architecture of the family and my job was to make it real.

When I got in, there was actually much less done than Vadez had told me. I mean Vadez told me that, you know, I mean, pretty much had the... you know, the design... the basic design was done and, you know, what I had to do was to finish it up and, you know, do the layout and do this thing, you know.

When I got in, there was nothing. I mean, there wasn't any struct... there were a few pages of, you know, a description of the thing with the instruction set and a block diagram and that was it. That was all I got and then I was on my own. [Laughs.]

And I was already late six months on the project because for six months they had not been doing anything.

RW: Well they, they didnít have a circuit designer.

FF: No, they didnít have anybody to do... nor a logic designer. I mean the logic design wasnít done.

RW: Well, Intel was at that time was a memory company...

FF: ...it was a memory company. Yeah. So, in fact, I still remember that as I got in, Stan Mazur--Ted Hoff was away--and Mazur gave me the specification and then he gave a bunch of... sort of random schematics which proved to be totally useless later on. But, you now, thatís what he gave me.

So I started reading this thing and then he told me that the next day, Shima would come from Japan to check the work that had been done during the last six months.

RW: [Laughs.]

FF: So I went to pick up Shima at the airport with Stan Mazur and Shima, you know, was, of course, the customer and in a sort of broken English was saying: ëI came here to check. Iím here to check.í

So fine. So when eventually we got into the lab, I.. he says: ëWhat... where is the, you know... what have you done?í I said: ëWell, I came here yesterday. I havenít done anything.í

ëYou havenít done anything?!í You know, he was really mad at me. I said: ëI show you what I had.í

And he said: ëI already seen this. This is just idea. I came here to check. Thereís nothing to check.í

[Laughter.]

And he was really pissed. And it took me at least a week to calm him down. I mean, he was absolutely beside himself because basically six months had gone by and no work had been done. They had been promised the chipset a year from six months before, so now we were already six months late. And Shima was irate toward me because I was the man in charge and so, you know, so I was obviously the culprit, and how come I have done that to them and it was... you know, I could not get it through his head that I had been hired the day before, you know. So that was really hilarious, sort of, and eventually I calmed him down and I said: ëHey look, if you help me, weíll get done sooner. If you want to bitch, bitch, you know, but if you help me we get it done,í and, in fact, he had been quite helpful throughout the process of designing the whole thing, checking in particular that things would work in his calculator, which I have here--I will show you later--and... so that ended up being quite a bit of help for me because I was by myself.

And basically, I was supposed to do four chips in six months... by myself.

RW: Without computer aided design...

FF: Of course, without computer aided design. But I had good pencils with lots of lead. [Laughs.]

RW: Well, the ah... why donít you... you have a photograph there of the 4004...

FF: Yeah, well the... you know, maybe... let me say a few words about the BUSICOM project because it needs to be seen in that context. The BUSICOM project had four chips, one of which was the first microprocessor, the 4004. There was the 4001, 4002, 4003, 4004. The 4001 was a ROM with I/O and it was a 2,000 bit ROM which was, in those days, was really pushing it because also there was a lot of I/O--input/output--electronics around it. There was... there was programmable both... both by.. at mask time as well as by the nature in which it was designed.

Then there was the 4002 which a 320-bit RAM plus output. There was no input in that case, only output... output registers. And then the 4003, which was a shift-register. It was a 10-bit shift-register, serial-in, parallel-out, static shift register so that was a... it was a very simple chip.

And then the 4004, which was a CPU. And the CPU with the instruction set was sort of tailored for calculator applications because that was the intention in those days, was to apply this chipset to make a variety of calculators for BUSICOM. It was an exclusive contract for BUSICOM so it could only... BUSICOM was the only customer. And hereís the result of the effort [holding up photomicrograph of 4004 die]. This is the worldís first microprocessor. Itís a chip roughly 136 square mils, 136 x 136... itís actually... itís not a square but it turns out to be about 136 square equivalent area.

And it has about 2,300 transistors and you can see here the registers, general purpose registers. This is stack for the addresses, the address counter is over here. The instruction decoder is here, all the...thereís control logic all around here and all around here. The timing is over... timing is... let me look at my... yeah, the timing is on this side, and this is the arithmetic and logic unit. So this is... this whole thing, ten years ago, required something like several hundred of these boards to be made and so this is the progress in ten years.

And, of course, in real size, here is the first microprocessor [holding IC chip]. Itís inside here, the package is shown here... 16-pin...and thatís, in those days, 16-pins was religion at Intel. There was, in fact, I wanted to use more pins than sixteen because it would have been faster, but... we lost a lot of performance by limiting the architecture to only 16-pins. We had to multiplex, on 4 bits, address and data... and wasting it all the time... so we wasted about a factor of three in performance in those days by a silly decision to go to 16-pins.

In fact, it took me a long time to convince my boss and, in general, Intel management to go to 40 pins for the 8080. The 8080 was my idea, the architecture, and that was one of the major battles that I had to fight to get Intel to agree that 40 pins was an acceptable package size. At any rate, this is it. This is the first microprocessor. It used to run at 750MHz [kHz] using p-channel technology so there were two power supplies, +5 and -12. And...

RW: Not 750MHz. You mean ëkilohertz.í

FF: Not 750MHz or 75MHz... it was probably... the equivalent would be more like 75 MHz because, in fact, this device could run a little fas... you know, could run more like 1.2MHz but because it was only for one customer, we didnít want to lose any distribution... we were selling 750kHz... everything that was functional.

So that corresponds to between 75 and 120MHz of today...

RW: Oh, I see.

FF: So thereís about a factor of a hundred in performance between 1970 which is this time, and 1995.

RW: Now, I remember prior to even Intel being formed that at Fairchild we were working on a similar design, a four-bit processor...

FF: Yeah.

RW: ...that would be used for a calculator...

FF: Yes...

RW: In fact, Hewlett-Packard was going to be the customer...

FF: Yeah.

RW: ...and... but we could never make the damn thing until... we eventually did and it came out as the ëPPS-25,í but then that was several years after the 4004...

FF: Yeah.

RW: But we were just limited to how much we could... how many transistors we could get on a chip.

FF: That's correct.

RW: And so, Intel had the hottest process around at that time and so I guess the confluence of the technology really drove the ability to put a computer on a chip...

FF: Sure... oh absolutely...

RW: It had been a dream.

FF: Absolutely. I mean, the idea of a CPU on a chip was around since the mid-sixties. When people realize that every few years you could take something that was in a board like this and make it into a chip like this, and then you put many of those in a board, and then a few years later, itís one other chip like this. You know, it didnít take much of that to go on before people realized ëHey, you know, a CPU that requires many boards one day is going to be in one chip.í So the idea of CPU on chip had been advanced since the early sixties and was talked about in the mid-sixties, so it was really a question of *when* the process technology would be mature enough that you could put enough transistors in a chip that were sufficient to create a CPU.

Well, in 1970, the technology to make microprocessors was really available only at Intel because Intel had developed the... they had silicon-gate and silicon-gate was the only way to do it in those days. To do it effectively... cost effectively... because the whole idea was: ëletís make this thing at a cost at which, you know, people are going to use it. If it costs too much, people are going to use the old ways.'

So the basic difficulty in those days to have microprocessors was having a process technology that could actually do it. And then doing it. In other words, designing it, designing in cost... in a matter that was economical so that, again, the minimum number of transistors would be used to get the function done. And then producing it. So that is the task that I performed at Intel, which was reduce an architecture that was done by Ted Hoff, into practice... and make it work.

And that was a job that took about eleven months of real hard work. I mean, I worked anywhere from twelve to fourteen hours a day, partly because we were, as I mentioned earlier, we were late before starting. Of course, I got back the schedule to where it would take a year to get it done. Actually, no, I got it back to where it would take nine months to get it done, so I already lost three of the six months and then it took two months longer than... than we.. than the customer really wanted.

Certainly, I wanted to have a year. Because four chips done by hand in those days was a tall order... to do that in less than a year.

So anyway, so thatís the story behind... I want to show you here the first product that used the first microprocessor. And this is a calculator... this is the engineering prototype than BUSICOM used to debug their product and you can see here--this is the printer by the way, itís a Seiko printer, drum printer--you can see here, if I can do this without breaking anything, you can see here the PC [printed circuit] board, it contains the 4000 family here. Let me take a look... those are the shift-registers, by the way, they were driving... providing the signals for the hammers of the printer and this is the... some transistor drivers for the... for the printer. And that was the only sort of non-integrated portion of the calculator, the rest of it was all done with LSI and the 4004 is *this* one. There were... there was one 4002 here, another one here and the rest of them were 4001s, which are the ROMs. So the program was contained in this ROM, one, two, three, four, and five over here... so five ROMs, two RAM chips, and one CPU and three shift-registers was all that was needed to do a... what in those days, was a high-end printing calculator. Of course, now everything else...

RW: Of course, today itís now one chip and it sells for less than a dollar.

FF: Today, yeah. All this electronics is in a very small chip that, yes, sells for less than a dollar. So this is the... but in those days, this was a major step forward. Although calculators were built routinely using custom integrated circuits so, in fact, what we provided to BUSICOM in those days was the opportunity to create, fast, a number of calculators using the same components so they real value of the 4000 family in those days was not that it could do something that could not be done before--as a matter of fact, that calculator was a little more expensive than if you had done custom circuits...

RW: Yes.

FF: ...but you could have the next calculator done faster and, in fact, over the... the life... there was a short life of the company, the company went bankrupt... but over the two years from ë70 to ë72, before the... before BUSICOM went bankrupt, they had designed a number of calculators and a number of other products using the 4000 family.

RW: But because itís programmable, it could be used as a controller, it could be used as anything.

FF: Of course, yeah, but in those days though, Intel believed that--and Ted Hoff in particular--believed that the 4004 was really only good for calculators. In fact, I was the one that really pushed Intel to go into the market with the 4000 family. The.. Hoff believed that the 8008, which as the first 8-bit microprocessor that Intel did, was very good for, you know, a bunch of applications and so on, and certainly was behind that, but as far as the 4004 and the family, he really was not... believed that is was only good for calculators. And I really wanted that product to be on the market and so I really pushed Intel management.

The first thing that I did was I developed a tester. It tested for the 4004 as a matter of fact, and I used the 4004 as the controller of the tester and so I could show ëlook, you know, this is not a calculator, right? I mean, you know, Iím using the 4004 to do a control function for the tester and itís doing the job and itís doing the job well.í And that certainly got into the ears of Noyce and certainly that was an important event because it turned their minds toward the potential of the 4000 family.

And then I also pushed Noyce to get released from the exclusive agreement that they had with BUSICOM because in those days, BUSICOM was the only company that could use the 4000 family. And so I was in contact with Shima and I knew that they really were hurting because of the cost they were paying for the chipset to Intel and the company was not doing very well. And I realized that if Intel was to give a price break to BUSICOM, they would have a chance to get released, you know, from the exclusivity. And I proposed that to Noyce when I found out that he was going to Japan to visit BUSICOM. Noyce apparently agreed and they negotiated, he and Ed Gelbach negotiated a deal, where basically BUSICOM released Intel from the exclusivity. So that set the stage for announcing that year... toward... in November of ë71, announcing the 4000 family. So thatís how that happened.

Then of course, after that happened, everybody agreed that it was their ideas anyway. [Laughs.] Because thatís the way it works. When something works, everybody thought of it. But, in fact, very early, in... early ë71, Intel cites the 8008 as the first microprocessor and, as you know, that was the Datapoint engine, thatís another piece of evidence that shows that people were thinking in terms of CPU on a chip even, you know, even outside of Intel. In other words, the 8008 was the architecture of CTC--Computer Terminal Corporation--Datapoint terminal. Then later on, the companyís name was changed to Datapoint.

And it was basically a CPU that was supposed to be done using as few as possible MOS chips. And back in the late...in ë69... in late ë69, CTC had visited Intel and Ted Hoff had seen that that architecture was... you know, could actually fit in the chip and so he proposed a single-chip solution for CTC and that project was started... it was started with the name ë1201,í when I joined Intel in April of 1970, the project was already on-going and Hal Feeney was designing or beginning to design, the 1201 which, as I said, later became the 8008. It simply was renamed the 8008.

So, the... as you can see, there were already two microprocessors sort of competing for being first in the market, even at Intel in 1970. In fact, I thought when I joined Intel, that I was going to be second because, you know, Hal Feeney had to design one chip and I had four to design, so you know, guess whoís going to come out first? But then later on, Hal Feeney was moved to doing something else and also the project, you know, was difficult and Ted Hoff was unable to really help Hal Feeney. And so the whole thing kind of got put on ice and then Hal Feeney was moved to work for me, helping me out with testing, test programs, the testers for the 4000 family toward the end of 1970. And then the project, the 1201 project, was resumed in January of 1971 and I was in charge of the project. Of course, Feeney was really the engineer who did all the detailed work under my supervision and I helped Feeney a lot.

In fact, having done the 4004 provided sort of the basic foundation on how to do it because it was not clear how to do random logic using silicon-gate, back in 1970. I mean, Intel had no experience with random logic and nobody had done random logic with silicon-gate. You needed to do things a bit different. For example, one of the first things that I did was to use bootstrap. You know, in those days, you probably remember, bootstraps were very important to get higher voltage and therefore more drive capability and being able to withstand more threshold voltage drop in dynamic circuits. And people thought that you couldnít do bootstraps with silicon gate without having an additional masking layer. But I had figured out a way to do it and I had understood how it could be done without that and so, I brought that technique that I had developed at Fairchild, at Intel. And that was a critical element of, you now, of design that was essential to make the 4004 work in those days, otherwise it would have been hopelessly slow.

So, anyway, thatís a... thatís a long story but the 8008 ended up... the 1201/8008, ended up being finished toward the end of 1971 and was introduced in early ë72 and it became the second microprocessor of Intel.

RW: Yes and that started... that coincided with Wilf shutting down my custom operation...

FF: I see!

RW: ... because people perceived that microprocessors would take over most custom and then TTL MSI [Medium Scale Integration ICs] dropped in price from about $5 to $1 a package and those two... those two items...

FF: Yeah.

RW: ... spelled the end of my custom career until I founded LSI Logic in 1980.

FF: Yes, yes... yeah... as a matter of fact, Hal Feeney went to... to see you guys...

RW: Yes, yes...

FF: ... back in early ë71...

RW: Yes, he wanted to build a silicon breadboard... us to build a silicon breadboard...

FF: Well, actually he wanted... you know, the idea was to see if... if it could be done with Micro Mosaic, not to build a breadboard actually to see if it was possible to you because we had a customer that wanted it right away. Datapoint had vanished, but there was another customer... Seiko, from Japan... they wanted to make a programmable scientific calculator and they wanted to use the 8008 but they were in a hurry and so, you know...

RW: And I looked at...

FF: No but... it... it couldnít be done, I mean it was...

RW: I looked at it and I said: ëNo, I canít do it with standard cell.í

FF: Yeah, there was no way. I mean, it was, as it turned out, the 8008 was able as far as it could go also with a year later technology because it was about 10 mils bigger on a side than the 4004 and the 4004 was already pushing it. Although today you laugh at it, you know, but in those days, 136 mil square chip was a big chip. [Laughs.]

RW: Well then did you... were you involved in the 8080?

FF: I... that was my idea, I mean the 8080. The 8080 was an interesting story because I went to... I went to... with Hank Smith, which used to run the marketing... the first marketing of the 4000 family and the MCS-4 and the 8008, to Europe on the summer of ë71, late summer of ë71, presenting, in anticipation of the announcement we were going to have at the end of November to talk to key customers showing the 4004 and also talking about the 8008 that was supposed to be available in early ë72.

And I visited a bunch of customers, Phillips and... Phillips and Nixdorf stand up in my mind. Particular Nixdorf because Nixdorf in ???born, they were particularly obnoxious to me. I mean they were just very, very... they seemed bitter that we had a microprocessor. I mean, they were really angry that, you know... and they were very critical about it, you know: ëOh, it doesnít do anything and it is bad and, you know, you should have done this way, you should have done that way...

RW: Well, it wasnít as powerful as a minicomputer of the day...

FF: Of course, of course... but there was more to it because I think that they saw that the semiconductor industry was really... with the microprocessor, was really emerging as... in a leadership position that before was the distribution of computer manufacturers like, you know, Nixdorf and Siemens and IBM and so on. So they kind of saw that and they were particularly... they were, you know, I could see there was more to it than just the fact that the 8008 wasnít a particularly good architecture, although it was OK.

On the other hand, I made treasure of some of the comments they made and so on my return from that trip, I came up with some ideas on how to make a much better microprocessor which became the 8080. And I started... I wanted to do it right away but Des didnít want me to ... Grove and, you know, sort of the top brass at Intel felt it was too risky to start a new microprocessor when still, you know, they had not seen how the 4004 and 8008 were doing in the marketplace.

And so it took me a long time, it took me about nine months of really pushing and lobbying to finally get permission to do the 8080 which I did the architecture, the basic design structure and then I hired Shima, from Japan, to work for me to actually do the detailed work. So after Shima came toward the end of ë72, I, you know, for a few months, three or four months, I taught him how to design, you know, and really help him along and then Shima took off. And Shima was very good and he was, you know, he carried the rest of the project mostly, you know, with minimal supervision, of course, I supervised him, you know, closely, but he was mostly by himself...

RW: Hm mmm. Well the 8080 was really the breakthrough part...

FF: The 8080 was the breakthrough part. The 8080 was the microprocessor that made the industry and it did not escape the attention of Intel, in fact, they changed their phone number: the last four digits became ë8080í back in ë74 as a matter of fact. And, it was really the first microprocessor that broke the... the performance barrier. And a lot of that was because it was in 40 pins and it used n-channel technology instead of p-channel technology. It was a better microprocessor, of course, than the 8008 but it was compatible with the 8008, I wanted to maintain the machine code compatibility. And it had more registers... it was a basically... it was a cleanup of the... the 8008, particularly the interrupt structure was quite a bit better because the one in the 8008 was totally useless. It was really useless.

In those days, I didnít understand interrupt structure, nor did Ted Hoff, and the old structure was really a joke in the case of the 8008. But later on, I figured out what really was needed to do an effective interrupt structure and so the 8080 reflected that. Um, so... so the 8080 *immediately* was adopted by the market, immediately opened up all kinds of applications that before were only *suggested* by the 4004 and by the 8008. And it was just the beginning of the microprocessor revolution.

RW: I, I remember being with Gordon Moore when the... it was announced, I think National announced, that they were licensing Signetics...

FF: Hm mmm.

RW: ... with the 8080, which meant that there were something like twelve or fourteen suppliers of the 8080 and Gordon was really upset...

FF: Yeah.

RW: ... and I really think that was the start of the real protection

FF: Yes.

RW: ... attempts to really protect the architecture...

FF: Yes.

RW: ... from others.

FF: Hm mmm.

RW: Because everybody copied the 8080--legally.

FF: Oh yeah. Absolutely. Yeah, including the Russians I found out, many, many years later. [Laughs.] But um, another thing that the 8080 did was the... it began to really create the substance behind the movement that was happening among universities and advanced industries... the movement of young people in the computer clubs, as you remember, toward the microprocessor and this microelectronics revolution that was happening. And out of that *milieu*, the personal computer came out, as you remember.

RW: Altair.

FF: Altair and MITS and those kind of, you know, those kind of machines that were 8080-based and that was there beginning of the revolution that weíre still in...

RW: Also Microsoft, Bill Gatesí first hardware...

FF: Yeah, Bill Gates first BASIC program was based on, you know... was for the 8080. So, anyway, thatís it. Yeah, the 8080 was really, in a way, was at Intel was my biggest contribution from a business point of view. From a, you know, from an *empowering* point of view, my biggest contribution was, of course, the 4004. But the 8080 was the one that created the business.

RW: Now, were you involved with the 8086?

FF: No. I had left already to start Zilog.

RW: Were you involved with the 432?

FF: No.

RW: That was a...

FF: Those were all the Intel *response* to Zilog.

RW: Hm mmm.

FF: Yeah.

RW: Well, the 432, which is a 32-bit microprocessor, was to be the new architecture...

FF: Sure.

RW: ...and... was an utter failure... because it was too slow.

FF: Yes.

RW: It was much too slow and too expensive. And so I was just arriving at Intel about this time...

FF: Yup.

RW: And the 8086 then was clobbered together very quickly.

FF: Yes.

RW: And was a 16-bit 8080.

FF: Hm mmm.

RW: And it would run code...

FF: Yeah.

RW: ... and that was its strength but it was also its weakness...

FF: Yup.

RW: ... because it was perceived as, correctly, as what it was... and it still contained artifacts ...

FF: Yeah.

RW: ... from the 8008...

FF: Yup.

RW: ... as opposed to the 6800 which was a clean sheet of paper design.

FF: Yes.

RW: And, in fact, there were two instructions in the 8086 that were designed for compatibility with the 8080, which were in the initial datasheets which we then *took out* during Operation CRUSH to... so that people wouldnít perceive it as a simple extension... and we needed to reposition it as a leadership kind of product...

Well anyway, in ë74 you started Zilog?

FF: Yes.

RW: What motivated you to start a company?

FF: Well, in silicon valley, you know, you *have* to start a company unless your manhood is going to be questioned right? Well, seriously, the... it was not one reason, there were several reasons. Among them, I had worked very hard at Intel for about... almost five years and I had grown professionally quite a lot. In fact, by the time I left, I had eighty people in my department. I had more than half of the overall R&D of Intel, which at that point was already a large company. It was about... they were... in ë74 they did about $135 million of revenues which was a lot in those days.

So, I had more than half of the R&D at Intel reporting to me. But, you know, I did not have the satisfaction that I was expecting--economical satisfaction--but not having been one of the early guys, I did not have a lot of stock and the company had, you know, a reasonable amount of stock but not very much. And the company was getting too big for my taste and it was getting a little too... Andy was beginning to become the man in charge and there were sign-up sheets where, you know, you had to sign-up if you arrive after eight oíclock, and the environment was no longer the environment that I really liked to be part of.

So I decided that it was time for me to go, time for me to leave, that I could start a company and work as hard and have a lot more satisfaction and having an environment that would be much more to my liking as opposed to having to sort of, you know, to be felt like you were subjugated there. So thatís how I did it.

RW: Well, I noticed that change at Intel in the culture. It used to be that when Noyce was very active in the company, there would be a meeting and Andy Grove would start off on one of his diatribes and Noyce would say: ëAndy, shut-up.í And that was sort of the end of it. So he was able to hold him in check and then as Noyce semi-retired and became vice-chairman, a lot of the decency went out of the company. Because Noyce and Moore are just such... Noyce was and Moore is.. such gentlemen and such, you know, brilliant but people... wonderful people that you would just love to be around. Gordon Moore never says anything dumb. I donít know if you noticed that.

FF: Yeah.

RW: He doesnít say much but whatever he says is either very funny or...

FF: ... very cogent.

RW: ... right on the mark. He will sit through a meeting and not say anything and then heíll make, you know, one comment which just sums it right up. And I really... I really appreciated that.

Well anyway, so you started Zilog in ë74.

FF: Yeah, at the end of ë74, yeah.

RW: And there was no venture capital money to speak of in those days, was there?

FF: No. The industry was just... had entered a recession, as you remember. In fact, that recession lasted for most of 1975 and venture capitals had disappeared from the scene after having overdone it in the late sixties.

As you remember, in the late sixties, there were a rash of electronics companies that had started. Typically things go in cycles and that was a trough of a cycle. But we were lucky enough--and I say ëweí because I started the company with one of the managers that working for me at Intel, Ralph Ungerman--so he and I were the co-founders of Zilog. And when we began to decide what we going to do and so on, was about the same time that we got a phone call from Exxon Enterprises. Exxon, the oil company, had a venture capital subsidiary that was playing in the venture capita... was interested in creating a new possible business for Exxon Corporation for the year 2000 and they had recognized information technology as one of the major technologies that could give the momentum needed for, you know... to have something that was commensurate with the oil business.

And there was an article that appeared in *Electronics News* about ëFaggin and Ungerman leaving Intel to start their own firm,í and it caught the eye of someone at Exxon Enterprises so I got a call. And they asked me if I was interested in some money and I said: ëWell, not really, I mean, we still havenít figured out what we want to do but, you know, if you come around in the area, give us a call and weíll... I certainly would like to chat.í [Laughs.]

I didnít know that that was probably the right way to attract Exxon Enterprises but at any rate, they showed up two weeks later and by that time we had already, you know... we had a more clear idea what we wanted to do. At that time, what I wanted to do was a single-chip microcontroller--what later became the Z8 for Zilog. And so we described what we were interested in doing and so on and we started the dialog and it ended up in their investing in the company in June of ë75. So it took, you know, about six or seven months of negotiation and back and forth but eventually they invested in the company. They put half a million dollars in Zilog which turns out to have been 5% of the total venture capital investment in 1975 in this country. Only $10 million were invested by venture capital in this year... thatís what I read in statistics. Compared to, I donít know, probably a couple of billion dollars last year.

So we started with that money and, in fact, we were in the market having spent about $400,000 of their money having developed the Z80 microprocessor, the development system, and all the software required to really bring to bear the... our new offering. In those days you could do a lot more with $400,000 than you can do today.

RW: Hm mmm. Well, you didnít have to build your own fab.

FF: No. We didnít have to build our own fab, but, you now, but even... even for a design team of developing a system, basically a computer system, all the software, and a chip that was state of the art in those days, it was still a very small amount of money.

RW: What was the reaction at Intel when you left? You said you were...

FF: Well, they were not pleased to say the least, they certainly valued my presence but, of course, you know, I was pretty set to go and there was nothing they could say or do that would change my mind. Andy even... you know... when I left... when I had my sort of ëexit interview,í ...no actually, he was still trying to make me stay but he intimated that I would leave no heritage to my children if I leave Intel... [Laughs.] So it was an interesting kind of a conversation.

But my mind was on creating a microprocessor company. Intel still, in ë74, was a memory company. Microprocessors always were taking second... second best... and I felt not appreciated, frankly, at Intel... so... maybe they did appreciate me but they were certainly not demonstrating that. Although I got promotions, in fact, what I did I ended up working *more* for them and doing *more* for them, so it was not the kind of environment that I wanted to stick around with. So there was no way that they could dissuade me to leave and Gordon tried and also... and I was pretty set and that was it.

RW: Well the Z80 was an immediate success.

FF: Yes, it was. The Z80, believe it or not, is still in high-volume production today. Itís one of the few products that is still enduring... I understand that over a billion Z80s have been built already.

RW: Well, itís a cell as well, or a megacell.

FF: Itís a megacell. Now, of course, you hardly buy the Z80 by itself. You buy it as part of an integrated solution but I would guess that even today there are probably thirty or forty or fifty million units, you know, built a year by many sources. But it was recognized very early that it was going to overcome the 8080. In fact, I have here, looking over my sold stuff, I found this cartoon. It was on a German magazine and it shows the Z80 conquering the bastion of the 8080 and on the background there are the Exxon tanks and oil towers... [Laughs.] Itís kind of an interesting portrayal of what really was going on in ë76-77. The Z80 was the dominant microprocessor and had taken the market by storm.

As I said, still today, itís a major seller. In fact, you have a picture here of the Z80. Thank you. That shows the layout of the Z80 and you can see the... this, of course, is a hand-made design like the 4004 was. But you can see the difference in complexity. The Z80 was about ten times more transistors more than the... ah, no, sorry, five, six times more transistors than the 4004--five years later. And you can see that the, you know, the 4004 is more like, you know, a portion of it. So, it was a sophisticated microprocessor for those days. Of course today itís a joke, itís a little thing compared to a Pentium or, god forbid, the P6 and what have you.

But, of course, there is a time for everything and in those days this was the best that could be done. This layout was done all by hand and I actually drew--my own hands--two-thirds of this. So this is a...

RW: Donít try that with two million transistors!

[Laughter.]

FF: Of course, itís impossible today. Without computers you couldnít design the chips that technology can build these days.

RW: Well, then there was the Z8000...

FF: Yeah, then there was the Z8 and then the Z8000. The Z8 was built... right after we finished the Z80, we started the Z8 project and a few months after that the Z8000. And the Z8000 was a 16/32-bit microprocessor that was supposed to really create the new wave of the industry. And it almost made it but not quite... [Laughs.]

RW: Well, yes, and I was at Intel at that time and the 6800 and the Z8000...

FF: Yup. The 68000 you mean?

RW: The Z8.

FF: No, the 68000.

RW: 68000, yes Iím sorry, and the Z8000 struck fear into the hearts of Intel because the ëgreat leap forward,í the 432, was an utter failure and the 8086 had been clobbered together and was generally perceived as a poor third in... quality and performance.

FF: Well, in fact, even the chip size of the Z8000 was less than the 8086. It was actually a very, very cost-effective microprocessor. It was much smaller than the 68000, for example, in terms of chip area so it could be prod... much more producible. But as history showed, that was not enough. There were other forces playing in the marketplace in those days and whatever happened... no.

RW: What is your take on the decision of IBM to use the 8086? Iíve heard so many different stories...

FF: Yeah, well one factor which is not recognized at all because, of course, things tend to be forgotten and not seen in the proper perspective, is that a lot of the decision of IBM to go with Intel was a political decision--because of Exxon. Exxon had declared war, basically, to IBM. As you remember in ë78, ë79, Exxon went out of the closet parading their companies, you know, Vilo... [unintelligible]...

equipment, Zilog and their ads, you know, on the *Wall Street Journal* and *Business Week* and so on, about the foray of Exxon Enterprises and Exxon Corporation into the information age, and information business. And, you know, sort of ëwatch out, IBM, here we come,í and here are point of attacks into this business.

And IBM wasnít going to give business to Zilog. In fact, they had an internal edict not to use Zilog products *because* of the affiliation with Exxon. So we basically were not in the running because of political reasons, and that is not understood. Intel, in fact, they did not think... they did know they were going to get the IBM order but, in fact, they got it because there was no other way. It was, you know, either Motorola--Motorola was too risky, the chip was too big, it was too new, there was not enough history that it could be producible in volume--or Intel because Zilog was not even to be counted.

RW: Well I also heard that the 68000 was *too* powerful and would have impinged on the minicomputer business of IBMís so that they felt using the 8088, which is kind of crippled, that it wouldnít be too powerful.

FF: Well but also there were issues... you now, a decision is never made because of one reason, right, in general? There were other issues like availability of peripheral components, and because... thatís why they used the 8088 instead of the 8086 early on because Intel was not ready with all these 16-bit peripherals anyway, so they had to use 8-bit peripherals which were already available. The... Motorola had the big mother but it didnít have the peripheral components required, so there wasnít enough to build a computer with, just with the 68000. And so thatís another of many reasons why IBM presumably went with Intel. Of course, you should ask them... [Laughs.]

Although even many of the people that were involved are probably gone, god knows where, even at IBM and so. And the main guy died in an accident...

RW: In a plane accident.

FF: Yeah, thatís right.

RW: Well, there was at that time... there was a group of salesmen, salespeople came to Intel management and said: ëWe are in serious, serious trouble,í so there was started something called ëOperation CRUSH,í and the idea was if we could somehow get the 68000, the Z8000 would be crushed between...

FF: Yup, between, yup.

RW: And there was all sorts of various schemes used in Operation CRUSH... promotions and ads and so many things. But what really proved to be the most effective was Bob Noyce going out and laying out the future of the x86, the 186, the 286 and so while the 8086 wasnít very much, frankly, customers like Olivetti... I know he turned Olivetti around... they saw this road map into the future which would lead to a leadership...compatible... program compatible leadership position and that and then of course the IBM decision swung...

FF: Yeah, that was it. I mean, the IBM decision *was* the ëcrush.í [Laughs.]

RW: Yeah. It would be interesting to speculate had they chosen something else. What would Intel be today? A much smaller company I would think...

FF: Absolutely, Or had we had different investors? Had I been a little more experienced in, you know instead of being 32 years old, if I had been 40 years old when I started Zilog or something... but who cares? The way things went, they went the way they went!

RW: Well then, eventually you left Zilog to start yet *another* company. What was your motivation to do that?

FF: Ah yeah. Well, the motivation was that I could see no way to succeed with Exxon, basically. As I mentioned earlier, Exxon decided--I think they had decided all along there were going to do this but they certainly did not tell me--decided to go after IBM and to create this, you know, huge empire in information of which Zilog was a piece of it. And that was not what I intended. I mean, what I intended was to have a company that would go public and like any other company in silicon valley and be dedicated to one thing, which was microprocessors. But because Exxon had the majority of the stock... in fact, they were the only investor in the company and they wanted to stay that way from very early, and I did not... and thatís one area of inexperience on my part.

I saw some level of danger of that but I sort of wanted to believe that they were going to honor the, you know, the desire of the founders to go public but it turned out not to be the case. So, I grew very tired of that situation. I tried very hard to have them sell their interest in Zilog to other companies for which Zilog was much more of a fit. But they wouldnít hear of it and so after a couple of years of trying, I said: ëThatís it.í I mean, I was spending more time in New York than I was spending in the marketplace. I was basically fighting Exxon instead of fighting you know, fighting the war out there. And that ës how also Intel got it easy because of this internal situation at Zilog that had gotten very difficult to manage.

RW: Similar to Shlumbergerís acquisition of Fairchild. You know, destructive.

FF: I would say that itís one of many examples. In fact, look at United Technologies and Mostek. They managed to destroy the old company. Honeywell and Synertek: they destroyed that company. Shlumberger and Fairchild: they destroyed that company. And I have to say that Iím actually proud that Exxon did not destroy Zilog because Zilog is still alive and kicking and is the only company that has survived this... from the Exxon empire. Exxon had started at least two dozen companies. They managed to destroy every single one of them.

RW: Yes.

FF: And Zilog is the only one that is still alive and still doing products which are Z80s and Z8s which was the early stuff that I did when they company started, so I feel actually quite good about that.

RW: So what was your next company?

FF: The next company was called Cygnet Technologies and the idea behind that company was to create a voice and data workstation for the manager, typically. Because the manager is the person that communicates and wants data/text and voice at his desk. By developing the other half of the voice and data workstation--which was the communication portion. So we developed what was called the ëcommunication co-system,í which was basically in appearance like a telephone, an intelligent telephone, connected with the personal computer , and the combination if the two would give an environment which was a communication environment and computation environment.

For example, I could call you with the co-system in the PC, push a button, and transfer to your PC the screen that I had in my PC, now both of you could talk about what I had in my screen. I could also, for example, create electronic mail, send it to a number of people in the world by timing the delivery that electronic mail would be sent. And the mail would be sent automatically by the co-system using commercial phone lines directly to your co-system.

So you would have a light on on your PC/co-system combination telling you that you got mail, and then you would read the mail, and so on. So, it was electronic mail without a central host computer, done directly, managed directly by each station. It was a very innovative product but it did not go. Basically, we sold 5,000 systems the first year. We needed to sell about 15,000 to really take off. And it was a pity because it was a good product but we ended up introducing the product just a few months after the AT&T was, you know, the de-regulation of the telecommunication industry. Everybody was confused, there were people that did not want to buy anything that was telecommunication. That was early ë84 and so there was a lot of foot-dragging by the people... by our market.. because we needed to sell that as a system and so we needed to sell that to the basic communication guru of a company, or czar of a company, and people did not want to talk to us basically.

RW: Now here in 1995, this is just starting to catch on. So you were ten years ahead.

FF: Yeah. But, of course, you know, it doesnít give you any good feeling to be ten years ahead. The idea is to be just right on time... but at any rate, the product is still in use by... many of the networks that were built with our product, are still using it today because they find it very useful. A very useful... It had, for example, all the software for keeping your calendar. For example, it would beep you when you had an appointment. Supposedly congress said ëcall Rob.í And then I would simply push the button and it would call you automatically because the counter was linked with the directory and it would call you immediately.

RW: Just like today.

FF: Yeah, just like you can do today, and this was in ë84. So it was a very advanced product for the day, both in hardware and software. But, as I said, it was too early and... we almost made it but not quite... we just... we just did not get into the self-regenerative, you know, you have to have enough business that you begin to pay the bills and get enough left over to create the next product and we quite not made it to even pay the bills, so we basically ended up having to sell the company. The company was sold and I started a new company.

RW: So, in ë86 you started your third company.

FF: Yes, called ëSynaptics.í And this company was from the very beginning, intended to be very different than my prior two experiences. The idea was to develop a basic technology first and then take it from there and go to market. But the first six years of the company, myself, and my partner, which is Professor Carver Mead of Caltech, focused our attention to developing basic technology for pattern recognition.

Well, Synapticsí idea was to combine together two emerging technologies that were just beginning. One was neural networks and the other one was adaptive analog VLSI. Let me say a few words about those technologies. Neural networks are basically structures similar to the biological neurons that we have in our head that are appropriate to do tasks that are very difficult for computers like pattern recognition, speech recognition, and writing recognition. All those very difficult tasks which AI--Artificial Intelligence--had promised they would solve ënext year,í and they had kept that promise but ... never delivered.

RW: Itís always ënext year.í

FF: Itís always a promise. So we decided that perhaps there is a way now that.. . sufficient knowledge existed on... although very primitive still...that sufficient knowledge exists on how the brain processes information, that perhaps if we use structures which we know work when it comes to pattern recognition, because *we* can recognize handwriting, and *we* can certainly recognize complex objects and faces and speech. Maybe there is a chance...

The other thing was to implement that structure, we needed a technology that was much more computationally dense that digital and also much closer to the sensory side, which is also analog. And that was the work that Carver Mead had done at Caltech on his silicon retina, his silicon cochlea and so on. And I felt that that technology combined with neural networks could provide a uniqueness for us to go after the market.

But, of course, we didnít know. Both of us didnít know what could be done because the things that could be done in ë86 when I started this company, were very primitive things. Basically we could solve toy problems, we couldnít solve... no real problems. But six years later, with just four or five bright young kids from university... just right out of university... we had enough technology that we could begin to solve real problems and so we started working on our first product which was introduced about six months go... yeah, about... by Fall Comdex last year, which we call the ëTouch Pad.í

And here is our product. [Picking up touchpad.] Itís a... itís basically a touch-sensing pad that recognizes the position of the finger and also the pressure of the finger... this is on one side. On the other side, of course, is the electronics that controls that. Thereís a chip that we have developed which is a mixed-signal device. Analog because, you know, capacitance are [is an] analog entity. And then digital on the other side because computers are digital. So you need both technologies. You need to convert human-generated signals which are analog and continuous into digital which are the signals the computers understand.

There is a microcontroller here which is about a Z80 kind of machine. Itís not a Z80 but itís that kind of class machine, with firmware which is firmware we have developed to do this thing. And basically with this device, you have X, Y and Z coordinates, both absolute and relative, so it performs both as a pressure-sensitive tablet as well as a pointing device. And the first target market is to replace trackballs and track points in notebook computers. And we have been already quite successful. We have already a dozen companies that have adopted these and theyíre just coming out in the market right now.

With this pad, you can move your finger and just tap. And basically you have moved the cursor and activated the, you know, the icon, the window, whatever you want to do. You can double-tap, you can click-and-drag, you can do gestures on it, you donít need any buttons. And, of course, if you are in tablet mode, you can write with your finger or with a pen... we have a special pen which... you can write on it.

For example, you could create a fax and then you sign directly on this pad so that now you can send the fax with your fax/modem with both the text and your signature captured by this device.

You can, you know... we have a brush... that you can paint on it. And the more you press the brush, the bigger the area of contact and therefore, the wider the brush stroke, so that you can actually paint with ... an object like this. Of course, if you want to paint seriously, you need something larger than this. This is just for the, you know, for a...basically as a pointing device and also as an entry device. Like in the far east, people are very excited about this because you can write Chinese characters on it...

RW: Kanji...

FF: And you write one character at a time anyway, so this is all you need for that purpose. So, this is the first application of the neural network and neural system technology that we have developed, and also the hardware technology that we have developed because this device is adaptive. In other words, it tracks the user. If you use this little finger of course itís different than if you use this large finger, and so on. And so, it adapts to the user. It does collective computation and it does parallel computation in order to minimize the effect of noise, because, you know, in your finger you have bout 80 volts at 60Hz if youíre in a room like this and you can only sense millivolts to sense capacitances. And so you basically have a noise problem which is not insignificant and so only through techniques of parallel computation and collective computation can we get reliable signals.

So this is an example of a technology that we have developed. We have much more sophisticated technology, as technology goes. For example, in recognition... image recognition, where you can recognize faces or hands. You can tell where the hand is in a complex picture like a picture youíre taking right now with background things move in... we can tell where the hand is, whether the hand is closed or open... with high accuracy.

We also work in sound and handwriting recognition. He have a handwriting recognition software now for pen entry which is a factor of five better than the best in the business using neural network technology.

So the big.. the fruits of this long labor are beginning to come due now. The harvest is coming... So weíre quite excited about it and the company is just taking off and we should be profitable in a few months and weíre, you know, weíre on our way...

RW: Itís very rare that a startup company can have that long a time horizon.

FF: Yes. I think that without the pedigree of Carver Mead and myself it would have been impossible, you know. Venture capital are not patient guys, as you know. And, but we told them early on, ëlook we wonít spend a lot of money but it will take time,í and we ended up building all this technology for which we have over forty patents, building our first product, and all the technology that we had behind which, you know I have no time to explain... with less than $7 million. And we got another round of financing basically, when we... after the announcement of the first product... of this touchpad.

RW: So how many VCs [Venture Capitalists] do you have? Ah, we have four, five VCs.

RW: Theyíre all local?

FF: Yeah, we have Connor-Perkins, TDI, Sprout, Dolp... [unintelligible]... Venture, and Oak Partners. In the last round of financing, National Semiconductor came in as a major partner because we made an alliance as well so now we also have a business partner as well.

RW: And will they fab the parts for you?

FF: Ah, if necessary. Right now weíre using external foundries but certainly a lot of the reason for this alliance is the manufacturing muscle that they can bring to bear on this. But they like our technology. We have a number of projects that we are working together with where they can develop products around the basic technology that is embodied here and other technology that were not disclosing at this point. So, they themselves are going to be able to develop a number of new products that are enabled by our technology and thatís good. And we are really working very closely together and itís a good relationship.

RW: Well, you started three companies, now. What does it take to be an entrepreneur? I mean, what qualities?

FF: Well, first, lots of physical strength. [Laughs.] If you... you have to have many qualities. The most important one, I would think, is the desire to create a new company. In other words, just the bare desire of doing something new in terms of organizational structure, something that goes after a specific opportunity in the marketplace, some idea about a culture that you want in the company, so this sort of Gestalt and the desire to create this thing. That is the most important aspect of an entrepreneur. Because itís really... itís almost like creating your own family, a new family, you know. You leave a place and you say ëOK, Iíll create a new nest over here.í And you have to have an image in your head of what you want. The type of people that you want...

RW: You get to... you donít have to repeat the mistakes.

FF: Of course, you get to do it better the next time, right? The other thing is that you have to have, and I was not completely joking earlier, you have to have a lot of strength, emotional strength and physical strength because the early years of a company are fun but theyíre also hard work.

RW: A lot of hours...

FF: Lots of hours. And you have to have also a family which is quite supportive of what youíre doing and Iím actually quite happy that my wife has been always supporting me. But certainly one sacrifice that I had to make, and I also had to make but it was my choice, it wasnít their choice, is to you know, not to be at home very much. And so my children could have standed seeing me more often, so that is not something that is good but it goes with the territory. So without a family which is supportive, you know, one would find himself either divorced or would find himself in a trap where one could not dedicate the energy to work at the same time having been unhappy... in an unhappy family... So that is an aspect that seldom goes acknowledged but I think is important to acknowledge because certainly my kid has been very important... my wife Alvia was very supportive of me and has endured a lot loneliness because of that.

RW: I hate to travel.

FF: Yeah.

RW: Thatís what... thatís my big problem. Iíve never been a CEO, never wanted to, because you have to be like the president of the United States. You have to be not only a manager and a leader but then you have symbolic things... and calling on customers...I just didnít care for that.

FF: Itís a very demanding job because it demands... you know, you have to be good just about everywhere. You cannot be a C, a C- student in any subject, I mean you have to be, you know, an A or a B student everywhere and that sometimes is difficult because the world we live in is very complex. You have to be very good in technology, you have to be very good in marketing and sales, you have to be very good in manufacturing, you have to be very good in finance, you have to know how to present yourself, you have to be a good speaker, a good charismatic figure, and all that is not easy to do.

RW: Yeah. Well you also have to be prepared to fail.

FF: And thatís harder to do. [Laughs.]

RW: Are the Japanese... not prepared to fail? ...

FF: Most people are not prepared to fail. That goes with the territory. You try new things, you can fail.

RW: Well thatís why... one of reasons there are so few Japanese start-ups, I think... Well thank you Federico, this has been great fun.

FF: Yeah, thank you... really appreciate going back to the old days... I still remember the days of Fairchild with the big computer clicking on the raised floor and doing not much more work than actually a Z80 was doing twenty years ago.

RW: It was an IBM 360/44 and it was about 0.7 MIPS...

FF: Yeah, unbelievable. I still remember punching cards and feeding this card reader and then fighting every minute with that stupid machine, because, you know, the human interface in those days was so awful.

RW: Yeah.

FF: And now we can begin to, you know, with this thing [trackpad] and with neural networks, we can begin to create human interfaces that are like humans. In other words, here Iím just touching [touching trackpad]... Iím touching a machine basically... Iím brushing lightly on the machine like you would touch skin and we have means of machines looking at me and recognizing me, recognizing if I smile, if I frown. And we have means to recognize, soon, voice and so soon machines will be truly anthropomorphic. They will be able to, you know, to communicate through sensory modalities that in the past were not even conceived possible.

RW: Maybe real people will be able to program their VCRs?

FF: Absolutely, in fact, I kid you not, one of the applications that National is going after is remote television where you basically hold something like that and you move your finger and you basically, with a graphic user interface you do whatever you need to do, you just do that... this kind of movement.

RW: Well I have to get out my... I donít record that much on my VCR. I have to get out my manual...

FF: Yeah.

RW: ...and it takes me about ten minutes.

FF: Anything that has more than fifteen buttons, you know, needs a graphic user interface. [Laughs.]

RW: All right, well thanks, Federico.

FF: Thanks.

[End.]

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