Oral History of Edson (Ed) D. de Castro

Interviewed by:
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Gardner Hendrie: We have Ed de Castro here for an oral history interview today [November 22, 2002 in Mr. de Castro's home in Boylston, Massachusetts]. Thank you very much for agreeing to do this.

Edson [Ed] de Castro: It's my pleasure.

Hendrie: I'd like to start with a little bit of early family history.

de Castro: Early family history. Well I'll start off by telling you, you'll probably notice that I don't have a Boston accent, which generally means that my early childhood was not spent in Boston. Most people, who've analyzed my accent and know, claim that it is most like people from Ohio. And I think there's good reason for that because between the time I was two and four years old, I lived in Ohio. I was born in New Jersey actually, in Plainfield, New Jersey, which is a city which has gone through many ups and downs since 1938 when I was born. At that time, it was pretty much of a suburban community. I didn't stay there very long. By the time I was two years old, as I've already mentioned, we moved to Ohio. My dad was a chemical engineer, and he tended to move from project to project, and as a matter of fact, he went to Ohio to work on the design and construction of the processes in a Procter and Gamble plant. We then came back to New Jersey, by the time I was four years old, and spent a couple of years there. And then two years later, when I was six, we arrived in Newton, Massachusetts, and that was where I grew up and went to elementary and high school.

Hendrie: Did your father work for the same company all of this time?

de Castro: No, his work tended to be project-oriented. He would sign on as an engineer to work on the design of a particular factory or facility. And once that was done, then he'd move on to the next one. During the Second World War, he got himself involved, to some degree, in the war effort, and he worked on a plant which was, at that time, very secretive, and he couldn't tell me much about it. But later on I learned it was a uranium hexafluoride diffusion plant. So he applied some of his talents to assisting us to end up a war.

Hendrie: Did you have any siblings?

de Castro: I did. I have one of each.

Hendrie: Are you the oldest?

de Castro: I'm the oldest. And everybody tells you that that gives you certain characteristics. I don't know if that's true or not, but I will accept the experts' opinion on it. I have a sister who's two years younger than I, and she is currently the Superintendent of Schools in Watertown, Massachusetts. I have a brother who is eight years younger than I am, and he lives in Atlanta, and he is a Professor at Georgia State, teaches psychology. I actually am the most undereducated of my siblings, who both have PhDs.

Hendrie: And the only one who went to a technical field.

de Castro: Yes. That's not quite true. My sister's undergraduate degree was in physics. So she certainly has a scientific background, but has pursued other avenues later in life. My brother originally started out at Northeastern, in a general science kind of background, but after his first year, his freshman year, decided that wasn't where he wanted to go, and switched to psychology.

Hendrie: What are your earliest memories of thinking about what you might want to do when you grew up?

de Castro: I'm actually one of those rare people who kind of knew what I wanted to do when I grew up. I've had the opportunity more recently to talk to a number of counselors and college advisors, and I've been told there were two types of kids in the world, and I'm clearly a third type that they don't know about. But in any event, they've told me that there were two types; one was the type who had absolutely no idea what they wanted to do after they finished their education, and the second one was one who knew exactly what they wanted to do, but would change their mind within a year. I was always one of those kids who liked to mess around with mechanical things. I always had my bicycle apart, I had a model train set, and got into playing with early televisions and things like that. And I was really pretty comfortable with the idea I wanted to be an engineer. And the fact my dad was an engineer probably helped along the way. But that was pretty clear in my mind, it's hard to say exactly when, but certainly by the time I got into high school.

Hendrie: What kinds of courses did you take in high school?

de Castro: Well, I really didn't have a lot of choice in what courses I took in high school. I went my entire twelve years to parochial schools. And in high school, I went to a Christian Brothers high school, and the curriculum was very much college preparatory and was very much set. And you took four years of Latin, which I've come to regard as probably less than the best way to spend my time. I took one year of each of the basic sciences, which I think was a good way to spend my time. I studied four years of mathematics, and the usual courses in history, and English literature, and writing. It was a very standard college preparatory course with no particular emphasis in any direction. It was I think designed with the kid in mind who really didn't know what they wanted to do, but to give them a broad base on which to build going forward.

Hendrie: When you started thinking about going to college, what were your thoughts about what you wanted to do?

de Castro: Well, I knew I wanted to go to engineering school, so it was pretty clear what the usual suspects were... MIT was certainly high on the list. And my dad graduated from MIT, so that obviously made that forefront in our minds. Somewhere along the way though, I kind of got untracked. I applied to MIT. I went and interviewed, and as a matter of fact I had a partial scholarship to MIT. But in looking at schools, I managed to get myself rather attracted to what at that time was called Lowell Tech, Lowell Technological Institute. It's always been a state school, but it's now been integrated fully with the UMASS system and is now called UMASS Lowell. It was a good deal smaller school than MIT. I was

really convinced I would be able to have more attention from the real faculty, and my dad really confirmed that. His take on MIT was that as a graduate program it's the best in the world, but for undergraduates the senior faculty probably doesn't pay a whole lot of attention to the undergrads.

Hendrie: Not very interested in teaching basic engineering but interested in research

de Castro: Exactly. So I guess we, basically together came to the conclusion that going to a smaller school, at least for undergraduate work, would make sense for me. And after, if I decided to do graduate work, then MIT would probably be a good alternative. At that time, Lowell Tech turned out two percent of all the engineers graduating in the U.S., so it was a significant factor in engineering education. Unfortunately, it's become less of a factor as the years have gone on.

Hendrie: So you decided to go to Lowell Tech.

de Castro: I did.

Hendrie: Were there a wide range of engineering choices, or had you already focused a little bit in high school?

de Castro: I had focused a bit on electrical engineering. During my high school years, I worked repairing television sets, which was actually a very fortunate occupation for a seventeen-year-old, because it paid quite well compared to other things that seventeen-year-olds do. So I got rather intrigued with electronic devices, and was able to make a bit of a business out of it.

Hendrie: So you thought you'd do electrical engineering.

de Castro: It wasn't required when I started at Lowell to declare a major in your freshman year. The freshman year was standard for all of the engineering disciplines. The major wasn't declared until your sophomore year. But I was pretty clear that was the direction I wanted to go in.

Hendrie: Tell me about the different courses at Lowell and which ones you really enjoyed.

de Castro: The first year at Lowell Tech was interesting. On the first day, when all of the newly arrived students were gathered in the auditorium and were addressed by the Dean of Students, who was a rather imposing gentleman who gave very much of a no-nonsense kind of presentation, he had a line, which everybody who's been to school who I've talked to in recent years there, remembers. And that was he said, "I'd like you to all take a look at the person on your left and the person on your right, and remember their faces well, because they won't be here next year." The admissions process at Lowell Tech was one where it was fairly easy to get in, but it was also fairly easy to flunk out. And the sophomore class was one-third the size of the freshman class. So there were several courses, probably the most notorious of which was freshman chemistry, which tended to cause a number of students to either withdraw, or not to be allowed to return for their sophomore year, as a result of their academic performance in those classes.

The freshman year was common to all engineering disciplines. You studied mathematics, and at that time, calculus really was not taught in the high schools, so we started off in our freshman year with differential calculus. We also had, as I mentioned, the infamous freshman chemistry course, which was pretty accelerated and pretty tough. We had a similar physics course. We were all required to take an English writing course, which was probably a good thing. I think that has tended to fall by the wayside in some engineering schools, although I believe it's being brought back these days on the assumption that maybe engineers do need to be able to express themselves in writing, among other things. And we had a course which was very unusual to Lowell Tech, but which I found to be extraordinarily valuable, and that was a course called machine tool laboratory. This was basically a course wherein you had to go into a machine shop and make metal parts. You actually learned to use lathes and milling machines and the like, to kind of give these theoretical engineering students an idea of what real hardware was about. And so I thought that was sort of unique, but I felt that very valuable in kind of getting your mindset to be not just theoretical, but a combination of theoretical and practical.

Hendrie: When did you have a chance to start specializing?

de Castro: Well the sophomore year was the first year in which specialization was possible, and as you went through the curriculum, more and more of the courses, as you got into your junior and senior year, were in your field and were elective. And in the sophomore year there was a general circuit theory course which was required for electrical engineers in which you discussed Thevenin's theorem and a whole bunch of things, which I probably can't recite the names of any longer. And then gradually, as I went through my four years there, you got into more and more detailed things, and ultimately in my senior year I arrived at a course called pulse and digital circuits. Well pulse and digital circuits unfortunately at that time was taught with a textbook which only included vacuum tubes. And this was in the late 50s, and while vacuum tubes were still being used, it was pretty clear that the handwriting was on the wall that things were moving to solid-state. But I did not in fact take a single circuit design course which included anything other than vacuum tubes. So I arrived as an electrical engineer, freshly graduated, whose circuit work was all done with vacuum tubes, to arrive in a world where vacuum tubes were fast becoming obsolete. But frankly, I'll have to say that the theoretical background, the mathematical background that I received in school was sufficient, so making that transition was not horribly traumatic.

Hendrie: Did they have a power major?

de Castro: They did. They did have power courses. As a matter of fact, they had a huge laboratory full of generators and, you know, big motors and things that you could get involved with, but I didn't. I headed more towards the small signal kind of electronics.

Hendrie: As you were approaching graduation, what were you thinking about where you might want to work?

de Castro: Well, there was another factor in it all at that time, and that was called the draft. I graduated in 1960, and at that time there was an institution called the Selective Service System, and every young man was required to fulfill a certain military obligation. And there were a number of choices one could make, as long as those choices were made in advance of receiving some type of notice from your local draft board, where they had made the choice for you. And so during my college years, it was normal to

grant deferment, so one was not obligated to join the military as long as one was actively pursuing college studies. But as soon as that was over, you then had to make a decision, and there were kind of three things you could do. One is you could do nothing and it was pretty certain you'd get drafted. Number two, you could continue in school and try to get another deferment, although they got tougher as you got in to graduate education. You could also choose to join some military service, or you could choose to try to go to work for a government contractor who could get deferments for their employees. I was really motivated with flexibility. I did not want to put myself in a position where my job opportunities were limited by a need to work somewhere that could get me a draft deferment. So what I decided to do was to join the Air National Guard and go away for basic training for a period of time, and then be a member of the Reserve component for eight years. And so upon graduating from Lowell Tech, I then, after ninety days or so, whatever time it took me to actually get it organized, went off to basic training and got that completed. That fortunately only required me to spend eight weeks of actual active duty for that basic training, and I was basically done by Christmas.

Hendrie: Where did you do your basic training?

de Castro: In Texas, at Lackland Air Force Base. And basic training, at least from what I understand from my son Dave who just completed his, hasn't changed a bit, <laughs> since 1960. You know, you get yourself in good physical shape, one would say.

Hendrie: Had you learned to fly yet?

de Castro: I had not. And maybe we should back up a little bit on that. During my tenure at Lowell Tech, it was required for your first two years that you participate in Air Force ROTC.

Hendrie: Specifically Air Force?

de Castro: Yes. That was the one they had on campus. And you did not have to continue after two years, you did not have to join the Air Force, but you did have to participate for two years. And I don't know all of the reasons why, but that was the deal. And at that time, the Air Force was looking for college graduates who basically were gonna be fighter pilots. And that that was not uninteresting to me. <laughs>. At the end of my two years' of mandatory ROTC courses, they sent everybody off for a physical. And I came back from the physical knowing what I already knew, which was that I was nearsighted. And they said, "Your physical health is great, but unfortunately we won't accept anybody who is as nearsighted as you are." And I said, "Okay." So that ended my Air Force ROTC career and any thoughts about being a fighter pilot. <laughs>.

Hendrie: So you might have gone and done that if your eyes had been better?

de Castro: I might have, yes. I have a certain interest in flying, and that I think would have been attractive to me, but unfortunately the stars were not aligned properly. <laughs>.

Hendrie: So you went and did your basic training.

de Castro: I did.

Hendrie: Now what happens?

de Castro: Prior to going away to basic training, I had been interested in pursuing an MBA, and I had applied to Harvard Business School. And at that time they were willing to, but not highly motivated to accept people straight out of college. And I think that their attitude toward that wisely, more recently, has changed to one where they just plain don't accept anybody out of college. I think they feel, and rightfully so, that the educational experience they can offer is much more valuable to somebody who's had some business experience prior to that. In any event, when I applied, they said, "Well, we won't take you this year, but we will take you next year. So go do something for a year, and if you still want to come back next fall, do that." So I kind of had that option open to me to go the following September. And I hadn't made a decision as to whether or not I wanted to do that, but in any event, when I finished my basic training, it seemed to me that it was now time to get a job. And so I started looking around, and talking to the headhunters, and all of the usual things that one does to find a job. And I ended up at a little company in Maynard, Massachusetts, called Digital Equipment, which at that time had somewhat less than a hundred employees.

Hendrie: So this is what year?

de Castro: This was 1961, the January 1961. Maybe December of 1960-- January of 1961 let's say. The company had been formed in 1957, so it was three and a half years old. And their business at that time was small, but growing. Their primary business was making what they described as modules, which were basically prepackaged digital circuits that could be used for the construction of various types of digital devices, and to demonstrate the efficacy of those they had built a digital computer of their own, the PDP-1. I joined as a systems engineer. And I don't think they called it systems engineer at the time. I think they called me an applications engineer, which was kind of the same thing, but in modern parlance it's a systems engineer. And my job was to work with customers and prospects to help them to utilize Digital's module products in the most effective way to achieve the design of the products that they wanted.

Hendrie: Going back to the Business School, what led you to be interested in going to business school? That's not typical for a graduating engineer.

de Castro: No, it's not. And I think that I probably, throughout my childhood, always had somewhat of an entrepreneurial bent. And I think I may have gotten that from my mother. My mother was very entrepreneurial and an extremely good salesperson. And while we were growing up, she had various jobs; some on the telephone selling stuff and some out selling china and silverware to girls who were graduating from high school. And my first job was as a paperboy, carrying newspapers. And I soon found that while it was advantageous to just deliver these papers, that it was a lot more advantageous if you could sell new subscriptions, because there were various bonuses and rewards for those who got new customers. <Laughs>. And well, that was an interesting lesson for somebody at ten or eleven years

old, to find that out. Actually just taking these papers and dropping them on somebody's porch, well you got paid for that. There was even more reward if you could sell new business. So I, probably as a result of some of the things I'd learned from my mother, got pretty involved in that aspect of it. And I was routinely always the winner of the sales contests and got my free trip to New York and my turkey every Thanksgiving, and all of those kinds of things. And then as I moved on into other things, I ended up in this television repair job where I worked for a guy who had an electronics store, consumer electronics store. And when he went on vacation sometimes I would kind of run that for him. So I got myself a little bit into some of the rudimentary kinds of business aspects. And I kind of found that I liked the mix of technology and business. And so that kind of led me to believe that I needed to learn more about it. And having a school like Harvard right in my backyard, that was clearly at the cutting edge of business education, it kind of all fell together for me.

Hendrie: How did you go about selling these newspapers?

de Castro: Well, there were several ways to do it, and a lot of it was just sheer work. You just bang on a lot of doors -- cold calling, talk to these people and got them to understand that they used to have their paper delivered, but the previous paperboy used to throw it in the bushes and you had to assure them that the quality of your service would exceed that. But I found that the most important thing to observe were moving vans, because the best opportunity you always had was when somebody new was moving into the neighborhood. And even though the old occupant of that house may not have had any interest, it was much easier to convince somebody who just moved in that they needed to have access to the news of the area. And so it was a pretty easy sell for a new arrival too. So I always was very attracted to moving vans.

Hendrie: Just spot them and then go back.

de Castro: Absolutely.

Hendrie: Did your mother stay at home at some point, or did she work?

de Castro: My mom was educated as a secretary, and she unfortunately grew up in an era when it was not very common for women to go to college, which was a shame because she clearly would have been very successful in any college, and I think could have maybe even had a more fulfilling career. But in any event, she ultimately gravitated toward MIT and got a job working as a secretary in the civil engineering department for a professor, Professor Swaford was his name, who has long since passed on. But he had a civil engineering firm that, among other things, designed the bridges across the Cape Cod Canal. So she was involved in a bunch of his correspondence, and she had a book actually that he wrote about that project. And I don't know where it's gone. I may have it somewhere, or my sister may have it. <Laughs>. But in any event that's how she met my dad. My dad was a student at MIT. Actually he started out at MIT just before the depression, and after two years he had to leave because his parents were unable to continue to fund his education. And so he had to leave and work for a number of years, and then he came back and finished up his education at a later time.

Hendrie: He'd saved enough money?

de Castro: Yeah, so that's where he met my mom.

Hendrie: You said she was sort of entrepreneurial.

de Castro: Yes, well she was a stay-at-home mother, but I think she felt she needed to do more than that, and among other things she wanted some more income. But in addition to that, I think she enjoyed getting out. And she was a person who liked to meet people and to deal with people, and she was very good at selling stuff. And while we were very young, she used to do various types of phone solicitation and selling, where she could be home and do it on the phone. And then later on she got involved with a number of firms who basically sold things to girls who had just graduated from high school and were putting together their hope chest, which I know is now an anachronism, but this was girls who were accumulating sterling silver and china and all this kind of stuff for their hope for marriage. <Laughs>. And she found that the key to that was to obtain yearbooks from high schools. So she would go and purchase a yearbook from as many high schools in the area as she could, and get the names of the girls who had graduated, and have their contact information from the phone book and call them up and make appointments and go sell them this stuff. <Laughs>. So I learned a fair bit. And as a matter of fact, at one time she had a job selling, I think it was advertising; it was either newspaper subscriptions or advertising in newspapers. And she had a long list of prospects to call. And sometimes she'd give me a piece of the list and I'd call some of them for her, <laughs> and try to sell some of this stuff.

Hendrie: So you got some experience then?

de Castro: I did, yes. Yes, I got to learn what it was like to get rejected. <laughs>.

Hendrie: I guess that really is the lesson to learn, isn't it?

de Castro: Hopefully if you learn the other lessons well enough, you can reduce the probability of that <laughs>

Hendrie: But you do learn you can still go back and ask again.

de Castro: Absolutely.

Hendrie: You decided on Digital Equipment. Did you look at any other companies?

de Castro: I did. I'm trying to remember who the others were I looked at. I believe General Radio was one of the ones I had looked at, at the time. And there were several others and I think there was a company called the National Company. I don't even remember what they did. But somehow this whole digital and computer thing kind of intrigued me. I must admit I did not know much about it before joining Digital Equipment, so in some sense it was a bit of blind luck to happen to have fallen into a field that was destined to grow rather rapidly.

Hendrie: Why do you think they decided to make you an offer?

de Castro: Well, you know, I think they looked at me as a fresh out of college, who wasn't gonna get drafted. I mean they were as worried about that issue as clearly their employees were. If they had somebody who was going to get drafted then that wasn't <laughs> going to do them much good. So I had that base covered. They knew I was going to be gone for two weeks every summer for my military duty. I guess they looked at my college grades, and my interview, and my interest in the applications engineering job, which was kind of a combination of sales of technical. I mean it wasn't sales, you didn't go out trying to get orders, but you did interact with customers to help them to make the best possible use of the company's products. And I guess that at that time there weren't too many engineers who wanted to do that. They wanted to get in the lab and design stuff. And that intrigued me. I kind of liked that mix. I did.

Hendrie: That was something you'd almost rather do than get into the lab and just design stuff.

de Castro: Yeah, well I was just out of college and I wasn't exactly sure what I wanted to do, but the prospects of that were interesting to me. And perhaps I conveyed that to them that this was something that I would approach with an enthusiasm. It wasn't punishment.

Hendrie: Did you do reasonably well in college?

de Castro: Yes I did reasonably well. I graduated cum laude, not summa or magna, but cum laude, so I did okay.

Hendrie: Who hired you at Digital?

de Castro: I was actually hired by Stan Olsen, and at that time Stan, who was Ken's younger brother, was running sales.

Hendrie: Was there an applications department already established?

de Castro: Yes, I was actually the third person to join the applications engineering staff at Digital.

Hendrie: Who were the other two?

de Castro: I'm trying to remember their names. One of them was man named Dave Dennison who I've totally lost track of. And the other was a women who's first name was Barbara. I'm trying to remember what her last name was.

Hendrie: They didn't end up being long-term Digital employees?

de Castro: No, not-- I really don't know what happened to them.

Hendrie: What was your first assignment when you arrived?

de Castro: Well, actually what they decided was that before I should actually go working with customers that I needed to get a little bit of experience with their products. And so they assigned me a design project to build a device. And this was basically a remote typewriter terminal to go to a trade show, which would allow them remotely over a telephone line to connect to a PDP-1 computer, and so I needed to build out of Digital modules the interfaces to this typewriter, which would go at the trade show booth and then also to the PDP-1 computer.

Hendrie: Was there a modem involved here?

de Castro: Oh, yes. As a matter of fact AT&T had just introduced a product they called the data phone. And the data phone we now know as a modem. And this was a very high performance device that transmitted data at three hundred baud, over ordinary dial-up telephone lines. And so needless to say, this was not real fast, <laughs> and it was necessary to put things in the interface to cause the computer to wait for the output typewriter strokes until such time as the data channel could handle them. <laughs>. So there was a bunch of synchronizing and things to be done.

Hendrie: Did you have a deadline to do this?

de Castro: Oh, yes. You bet.

Hendrie: When did you arrive there?

de Castro: I arrived in January, and I can't tell you I remember when the trade show was, but we moved pretty quick in those days. <laughs>.

Hendrie: Had you had a course in logic?

de Castro: I actually had not, but I was a pretty quick learner. And there was something to read and there were people to talk to, and one way or another I managed to get myself through it and figure this thing out.

Hendrie: Did you go to the trade show to mother it, or did they just send it off?

de Castro: They just sent it off. And I guess I was on the other end. I was at the home office, and apparently it all worked.

Hendrie: How big was this?

de Castro: Oh, this was pretty big. <laughs>. The modules were packed in nineteen inch racks, and as I recall you could put maybe twenty or twenty-five modules in a rack. And this took up a full rack. <laughs>. So it was quite a bit of stuff. But, you know, each module consisted of maybe one flip-flop or four NAND gates or something like that, so it was, by today's standards, not very dense.

Hendrie: And were they interconnected with pins?

de Castro: There were actually soldered connections on the back panel, so each module plugged into a connector, and then on the back panel there were just soldered wires.

Hendrie: What comes next then?

de Castro: Well, as this was going on, I sort of got enough insight I guess into the company's products that I then began to talk to customers on the phone about various designs, and to sketch things out for them, and send them kind of sample designs of how they might use the modules. At that time, Digital really was not in the business of building systems for their customers to any degree. There were a few exceptions to that, but by and large the mission was to sell the modules to the customer and have the customer do his own design and assembly.

Hendrie: So they had a lot of support documentation?

de Castro: Well I wouldn't say a lot, <laughs> but they did have some. Right.

Hendrie: So the customer could figure out the modules and safely put them together.

de Castro: Yup, yup. That was the theory.

Hendrie: Did you end up selling any customers on a design?

de Castro: Well my job was not really to sell them. There was a sales rep involved, either a Digital employee, or at that time they had a number of manufactures' representatives who were actually soliciting the order. My job was to make the customer comfortable technically with the product, so he understood it and felt he could use it, and when they had problems to help them to get through those issues. So I wouldn't say I sold anything, but I think I probably helped the sales reps to get through some of the technical issues.

Hendrie: How long did you do this kind of thing?

de Castro: Well I had a decision point facing me the following September as to whether or not I was going to continue at Digital or I was going to go back to school.

Hendrie: Did they know about that?

de Castro: No, they didn't. And I hadn't made that decision. Actually I didn't make that decision until probably July or August and so I ultimately decided that that's what I was gonna do. And so obviously informed them as soon as I knew what my plans were, and I clearly hoped that when I got out of school that there might be some opportunities there for me, but I did feel that going back to Harvard Business School would be a good thing for me to do. And so that's what I did. And so I finished up my work at Digital in late August, and arrived at Harvard in September.

Hendrie: It doesn't sound like you were in the middle of some big project.

de Castro: No, I don't think I left them in the lurch in any sense.

Hendrie: What were your thoughts about what you wanted to do at Harvard Business School? Was there a specific area you were interested in learning about?

de Castro: No, I didn't. I'll have to say that my foreknowledge of what to expect in going into a business school was an awful lot less than it was going into an engineering college. And so I arrived as pretty naïve, only one year out of college, with very little <laughs> business experience, student, and ended up meeting people who had liberal arts educations, who'd worked in various types of jobs, and it was just a very broad diversity of people. And I'll have to say much more diverse than I'd ever encountered before, because engineers in a certain sense were all the same. Well, that's not true, but there's more similarities than there are in a business school class where of it's everybody. <Laughs>. And so in some ways that was a rude awakening to find that there were a lot of smart people around who weren't engineers. <Laughs>.

Hendrie: Did you live on the campus?

de Castro: I did not. I continued to live in Newton, which probably was a mistake.

Hendrie: Was this a two year program?

de Castro: It is. It was a two year MBA course. And I started off obviously in the first year and I guess I found it rather difficult for me to adapt to, coming out of an engineering background where solutions to problems were pretty mathematical, and where there was in fact a solution to most of the problems, <laughs> or at least one within some measurable tolerances, and to get into a course of education, where frankly there were not specific solutions to the problems. And virtually all the courses were taught using the case method, where certain cases were presented and during class a discussion was had as to various alternatives and directions and approaches. And there was never any unanimity of opinion as to

what the right thing to do was. And the professor, well he kind of guided the discussion and pointed up all of the dilemmas and possibilities rarely had his preferred answer either. <laughs>. So this was a new thing for an engineer <laughs> fresh out of college. And in addition to that, there was a very high premium on written and oral communication, where one needed to debate and defend one's point of view orally in class, and in writing, in terms of various assignments. And frankly, I hadn't developed those skills, certainly not to the extent that those in the class who had a legal education had already developed them, and many others who had been creative writers, or whatever. So frankly I found it very hard. It was really my first educational experience that I found extremely difficult.

Hendrie: What happens next?

de Castro: Well, the upshot of all of this was that at the end of the first year I ended up with grades which were insufficient to qualify me to return for the second year. And so I went and met with the deans and the professors and tried to convince them that they really ought to give me a shot at the second year, but that didn't work. They decided that I really should not come back for the second year. And so I actually, even prior to figuring all this out, had in looking for summer employment I had applied back to Digital for a summer job, and they had accepted me to work actually in their custom products, special systems division for the summer. And so I went back there, and for a part of the summer I was involved in this appeals process to try to convince them that they really ought to let me back in for the second year. And when that was ultimately unsuccessful, I asked Digital if I could stay, which I did.

Hendrie: To which they said, "Fine."

de Castro: Yeah, well I don't know if they said, "Fine," but they said, "Yes," anyway. They did not say, "No."

Hendrie: There was not a premium on expressive communications.

de Castro: Well, it didn't hurt. No. <laughs>. And I'm sure that despite the fact that I didn't distinguish myself at Harvard in that field, I'm sure I improved my capabilities to some degree. <laughs>.

Hendrie: What kinds of courses did you take that year?

de Castro: The courses were in fairly normal subjects, but in some cases by strange names. For instance, there was an accounting course, but that was called control. And if you've ever studied accounting by the case method, it's a little weird, but I ultimately got the picture. <laughs>. I think they have since changed that one. The case method is clearly a good way to teach some types of subjects, and it's not a good way to teach others. But I think that they were kind of at the peak of their belief in that pedagogical technique.

Hendrie: And they tried it with everything?

de Castro: With everything. And I think now they've kind of gone and said "This is a good technique and we'll apply it where it's most relevant." I took a course in marketing, a course which they called administrative practices, which basically was personnel management and employee psychology, that type of thing, a course in manufacturing and, I don't know, there may have been something else that I don't remember. But it was pretty the normal kind.

Hendrie: What are the things that stuck in your head that you learned there?

de Castro: Well fortunately, I'll have to tell you that, well I didn't know it at the time, with hindsight, I am now convinced that that year I spent at Harvard Business School was the most valuable year of education that I've had. And sometimes having a hard time and not doing well and struggling, I guess can be more valuable to you than doing well. And I think in terms of what I learned, maybe it was because I had to struggle and really work at it, and perhaps it was because it was studying subjects that I really had had no exposure to before, and I guess your learning curve is steepest when you have the least-- when you know absolutely nothing. <laughs>. So from that perspective, it was a great educational experience. I learned a great deal in a number of subject areas that were totally new to me. And some of the concepts were pretty unusual, like in marketing. The professor told us the first day of class that he wanted to make sure we understood that the objective of marketing was to separate the unwary consumer from his loose change. <laughs>. It was pretty straightforward. <laughs>. And he was actually a pretty colorful guy, who was extremely good. <laughs>. The professors there were all extremely good, and they didn't have any lightweights teaching courses there, <laughs> and so a lot of it sunk in. I mean I really did learn accounting by the case method, and while I never became and accountant, knowing how the score is kept is always valuable.

Hendrie: Who was your best professor?

de Castro: I think it was clearly a man named Ted Levitt, Theodore Levitt. And he was a marketing professor, and he wrote a number of books.

Hendrie: He has written some very interesting books.

de Castro: He has. He was very, very good, and very colorful. And I mean some of his, I'm not sure lectures, I mean they were more dissertations on various things, were extremely colorful on particular matters. I can remember one in particular that stuck with me all these years. And this was a class on marketing of floor care products, basically soap for cleaning the floor and stuff like this. And we'd discussed this case at length about how they were advertising it, and how they were promoting it, and what distribution channels they had, and this and that. At the end of the class, he said, "Well," he said, "What do you think the customer's looking for in a floor care product?" And all these people said, "Well they want something that's easy to use, and that's effective, and low price, and yah dah, yah dah, yah dah." And he said, "I don't think so." He said, "How many of you have ever scrubbed a floor?" And everybody put up their hand. And then he said, "Well what kind of an experience was it? Did you enjoy it?" And they said, "No, it wasn't a lot of fun, you know, it was pretty hard." He said, "Yeah," he said, "That's right. So what do you think the customer's looking for?" And he said, "Look." He said, "The customer is looking for a miracle. It is not fun to scrub these floors, and what they're looking for is something which is going to make this easy". He said, "Why do you think it is that every floor care

product you see says, new and improved, on the bottle? It's because the last bottle of it they used was still tough to use." <laughs>. So he had a lot of insights like that into various businesses. I mean he was excellent.

Hendrie: You now are back at Digital. This is a different group.

de Castro: Right. This is the custom products group.

Hendrie: Is this part of engineering?

de Castro: It's actually a separate group that had a major mission, and then kind of a side mission. Its major mission was to build memory test equipment. And I'm not sure I can tell you how they got into that, but they had a significant market share in building test equipment for manufacturers of core memories, that tested these devices at several levels, first off at the individual core level, and then at the plane level, where they'd been actually strung into a plane, and then at the stack level, where these stacks had actually been built up into their final form. And this required some fairly sophisticated equipment to determine the magnetic characteristics of the cores, stand alone, and also in combination with others.

Hendrie: And so they had gotten some contract and worked on it.

de Castro: Right. That was a major mission in custom products. I was never heavily involved in that, although I did get involved in it peripherally when one of the other engineers had a family illness problem and I ended up having to go to Japan to install one of these things. But other than that, I was not really involved in it. I got into kind of the ancillary projects. They were projects that came up that the company felt would be valuable for them to actually take on the design and development of that on a custom basis for a customer. And while they felt their main business was selling these modules, rather than actually integrating them into systems, there was some belief that there were some systems that ought to get done.

Hendrie: You worked for somebody different?

de Castro: I did. I worked initially for a man called Jonathan Fadiman. He was one of these people if you talked to him on the phone, you developed absolutely the wrong image. He was a very short, slim man, who had a voice that sounded like he was eight feet tall. He had a very deep, booming voice. And his father actually was a radio personality named Clifton Fadiman. And obviously he'd been selected as a radio personality based on his voice. <Laughs>. And so in any event, I worked for John initially. He was running the custom products group.

Hendrie: How many people were there in the custom products group at this time?

de Castro: I'd say probably seven or eight people.

Hendrie: So it was again very small.

de Castro: Yes. Just to give you an example of the size of Digital, when I arrived the first time, I think I was employee like one twenty. And when I arrived the second time, I believe I was employee four thirty-four, or four thirty-six, or something like that. So it had grown quite rapidly over that nine month period, but still small by most measures.

Hendrie: Do you remember what your first assignment was?

de Castro: Yes I got sent off to Canada, the Atomic Energy Commission in Chalk River, and they were building monitoring equipment for power plant reactors. And they were going to use a Digital computer, a PDP-4 at that time, and they needed a front end to go on this to input analog signals, and they wanted to do some things which were independent of the computer, because they wanted to have some redundancy. In case the computer went down, they wanted to make sure that certain things could be checked on that front end. And the front end basically input analog signals, converted them to digital, did some limit checking, and passed them on to the PDP-4. And so I was assigned to build this front end as a custom product. And Digital did not have analog capabilities at that time, but we did have a teaming arrangement with a company called Adage at the time, who was in the analog business, and so together we were going to take systems responsibility to put this together, but Adage was gonna supply us with the analog multiplexers and converters for the front end of this thing.

Hendrie: Is this just an acquisition system? There's no control coming back the other way?

de Castro: There was some control coming back the other way, but that was on the computer side. Okay? The piece I was responsible for was just getting the data into the computer. I can remember going off to Chalk River with one of Digital's computer engineers, a guy named Gordon Bell, and he had designed the PDP-4. And at that time, as I recall, the PDP-4 was not yet being shipped, but it was pretty well along in its design phase. And I guess one of the anecdotes actually I remember about that is Gordon was driving, and we were a little late for our flight out of Ottawa. And we were coming back from Chalk River. And Gordon had the pedal to the metal pretty good to make sure we met our flight, and we ran into one of the members of the Royal Canadian Mounted Police. And I had been familiar with the U.S. police force. And this very proper British sounding policeman came up to the car, and he said to Gordon, "Don't you know it's improper to drive at that rate of speed?" <laughs with imitation>. I don't remember what Gordon said, but we were all just so taken aback by the way he approached it. <laughs>. So anyway, I think Gordon got a ticket or something, but we ended up making our flight back to Boston.

Hendrie: So you started working on this.

de Castro: We started working on it, and Gordon said, "You know," he said, "It really is not the best way to do it. It would really be smarter if we built a very tiny computer as a front end processor, to do the work of this custom box that you are starting to build. And once we build this tiny computer then it would have application to other things. We could get some return on our engineering investment rather than doing it all over again for the next customer who wants to do some similar thing."

Hendrie: How far along were you in sketching out the design and all of the logic?

de Castro: I think it was basically on paper. We hadn't built anything, but it was on paper.

Hendrie: So you had the logic diagrams pretty much done.

de Castro: Yeah, it was pretty well thought out.

Hendrie: So you'd done the system design and pretty much the detailed logic.

de Castro: I don't recall exactly the point, but there was a fair bit on paper, let me put it that way.

Hendrie: So you had a good view of what the complexity and cost would be in modules.

de Castro: Oh yes, the cost I had well under control because we had submitted a cost proposal to the Atomic Energy Commission. It was a first cut on the design to understand what was all involved. And so that was pretty well under control. And so…

Hendrie: Do you remember where the cost level was?

de Castro: I think it was kind of in the $50,000 kind of range, is my recollection. There's a lot of engineering, and I'll have to tell you, one of my earliest impressions upon arriving at Digital and looking at the modules and these flip-flops, is I said, "Look at these things." And I'd kind of had some involvement, as I mentioned, in the consumer electronics world just in the TV stuff. I said, "God these things are expensive. I mean this is amazing. How can these be that expensive?" <laughs>. And needless to say, time has kind of proven that they didn't need to be that expensive. So anyway, that was kind of the ballpark as I recall. It was around the $50,000 kind of range for this front end system, which at least I guess was acceptable to the Atomic Energy Commission in terms of the cost of that type of equipment in that day in age. So Gordon came around and said, "You know, why don't we look at doing a baby computer?" And so he had sketched out, together with another engineer he had working with him, a design for a 10-bit computer.

Hendrie: Who was the other engineer?

de Castro: Alan Kotok. And they had this 10-bit machine, which was pretty focused on this kind of data; this front end data acquisition application. And I think it ended up as 10-bits because 10-bits was the analog precision that was required for this particular…

Hendrie: So they felt all the analog values were going to be at least 10-bits.

de Castro: Right. And so that was how this thing worked. And it was pretty limited in terms of its general application.

Hendrie: Was there an instruction set?

de Castro: Oh there was an instruction set. They had proposed an instruction set, and the instruction set, needless to say, was very limited. And so I got hold of this thing and started to think about it. And there were a couple of aspects of it that I thought were inconsistent with it being more generally useful. First off, the established quanta of data, at that point was a 6-bit character. IBM had kind of established that, all of their typewriters and tape drives and what not, process 6-bits at a time. And so it seemed to me that taking something which had 10-bits and trying to figure out how to connect that to a world which was 6-bit oriented was not gonna be very efficient or effective. And so I kind of gravitated toward a 12-bit design, since it would fit better into that world. And that also gave me the opportunity to enrich the instruction set a bit. As I recall, the original design had no ability to call subroutines, which I guess for a dedicated front end wasn't too bad, but if you wanted to get more generally useful, the ability to call subroutines and to return from them was useful. And there were however some unusual aspects of the original design that I did retain. For instance, it had, built into it, the logic for an A to D converter. And there was an instruction that utilized internal registers to effectively do the digital part of an A to D conversion. So all you had to do was attach a ladder network and a comparator.

Hendrie: So there was a ladder network on the end of the register?

de Castro: Right. Well, the outputs of the register were there on which one could put the ladder if you wanted, and its drivers, and the comparator. And there were a few asymmetries in it that made this all work. So that got put into it. And that got retained into the 12-bit design. So I ultimately, and with a lot of help from Gordon and Alan, scaled this thing up to 12-bits and put together an instruction set which was more generally useful, and went back to the Atomic Energy Commission and said, "You know, we have this proposal to you guys, and we're going to stick by our quoted price, but we have another approach to the internal design which we think would be valuable for both you and us, and that is to substitute this 12-bit front end processor, which will perform all the functions, and we'll provide you the software that does exactly what we contracted to do." And they liked that idea. They said, "That's great."

Hendrie: Because they recognized the flexibility.

de Castro: They recognized it gave them a lot more flexibility to make changes. And so they said, "Great, you know, we're willing to accept that as an alternative approach to the equipment, and the price will remain the same." So I went away and designed this thing. I took in so-called standard modules. And there was always a bit of contention in the system between the standard module guys and the people who actually had to use them, because when you <laughs> went to actually design products out of these standard modules, you found that it took quite a large number of them to accomplish what you wanted to accomplish. And you could always see ways to redesign the modules so maybe they weren't quite as standard, but you could use an awful lot less of them and still get the job done. And so I found that I was negotiating with the engineering department on the design of some new modules, which were uniquely suited to the task at hand. So we used some standard modules and we used some not quite standard modules <laughs> to implement the design of this computer, which I was assiduously told by

the management could not be called a computer, and could not be a member of the PDP family, because it was too small and cheap, and they were afraid that that might cheapen the value of real computers. And so it had to be called a Digital controller, or a DC-12. And so we went ahead with that and got the thing built and running. And I actually wrote, in assembly language, the program to do the job we had bid for the Atomic Energy Commission. So it input analog data, compared it with limits, set alarms if it's out of limits, and passed it on to the PDP-4. So I can't say that I'm a software expert by any means, but I did write one working program in my career. <laughs>.

Hendrie: What sort of experience had you had in software and programming? You said that you thought it needed some sort of ability to jump to a subroutine. Where did this insight come from?

de Castro: Well I don't think this was particularly insightful. I had obviously looked at the other Digital computers, the PDP-1 and the PDP-4, and I understood their instruction sets. And I knew how they worked, and I'd talked to Gordon about it, and I'd talked to a few of the programmers that they had. I mean they had two or three programmers at the time who were working on this stuff. And I had just kind of assimilated all of this information, and I guess given some of my own thought processes on how these things might be used in lieu of custom products; that these were capabilities that were pretty rudimentary in terms of being able to sort of reuse it. And while this didn't end up with a very rich instruction set, it did have all of the basics out of which you could get done what you needed to get done.

Hendrie: And expanding it from 10 to 12-bits gave you a little bit of opportunity to think about how you might add something.

de Castro: That gave me a little bit of elbow room to do that. Yes.

Hendrie: Did any of the programmers participate in this?

de Castro: Not initially. Initially this was not a real computer. This was a toy. You know, Gordon believed in it, Gordon understood it. I mean he was very supportive, and he I think had the foresight to see that this was...

Hendrie: This was a good to thing to do, even though they didn't know where it was going.

de Castro: Right. No, it made a lot of sense and he was insightful enough to recognize that. So he was the original brains behind the idea and was supportive of it. I was essentially the engineer who implemented it and added a few bells and whistles here and there along the way. <laughs>.

Hendrie: You said that you had built the assembler for it.

de Castro: No, I did not build the assembler for it.

Hendrie: I'm sorry; you programmed the application, which was what you had built.

de Castro: Right.

Hendrie: And you understood that pretty well.

de Castro: Interestingly enough, there was…

Hendrie: Was there an assembler?

de Castro: Yes, there was an assembler.

Hendrie: Or did you have to do this with ones and zeroes?

de Castro: No, well there were some things you had to do with ones and zeroes. For instance, this did not have a bootstrap loader. And so there was a very brief, I think it was like twelve instruction bootstrap loader that you had to put in with ones and zeroes, using the switches on the front panel. But that was all. And from there you could then load the next level of loader which would actually load the assembler. The assembler was written by a salesman. At that time there was a man named John Kudela, who I've totally lost track of, I have no idea where he might be, who was a salesman who worked for I guess Stan Olsen at the time, selling PDP-1's. And he saw this project and he was fascinated with it. And he said, "I would like to take a vast amount of time, you know, three weeks or something, away from my salesman's duties and write an assembler for this." So he was allowed leave from selling for, you know, a month or whatever it was, and he wrote the original assembler for this tiny computer, and taught me what it was and how to use it. And I then used it to actually assemble the code for the Chalk River application. So I wrote it in assembly language, which was a major step up from ones and zeroes, needless to say. <laughs>.

Hendrie: A major step up in your time.

de Castro: Right.

Hendrie: So it has symbolic addresses, or did you have to put all the addresses in in binary?

de Castro: No, it had symbolic addresses. And what I'm trying to remember is if that was in the first iteration of the assembler. I think there may have been an iteration of the assembler which did not have symbolic addresses, but they came very quickly.

Hendrie: This also had a core memory?

de Castro: It had a core memory.

Hendrie: Now how did you do that?

de Castro: Well, Digital had quite a bit of expertise in core memories at that time. As I mentioned, they had a group that did test equipment for core memories, and they had designed and built core memory for their PDP-1 and for the PDP-4. And so there were a couple of engineers who were very much involved in that. And as a matter of fact, there was a very tragic story associated with that. Probably the lead core engineer was a man, his last name I don't recall, but his first name was Alan. And the lead computer engineer was a man named Ben Gurley, who had designed the PDP-1. And there was some issue between the two of them which I never understood, but Alan ended up shooting Ben Gurley in his home, and killed him. And Alan of course was arrested and convicted, and I assume he's, you know, still incarcerated. I don't know, but it was- I think it was- I don't remember. Was it Bloomfield?

Hendrie: Blumenthal?

de Castro: Blumenthal. That's who it was.

Hendrie: I actually know that it was Alan Blumenthal.

de Castro: Okay, so you know that side of his…

Hendrie: I actually know him.

de Castro: Oh, do you?

Hendrie: Before he went to Digital he worked at RCA where I worked, and he and I had a few interesting run-ins.

de Castro: Okay, I never had any run-ins with him. I mean I worked with him as an engineer on the design of this thing. I mean we never had any-- other than engineering and, you know, he was a competent engineer and so-- but-- and I don't really know the roots of his issues with Ben Gurley.

Hendrie: It was a psychological thing that he probably would be viewed today as a paranoid schizophrenic. And Ben was very kind to him and had befriended him. And then Ben left Digital and went to work I think at another company.

de Castro: I think that's right, yeah.

Hendrie: And Alan fundamentally felt that he had been abandoned and betrayed. Very sad story.

de Castro: Yeah, very sad. Because, you know, I had worked with both of them and, you know, I had no insight into Alan's problems. He was just an engineer was what-- and did a competent job.

Yes. I got bits and pieces of this design from other parts of the company. The company made modules which did various things, and there were core memory drivers which were part of the module family, and there were sense amp parts, which were part of the module family. And so I kind of worked with these guys to integrate all of this into this design. And the original computer, as delivered to the Atomic Energy Commission of Canada, incorporated a 1K 12-bit word core memory. The design of the PDP-5 allowed for a 4K memory as well, so it could be either 1 or 4K. And that was one of the other things that the 12-bits enabled. The original design that Gordon had done was limited to 1K, but by going to 12 bits we could easily move it up to 4K, which seemed more useful to me at that time.

Hendrie: I'm sure proved more useful too in the future.

de Castro: Proved more useful. <laughs>. That is true.

Hendrie: I didn't realize that Digital had sense amps and core drivers in their module line. It sounds like it was the standard product people influencing the module people.

de Castro: Well, there were sense amps and core drivers but I don't think they were modules that were actually listed in the catalog that they passed out to customers. They were there, and if a customer really wanted them they could be made available to them. But they were modules which had been designed primarily to support the computer effort.

Hendrie: Do you remember what sort of integration or change that you made in the modules? It sounds like it's the beginning of putting bit slices onto a module.

de Castro: Absolutely.

Hendrie: That certainly is what happened in other companies that had a module business.

de Castro: The major module that I did the logic for, and prevailed on the module design engineers to actually implement for me, was one slice of the computer. It included 1-bit of the accumulator, 1-bit of the memory buffer, 1-bit of the memory address register, and the adders and logic that surrounded all of those. And this had some mechanical problems, because there weren't enough pins. The connectors that we used were fairly dense. There weren't enough pins on the rack to be able to support all of this stuff coming and going, so we ended up having to put a bus on the back which handled signals which were common to all of them. And so there was some mechanical as well as some electrical design stuff. And my job kind of as the project engineer was to do the basic design and then go lobby with all of the

other people <laughs> to do the other bits and pieces that I needed to actually put it together and make it happen.

Hendrie: Did you have anybody helping you with this?

de Castro: I had a technician who worked with me on the actual assembly and test.

Hendrie: So you didn't have to solder all the connections yourself?

de Castro: Well, the technician didn't either. There was a manufacturing organization that did the actual building of the original design from the logic diagram. The drafting department then turned that into a wiring diagram, and the wiring diagram went to manufacturing, who actually soldered the wires on the back plane, and delivered a back plane, which we then put the modules in, connected up to the power supplies and stuff like that, and then begun on the troubleshooting and rewiring of the back plane <laughs> as troubles were found.

Hendrie: What were the most difficult problems in the design that you recall?

de Castro: Well, I'll have to say I don't remember any real showstoppers. I think it was more there was just a constant series of things that had to be dealt with, as with any design you put together. You know, you put it all down on paper and it all looks great, and then when you put it together there's cross talk and stray capacitance. And <laughs> there are things that don't go as fast as they're supposed to go. <laughs>. And so all of those had to be dealt with.

Hendrie: Noise in the A to D.

de Castro: Oh, yes. All of those had to be dealt with in the usual fashion. That's what engineers get paid to do.

Hendrie: But it effectively worked.

de Castro: At the end of the day it all worked.

Hendrie: Did they initially just build one of these for Chalk River?

de Castro: Well, we built one for Chalk River, and as the project kind of got more notoriety within the company, people began to feel a little differently about it than they originally had. I think that probably it was some of Gordon stirring the pot that the enthusiasm level came up within the management. And they ultimately decided that this thing really was a computer, and it should be given the name of a computer and a member of the PDP family. So it was destined to go to a trade show before it went to Chalk River.

And about a week before it was due to ship, and this thing was at that time called the DC-12, the Digital Computer 12. But they decided that there was gonna be a whole new life for this thing and that it was gonna be christened as the PDP-5. And they had to redo all of the promotional brochures and the literature, and so there was a mad dash to get all of this stuff up to the new name. <Laughs>. And the industrial design was polished up and, you know, different doors were put on the cabinet and it was now in PDP blue. <laughs>. And so all of those things happened. And it went to a trade show. And I don't--to tell you the truth, I don't remember, but it was probably one of the joint computer conferences of the day. And I guess it attracted a fair bit of attention, which then kind of got the company's excitement about it up even more.

Hendrie: Well they had to price it too, didn't they?

de Castro: Yes. It was $27,000.

Hendrie: That's pretty inexpensive. I'll bet a PDP-4 was a lot more.

de Castro: It was. I think the price of course was one of the major attractions. I think a lot of people, particularly with scientific and industrial applications, saw this as being sufficient computer power to do things they needed to do.

Hendrie: I think the Computer History Museum actually has a brochure that predates the naming as the PDP-5.

de Castro: Oh, really?

Hendrie: Yes, a brochure for the DC-12.

de Castro: Great. There was certainly a brochure done for the DC-12. I don't know whether it was ever distributed en masse.

Hendrie: I think it got to Foxboro.

de Castro: Okay, so that's how you got it. <laughs>. That's great. I'm glad you've got one of those. That really is a piece of history worth having.

Hendrie: When did they decide to build a few PDP-5's for inventory?

de Castro: Well, as soon as this trade show was over, there was enough interest in it that I think it was pretty clear that there was gonna be some sales opportunity. And whether or not they actually got built

for inventory or they ended up getting orders first I'm not sure. But manufacturing did get started pretty rapidly on it.

Hendrie: So the Chalk River special project was displayed as the first PDP-5.

de Castro: It was, and as a matter of fact, the Atomic Energy Commission of Canada on, you know, coming to inspect it and see it, immediately ordered an upgrade to a 4K memory, so we never actually delivered the 1K memory to them. So I don't know if there ever were any that got in the field with the 1K memory.

Hendrie: As I remember the brochure for the DC-12, it was even offered in 256 word memory, if you can believe that.

de Castro: Okay. You're probably right.

Hendrie: It may have been 512, but it was very small.

de Castro: You're probably right. But the Atomic Energy Commission people just-- it did not get delivered as a 1K. They ordered and paid for the upgrade to 4K. So it was designed to be 4K right from the get go.

Hendrie: It had room for a 4K core stack.

de Castro: Right, so it was not a huge big deal to upgrade it to 4K.

Hendrie: Switching over to the software side, did the assembler that was written for it actually run on the DC-12 or PDP-5?

de Castro: Well, it was written to run on the PDP-5, but it was developed using the PDP-4, but targeted to the PDP-5. And there may have been an assembler, a PDP-4 hosted assembler that generated PDP-5 code. I'm not sure, but the one I used actually ran on a PDP-5.

Hendrie: What are you supposed to work on next?

de Castro: Well, it turned out that there was enough customer interest in this thing that I ended up getting back to my original profession, which was being a systems engineer. So I started spending most of my time out in the field with customers helping them to understand how to use PDP-5's. And I was still working for the custom products department, but I was spending most of my time out with customers, or dealing with customers on the phone, or one way or another working with customers and getting to

understand their applications. And I also developed a few peripheral interfaces as we were going along, but nothing of any great moment.

Hendrie: Did it initially run with a flexowriter or a teletype ASR-33?

de Castro: An ASR-33. Those had just become available at that time, which was economically a good match, if not performance wise. <laughs>.

Hendrie: Was there any bulk memory like a drum or any kind of tape?

de Castro: Not initially. We ultimately did a drum interface, but I'm not sure whether that ever got actually done to the PDP-5 as opposed to its successor, which was the PDP-8.

Hendrie: What do you remember were added during the PDP-5 era?

de Castro: High speed paper tape was clearly one of them, both punch and reader. And it was all of the analog stuff, which was kind of fallout from the Chalk River job.

Hendrie: So maybe D to A's, as well as A to D's?

de Castro: Yeah. There was pretty much all of that stuff and it was basic.

Hendrie: Contacts and dry contact inputs?

de Castro: Exactly, the discreet ins and outs and some of that kind of stuff.

Hendrie: So it continued to be viewed in applications as a controller?

de Castro: Yes. Yeah, its applications were I'd say totally industrial and scientific. One of the applications that it soon got into was pulse height analysis.

Hendrie: What's that application?

de Castro: That's an application that's used by atomic physicists to determine the energy spectrum of radioactive decay. And you basically look statistically at the energy value of a series of decay indications, and use some piece of instrumentation which gives you an electrical signal which is proportional to the energy in the decay event. And you convert that to digital and put it into a histogram and you effectively generate a histogram that shows the shape of the energy values in the decay of this particular element.

And so that is one of the other things we interfaced. We interfaced a Techtronics-- I guess it was just an X Y plotter, so we could display histograms.

Hendrie: Was there a particular piece of equipment for detecting the pulses?

de Castro: Yes. Yes, there was some instrument manufacturer that manufactured the analog piece of this thing. And it basically output a digital value which was representative of the energy in this pulse. And we input that digital value and did the histogram generation.

Hendrie: Do you remember the dates when the DC-12 was built and when it metamorphasized?

de Castro: I went back to Digital in September of 1961, and my recollection is that we were in Chalk River, the original visit, in the winter of 1961, and then begun the actual design of the equipment shortly thereafter. So I'd say that the design begun in early 1962. And I'm not sure exactly when we began the delivery, but it was probably the latter part of the year, I would say maybe the fall of 1962.

Hendrie: So you had probably done the preliminary design of the original bit in either late 1961 or early1962, and then you swapped over the design for what you actually delivered in 1962 and built it then?

de Castro: Right.

Hendrie: And delivered it late in 1962?

de Castro: Yeah, late1962, early1963, that general time frame, I-- that's enough years ago that I don't have a detailed <laughs> memory of it.

Hendrie: When you go back and you're working with the customers, you're physically working in custom systems?

de Castro: I was officially assigned to that, although I really was not doing any of their work. The reality is that the majority of my time I was spending as a systems engineer and working with customers on the application of PDP-5's.

Hendrie: Was there a group in Digital that did that for the PDP-4? Probably you were still building the PDP-1 at that time.

de Castro: I think the PDP-1 was down to one customer. They were basically building those for AT&T for what today's called a router, and this huge thing which basically routed telegraph messages. And other than that, I think virtually all of the new customers were buying PDP-4's.

Hendrie: Was there a group that did what you were doing with the PDP-5 in the PDP-4?

de Castro: I think there were some people who did the PDP-4, but I can't tell you I know there was absolutely a group. Clearly somebody talked to customers about PDP-4's.

Hendrie: Somebody had told me that Dit Morse had had some involvement in the DC-12.

de Castro: Dit Morse was responsible for software development at the time. And he was doing primarily PDP-1 and PDP-4 software. And he had several programmers who worked for him. I don't know if he did any PDP-5 software or not. He may have somewhere down the line.

Hendrie: So he was not directly involved?

de Castro: He was not involved in any of the hardware side. He was a software guy, and he may have done some software for it.

Hendrie: You're now doing these applications and spending your time trying to help customers. You said pulse height analysis was an early one that people used this 12-bit machine for. Were there other interesting early applications that you happen to remember that were interesting enough so you do remember?

de Castro: <Laughs>. Oh, unfortunately I'll have to say I don't recall any right now. Some may come to mind as we go along, but I can't think of them right now.

Hendrie: I know that Foxborough became interested in the machine and did start using them in some process control applications.

de Castro: Yes. Right, and that's how we originally met of course was when you were at Foxborough. Did you actually use PDP-5s, or were they PDP-8s by the time you used them?

Hendrie: I believe we actually used some PDP-5s, but my memory is not wonderful, so I would not swear to it. I remember our software people and the people who looked at applications became interested at the DC-12, and we went back and talked to, I think it was Harlan Anderson, about the possibility of buying the DC-12 machine. And we heard that Bell Telephone Labs was also interested.

de Castro: Yes, I don't recall Bell Labs. Yeah, but it well may be.

Hendrie: I remember distinctly that they were, "Oh this is interesting. We didn't expect anybody to be interested, but you're interested and Bell Labs is interested."

de Castro: Right, well that was kind of what was going on was…

Hendrie: Just more and more people getting interested, and that's what pushed it over into becoming a standard product.

de Castro: Right, exactly.

Hendrie: How long did you work on this applications side?

de Castro: I did that for say maybe eighteen months. And at that point, it became clear that not only was there a market for this product, but there was also opportunity to significantly improve the product, and to cost reduce as well as to improve its performance. And so I then went back to designing the upgrade for this, which ultimately turned out to be the PDP-8. And in the meantime, Digital had changed the mechanical format of their standard modules. Originally the modules were designed to fit in a five and a quarter inch rack, nineteen inch wide, five and a quarter high. And they were some height slightly less than that, maybe five inches for clearances, and they had a depth of maybe seven or eight inches. And they had an actual physical connector which was riveted to a frame and a printer circuit board, and they then plugged into a back plane. Well in an effort to cost reduce that, they had designed a new set of modules which were called flip chip modules. And those modules had the characteristic that they were only half the height of the original ones, and they had as a connector a gold-plated fingers which actually plugged in. And they were somewhat higher density than the older ones and they didn't have this aluminum frame around them. The flip chip nomenclature was based on the plan at that time to build hybrid integrated circuits along the lines of something IBM was doing, which they called flip chip, in which you would take the actual semiconductor dye and put solder balls on it and flip it over and solder it to this ceramic substrate. And so the plan was this new line of modules was gonna be totally made out of these hybrid integrated circuits. And Digital had a program going to actually manufacture these things. In my mind at the time I couldn't convince myself that I could really count on these things. But I was told, at the highest levels, that I was to design this computer to use these flip chip modules and I was not to worry about their availability.

Hendrie: And that didn't keep you from worrying about it.

de Castro: That did not keep me from worrying about it. I used to visit these guys who were designing this thing on a daily basis <laughs> to see how progress was coming. I went ahead and designed this thing to use these modules. I kind of felt I needed some backup. And there were a couple of areas in which I could have backup. There were some very basic modules which had a couple of maybe a couple or four NAND gates on them. And as backup, I could design boards which just had discreet components on them, all of which would fit on that board which would do everything that the hybrid integrated circuits were allegedly gonna do. So I designed a few boards which kind of mimicked these things, and I told them this was for test purposes of course, to make sure…

Hendrie: You could get them actually done.

de Castro: Well, just for test purposes to, you know, we got advanced. I did though have some problems, because one of the boards we designed was a very dense register board which had this slice of all of the registers on it. And it was fairly complex. And unfortunately, there was no way I could fit enough discreet components on it to take the place of these hybrid integrated circuits. These hybrid integrated circuits were ceramic elements which were designed to mount on edge on the board so that they projected up vertically and thus didn't take as much horizontal real estate. And well this worked fine as long as I had those. If I didn't have 'em it was gonna be trouble. I took in a bunch of the discreet components it would take to mimic one of these things, and kind of soldered them together in a <laughs> funny way. And I took them over the model shop and I said, "You know," I said, "I really don't want to get behind on my test schedule for this thing, so if you guys could go and make a few of these things out of welded components, if you could take these little components and go get them welded so they were mechanically strong." The soldered things I had made were, you know, not really fit for prime time. They sort of worked. So they went out and got some welded cordwood kind of modules and stuck them in these little plastic cases, <laughs> which were there strictly for backup and test purposes. <laughs>. And we ultimately built the first version without a single hybrid integrated circuit. Meantime, the hybrid integrated circuit thing was not going well, at least in my view, although I was told not to worry. That was not my thing to worry about; that others would produce these things.

Hendrie: Where did we leave off? You were telling the story you had gone through the cordwood modules.

de Castro: So we, you know, took a bunch of these cordwood modules and populated the boards and built up the system, and got it debugged with all the usual engineering <laughs> problems that always happen in debugging. You know, there was noise in the sense amps and there were a few logical issues, and the this and the that. But it was just normal engineering stuff, and ultimately got through it. And so we were pretty much ready to announce this product and put it into manufacturing. When, I guess Ken pretty much came to the conclusion that these hybrid integrated circuits, if they were gonna work they were gonna be so damned expensive it wasn't worth doing them. And so we were then left with the question of how are we gonna build this thing? <laughs>. And so I took this very complex board to one of the best board layout guys, a guy named Norm Perryman, and company. And I said, "Norm," I said, "I know that it's virtually impossible to fit all these components on this board, but why don't you take a shot at it?" And so he struggled with it for quite a while, but damned if he didn't get them all on. <laughs>. And so we ultimately managed to build these boards using conventional discreet components.

Hendrie: Without even the cordwood?

de Castro: Without the cordwood, yes.

Hendrie: These are still two layer boards?

de Castro: Yes, still two layer boards. Yes.

Hendrie: Were your bit slice boards extra?

de Castro: The module concept allowed for different heights of boards, so they could be single height or double height or presumably quad height, although we didn't have any quad height, we had only singles and duals. The bit slice boards were dual height.

Hendrie: So you had a little bit more to play with?

de Castro: Well, no. We had exactly the same amount to play with as we did in the PDP-5, because a dual height was the same. We had, as you mentioned, double sided boards available whereas in the PDP-5 they were only single sided. So, you know, technology was moving on.

Hendrie: Was this original prototype that you built with the cordwood in the same form factor as the PDP-8?

de Castro: Yes.

Hendrie: So you had already figured out the mechanical pieces.

de Castro: All the mechanical…

Hendrie: Without how to do the…

de Castro: Put those wings, yes, so they swung open and all that, as you can see right there. <points off screen> So it was all tested exactly that way**.**

Hendrie: So part of the project had been to work on the mechanical design?

de Castro: Oh, absolutely.

Hendrie: Were there any problems in getting people to agree to go and redesign this?

de Castro: No, it was really a cost performance technology upgrade. There weren't a lot of issues that used the same software as before. And there was really not any opposition to the PDP-8 project. I think most people were pretty excited about it. And in essence, I think the PDP-5 kind of got lost in history, and the PDP-8, in many people's minds, was the original of the 12-bit machines.

Hendrie: I know that's true. I've seen people that don't know about the PDP-5.

de Castro: Yes, right.

Hendrie: And I think that's one of the interesting stories of how these things really happened, as opposed to how people imagine that they happened.

de Castro: Exactly. I think the PDP-5 kind of conditioned the market, kind of got things rolling. And then the PDP-8, at a lower price point and higher performance, dropped into that basically prepared marketplace.

Hendrie: And to some extent the existence there that you could do it and it did work and there were people interested.

de Castro: Yes, sure…

Hendrie: It would have probably been very hard to do the PDP-8 from scratch.

de Castro: That's right. I think it would have been very difficult, but given the background of all that, it was not difficult at all. It was very well supported. The major, I would say, management problem was with the flip chip hybrid integrated circuits that they were on a track which didn't work. <laughs>.

Hendrie: Were you still working in custom systems when you did this?

de Castro: Well, you know, one of the funny parts of all this is during my entire tenure at Digital I never worked for the engineering department. During the PDP-8 phase I was working still in the custom products, during the PDP-8 design phase. Shortly after the PDP-8 was designed and introduced, and it was clear that it was significant, the customer interest in it, Digital decided to reorganize in to product lines. And the product line manager for the PDP-8 was a guy named Nick Mazareese**.**

Hendrie: Where did he come from?

de Castro: He had been working in the sales and marketing organization. He had a technical background. He was, you know, technically savvy. But he had been working for Digital, and he worked for Stan Olsen in a sales marketing role, and I'm not sure exactly what it was, but anyway, he then became the product line manager for the 12-bit machines. And so I ended up then working for him. And I think he continued to report to Stan Olsen, but I'm not a hundred percent sure of that. That may have moved at some point.

Hendrie: Who had you worked for in custom systems?

de Castro: I was nominally working for John Fadiman, although John at some point left, and was replaced by Pat Green. And I don't remember exactly when that was. The reality was that my reporting relationship to custom systems was not real. I mean it was kind of administrative.

Hendrie: You had to be in some box.

de Castro: I had to be in some box, but the reality was I was kind of alternating between computer design and systems engineering.

Hendrie: So you'd do a little bit of one and then come back.

de Castro: Exactly, so after the PDP-8 they were up a larger number of interfaces that were done. We did an interface to a drum and we did an interface to a tape drive. I think there were probably more, in addition to all of the things that had been in the PDP-5.

Hendrie: Which you of course had to redo.

de Castro: Because it was a different format…

Hendrie: Were there any other real challenges? Did you have any trouble with the core memory in the PDP-8? Do you remember what the performance was of the PDP-5s memory and the PDP-8s memory?

de Castro: The 8 I believe was a 1.2 microsecond cycle I believe. I believe the 5 was maybe two and a half, something like that. So it was like a factor or two improvement and it was a smaller core. I don't recall any showstoppers. I mean I know there were always issues around the memory, and they were mostly noise issues and packaging issues.

Hendrie: And you had a memory engineer.

de Castro: Well, at that point I had learned enough about the memory so that I was into it pretty heavily myself. But I also had another circuit engineer, a man named Dick Sogge who was helping work on primarily the analog circuitry, the memory related stuff, but some of the digital stuff for the PDP-8.

Hendrie: So you had acquired him when you came back.

de Castro: Well he worked for the engineering department.

Hendrie: He was loaned out to you?

de Castro: Yes, he had a number of projects and, well one of my roles was to kind of enlist the resources I needed to get this thing done.

Hendrie: It was sort of an entrepreneurial company, wasn't it?

de Castro: Yes. I mean that's the way it worked, and I did a lot of it myself, but there were some things that I couldn't do and I had to get the guy in the model shop to make my cordwood, and I had to get Dick. I mean they were resistive, but they had other things and so you had to kind of get the stuff pulled together so it all came out and worked. And so I'd say, on the memory, Dick helped me a lot with the circuits, the sense amplifiers, the drivers, and all that stuff. But I'd learned enough about memory at that point that I could kind of know where the issues were.

Hendrie: You might be able to figure out what the problem is.

de Castro: Exactly.

Hendrie: Did you do most of the logic yourself?

de Castro: Yes, I did all the logic design. And it was pretty well integrated with the memory design as well. The registers for the memory were in these bit slice modules and stuff like that. So it was a pretty integrated design, although there was help on some circuit stuff.

Hendrie: What about the software for this machine? Had anything more than just the assembler been done for the PDP-5?

de Castro: Well, we ultimately did a basic interpreter, and I don't think that happened on the PDP-5. I think we were into the PDP-8 by the time that happened. But it's a little hard for me to draw the exact time boundaries on all that. One of the more interesting, I think, software things that happened with the PDP-8 was that I believe it was Nick Mazareese, but I could be wrong, ultimately identified an opportunity to apply this to typesetting. At the time, newspapers were using linotype machines, and there were all kinds of union problems. The typographers union was requiring that newspapers set this type by hand. If they used a linotype machine then throw it away. And it was cost wise very, very prohibitive. And with the arrival of computers and photo typesetters, which were basically things with lots of fonts in them and flash tubes which allows you to basically set this type on film, you needed computer support for those which would select the types and the fonts and the hyphenation and all this stuff. And so there was a very young programmer who had arrived named Henry Burkhart who was assigned by Nick to develop this software for typesetting. And so that became a very interesting market for that product, and ended up selling it to a lot of newspapers, who replaced old technology. And this was very interspersed with a lot of labor issues. <Laughs>.

Hendrie: A lot of the economic benefit came because there were labor issues.

de Castro: Exactly, and-- but it finally got to the point, the technology finally got to the point where they just plain didn't need the labor at all. <Laughs>. And that solved the problem. But there were a lot of strikes, and Henry had a lot of stories when he was in installing these things in various newspapers <laughs> about things that were going on from a labor point of view.

Hendrie: So he wrote code for the PDP-8 at this time?

de Castro: Yes. It was the PDP-8. It got started with the PDP-8. I don't believe there was any activity on the PDP-5 on that.

Hendrie: Did anybody do FORTRAN?

de Castro: There ultimately was a FORTRAN, but I can't remember what its time sequence was.

Hendrie: When was the PDP-8 done?

de Castro: I believe it was introduced in 1965, is my general recollection. I may be wrong on that. It may have been 1964, 1965.

Hendrie: I have a suspicion 1965 might be right.

de Castro: Okay, that's plus or minus a year. <laughs>. It's hard for me to recollect this far out. Yes.

Hendrie: Can you think of any stories about the PDP-8 when it was put together? Who did the industrial design for the PDP- 8?

de Castro: Well Ken was very involved in everything mechanical and industrial design. But there was an industrial designer, and his name was Scott was his first name. I do not recall his last name, although actually if we go look at that picture I think he may have signed it, because that was his sketch. And it was a combination of this individual who was a pretty talented, artistic kind of an industrial designer, and Ken, who was very involved in a lot of the mechanical details. The glass panel with the lights behind it was a Ken Olsen idea. And so it was kind of that interplay of the two.

Hendrie: So a little bit of everything.

de Castro: Yes.

Hendrie: What did you do after you developed the PDP-8?

de Castro: Well, I did the usual thing. I went back to systems engineering, and went out and spent time with customers. <laughs>.

Hendrie: Every time I hear of an engineer who designs products, who likes talking to customers, you usually discover there's a good product there.

de Castro: Yes, and you also learn more about how to improve it.

Hendrie: Exactly. And you understand what people really like and what they don't like.

de Castro: Yes, what they do with it…

Hendrie: What would be useful.

de Castro: Yes.

Hendrie: Any particular customers you remember that were interesting?

de Castro: There were lots for the PDP-8. The PDP-8 was very well received. It began to get a lot of publicity, and there were just lots of people who wanted to know about it.

Hendrie: What was the price that they offered it at?

de Castro: The base configuration was $18,000.

Hendrie: And how big a memory did you get for that?

de Castro: 4K. And we never offered a 1K memory in the PDP-8. We never sold any on the PDP-5. <Laughs>. So, why bother. Right?

Hendrie: Was there memory expansion available?

de Castro: There was memory expansion available. As I recall it was expandable within the chassis to 8K.

Hendrie: So you had a choice of 4 or 8K.

de Castro: Yes.

Hendrie: Anything in the applications besides the typesetting?

de Castro: Typesetting was an interesting one. I don't know. I can't think of any others right now.

Hendrie: OK, so what happens next in your career?

de Castro: Well, you know it's back to the field basically. An interesting thing happened in 1964. IBM introduced the System 360 and the System 360 was quite a revolution for IBM and for the industry as a whole from many perspectives. They introduced a number of concepts which were going to be very important going forward. First off they changed the fundamental quanta of data from 6 bits to 8 bits, and they introduced a whole series of machines, which were multiples of 8 bits. They also introduced the concept or I guess they introduced it in a more developed way than it had been before, of a whole family of compatible machines all of which could run the same underlying software but at different performance levels and different cost levels going on up and down the line. And I think this got a lot of people thinking that if maybe there were some opportunities to do some things better. At that time one of Digital's major competitors was a company called Scientific Data Systems in California and they, fortuitously for them, had manufactured a series of 24-bit machines, which were competing with Digital's 18-bit PDP-4s, and they had been quite successful and I guess they were just plain lucky that they had a number which was divisible by both 6 and 8. But even they decided that they needed to move to 32-bits which was becoming a very standardized number and you'll recall there was another competitor over in Framingham who ultimately was acquired by Honeywell, called Computer Control Corporation which decided they needed to do a 16-bit machine.

So the world was kinda getting organized around this new standard that IBM had brought forth in 1964, and Digital was sitting there with 12 and 18-bit machines, which really didn't play in any of these new standards. The 12s were not upward compatible with the 18s and none of them fit with the new quanta of data. And being out in the field I began to kinda hear this stuff from customers that they were concerned as the product they were buying was going to be adaptable out in the future. And so I began to talk to a number of people about the feasibility of building a new line of computers, which would incorporate some of these new standards. Unfortunately I was not able to foresee a way to do that which was compatible with the older machines. The new line really had to be a clean sheet of paper, at least in my perspective. There were also some things going on in the underlying technology at that time. Monolithic integrated circuits, which prior to that time had been quite expensive and mainly the province of military types of applications, had become very feasible and economical for commercial applications and offered the opportunity for a much lower cost way to design these things. And that in turn had some packaging implications. As you were able to put the functions which generally were contained on a digital module into a single chip, it didn't really make a whole lot of sense to put a single chip on a single board and then plug that into a back plane. But Digital, believing they were in the module business, effectively did that. They took single chips or a couple of chips and put them onto a single of these so-called flip chip modules and plugged them into a back plane, which in my mind resulted in a lot of redundant inter-connects that didn't add much value but added a bunch of cost and unreliability.

So having kind of synthesized all of these things, I made a proposal to what was then called the Computer Guidance Committee. Since the company was now broken up into product lines, there was now a centralized function which was a committee that oversaw things related to computers. And this proposal was to build a byte oriented line of computers that was scalable through 8, 16 and 32-bit word lengths and that was built using monolithic integrated circuits, and was contained on the quad version of the flip chip module.

Hendrie: OK.

de Castro: Namely four high and quite deep. And I built a couple of these boards, these quad boards which had certain functions on them but were not rigorously designed , but had parts to kind of show what they'd look like. And I took this model to the Computer Guidance Committee and showed them these boards.

Hendrie: Yeah, it wasn't working. This is just--

de Castro: It was just a concept idea.

Hendrie: Yeah, concept.

de Castro: -- idea of how these things would be built. And Digital at that time built their own printed circuit boards but they didn't have the ability to build them this big, so I had to get them subcontracted outside to make them. <laughs>

Hendrie: OK.

de Castro: At that time I was spending quite a bit of time out in the field with customers and getting to understand some of the implications of the IBM product announcement, the advent of the monolithic integrated circuit and its economic impact. And so I put together a proposal for the Computer Guidance Committee, which consisted of a written specification, or at least a product requirements kind of detail. Not to the last nit but it did have an instruction set, it had a register organization. And some thoughts on how this thing scaled from an 8-bit implementation through a 16-bit implementation or a 32-bit implementation with obviously increasing cost and computing power, but nonetheless compatible in terms of the underlying software. I also built this quad flip chip module, which was a module that was ten and a half inches high -- a little less than that just for clearance. 10 plus inches and roughly square, so it was roughly a 10 x 10 board. I had some fabricated by an outside printed circuit board vendor because this was beyond the size capability that Digital had internally at the time and brought this all to the Computer Guidance Committee.

Hendrie: And who was on the Computer Guidance Committee?

de Castro: Well it was clearly Ken, Nick Mazareese, Stan Olsen. I think by that time Harlan Anderson had left, although I'm not sure of that. And I don't recall who else.

Hendrie: Was Gordon on it?

de Castro: Gordon quite likely was on it.

Hendrie: Yes, OK.

de Castro: I'd be very surprised if he wasn't.

Hendrie: OK.

de Castro: In any event, they looked at this and we had a bunch more discussion and they had a bunch of other people come to talk to them about the pros and cons of all this. And unfortunately there weren't a lot of people in favor of it. The marketing people were very concerned about the incompatibility of this with their current products. They were afraid that we would be pushing away our current customers by basically telling them they had to rewrite all of their software to move to this new line of computers. And that whatever we did for future computers should have compatibility with the past. The manufacturing people were concerned that they would not be able to make these large printed circuit boards with the kind of tolerances that were necessary; and the field service people felt that it would be virtually impossible for them to maintain a product in the field which utilized boards that were this large. And so at the end of the day.

Hendrie: <laughs> Yes. Sort of the cards were stacked against you.

de Castro: They were stacked against me and I was lobbying ferociously in all directions I possibly could to get this thing to go but it really was not in the cards I guess at Digital at that time and space. So they decided to reject that proposal and during this time -- I can't quite remember all of the time intersections -- I was working on an integrated circuit version of the PDP-8 called the PDP-8/I, and it was the incorporation of the new line of flip chip modules which had monolithic integrated circuits on them but nonetheless utilized the same fundamental packaging concept of modules plugged into a back plane and the back plane was wire wrapped to implement the logical function.

Hendrie: OK.

de Castro: As opposed to the PDP-X function was that logical function by and large, would be implemented on the printed circuit boards and the back plane would be used to interconnect with some very major functional blocks, not the gates and flip flops.

Hendrie: Right.

de Castro: So I continued working on that and completed the PDP- 8i, and had that into manufacturing and ready to go to market.

Hendrie: Now was this a cost reduction, the PDP-8/I?

de Castro: It was definitely a cost reduction and also another bump in performance, as I recall the cores were a little bit smaller and little bit faster.

Hendrie: OK. And the circuits?

de Castro: And the circuits, being monolithic integrated circuits, were faster than what we had in the discrete component implementation. So it was pretty easy upgrade. It ran the same software. Customers could use what they had in the past.

Hendrie: Same instruction set?

de Castro: Same instruction set.

Hendrie: And basically the same kind of packaging?

de Castro: It was a somewhat different package. It didn't utilize the wings that the PDP-8 had.

Hendrie: Oh OK. It was more back toward more rack-mounted.

de Castro: It was kind of component to a drawer and that kind of thing. Yes.

Hendrie: OK more rack-mounted.

de Castro: So anyway.

Hendrie: OK. Now what time frame is this?

de Castro: This was 1967-ish.

Hendrie: OK.

de Castro: At that point I was getting less and less motivated to keep doing upgrades to the 12-bit family but really felt that there was an opportunity to move on, and having spent a lot of time out in the field gave me an opportunity to see what customers were doing, what competitors were doing, what customers were saying, what they claimed they wanted. And also staying close to the technology gave me an understanding of what was reasonable and feasible and economical given the technology of the day. And so more and more I was beginning to think that Digital probably was not the place I wanted to be a whole lot longer because I wanted to do some different things and they wanted, in my mind, to kinda stay on the proven path that had been very successful for them to date.

Hendrie: Hmm-mm. And nobody had even thought about a 16-bit machine, and of course they eventually did go.

de Castro: Well they'd thought about it because I'd proposed it.

Hendrie: Yeah but they weren't ready.

de Castro: They weren't ready to do it.

Hendrie: Yes, they didn't see enough competition yet.

de Castro: Right. So then I started thinking about what else I might wanna do and at that time the market for these small computers was just exploding.

Hendrie: Yes.

de Castro: And thought it just seemed to me that I had a vision of the market that was based on real solid customer contact as well as the technology and that I could put together a business plan to go through something on myself. I didn't really feel I could do the PDP-X, because the PDP-X was a pretty ambitious program which required the doing of a 32, a 16 and an 8-bit implementation all kinda simultaneously, and I thought we really needed to kinda tailor it back a little bit to what was more doable for a start up company.

Hendrie: Alright.

END OF INTERVIEW ONE / BEGINNING OF INTERVIEW TWO

Gardner Hendrie: We're here with Edson de Castro in his home [on January 13, 2003], and we're continuing an interview that we started about a month ago [November 22, 2002] for the Computer History Museum's Oral History Project. Ed, I think last time, we were talking about your career at Digital, and I think we got most of the way through that, and we got to the point where you clearly were having thoughts about maybe wanting to do something else; you might want to leave. When do you remember those thoughts first starting to cross your mind?

Edson de Castro: Well, I don't recall precisely where we left off, so maybe some of this will be a little bit redundant with the last interview, but better that than we leave something out. I do believe we talked about the proposal that I made at Digital for a machine which, at that time, was classified as a PDP-X. That actually was a proposal for a family of machines which would have incorporated an 8, a 32 and a 16-bit member. It was a rather ambitious undertaking frankly, to have replaced Digital's entire line, which at that point was based on 6-bit characters, and included 12, 18 and 36-bit members. But given the trajectory of the industry, following IBM's introduction of the 360, I felt that that direction was warranted. Needless to say, it was not embraced wildly by those who had vested interest in some of the older equipment.

In addition, some of the concepts, in terms of the packaging of the equipment, were fairly new, and were not received well by the field engineering or the manufacturing people. And I think we discussed that last time. But I was convinced that these concepts made sense, and were in fact going to be adopted in the years ahead, whether Digital did it or not. Unfortunately, the scope of the PDP-X project was way too large for me to contemplate doing as a startup company. And I guess when one tries to make a proposal to the company one's working for and is rejected, one starts to think, or at least I started to think, is there an opportunity for me to do something on my own? And so I gathered a few friends, acquaintances, associates, and we started to talk about what might make sense in the marketplace. And it was quite clear to us early on that it would have to be a much less ambitious project, at least at the outset, than the PDP-X; that we would need to define one machine that we could build fairly rapidly, and to get it to market fairly rapidly. And so while there were certainly some rumors at the time that the Nova, which was the Data General first product, did indeed have its roots in the PDP-X, that's really not true in terms of the design or architecture of the machine. I guess it's true in terms of the frustration of not being able to move forward with something that we felt was a good business opportunity.

Hendrie: Was the PDP-X proposal the last thing you had done at DEC, or did you do the PDP-8/I?

de Castro: After the PDP-X had been rejected, I moved on and did the PDP-8/I, which was really just an updating of the PDP-8 to use integrated circuits. And I got myself in a fair bit of trouble over that too. It turned out that Digital had certain drafting standards which were rather unique in terms of how they represented logical functions. And those standards were really kind of hard to adapt to integrated circuits.

Hendrie: I remember those somewhat peculiar symbols.

de Castro: Okay, I was one of those who wasn't going to let some minor issue like that slow me down in getting this product designed and out to market. So I, rather than going through all of the hoops that one needed to go through to get the standards established, just adopted the mil standard set of logic symbols, and made all the drawings for the PDP-8/I based on those logic symbols. Well I got beat up pretty good by the powers that be that I was causing all kinds of trouble, because this was an important change for the company, and that I shouldn't have just done it on my own. <laughs>. But I did it anyway, <laughs> and got the product designed, got it out. It was successful. And I think they ultimately adopted a set of symbols that was very similar, and everybody else was using them.

Hendrie: They had to go there sooner or later.

de Castro: And it wasn't anything that I created, it was just adopting what appeared to me to have been the standard in the industry for some time. <laughs>. But anyway, all of these, I'd say frustrations, some of which were probably legitimate, and some of which were just the necessary kind of administrative procedures that a larger company needed, were frustrating to me as a young engineer who just wanted to get stuff done. And so at that point, I started thinking about how I might want to do something on my own, albeit something different from the PDP-X, just simply because the scope was too much to undertake as a startup company. So I had some conversations with some associates on how we might put this together, put together a number of trial architectures. Originally we thought of building an 8-bit machine because we felt that getting into the market at the low end would be a lot easier than getting in on up

higher where the customers' expectations were greater in terms of software availability and things of that sort. So the initial point we thought would be fairly low.

Hendrie: Who were you working with?

de Castro: Well, at that time the group consisted of myself, of Pat Green, who was a department manager at Digital.

Hendrie: In the systems...

de Castro: He was in custom products, special systems division, Henry Burkhart who was a programmer, Dick Sogge, who was a circuit engineer. And we also brought in one outsider, and that was Herb Richman, who was a salesman, who at that time worked for Fairchild Semiconductor, and he called on Dick and me to sell us semiconductors, which we would incorporate in the design of our products. And we were impressed with Herb as a marketing presence and we certainly needed somebody with those skills. So we went through a number of iterations of the design. And we had thought we would build an 8-bit machine because it would be inexpensive to implement, but it ultimately dawned on us, and I think Henry was the one who originally made this observation, that the architectural word length of the machine and the implementation word length could be different, and that while the machine to the outside world might look like a longer word length, everything internally could be done in smaller pieces. And so we ultimately settled on a 16-bit architecture externally, at least that's what it looked like to the outside world, which we implemented 4-bits at a time internally. And we chose the 4-bit number primarily because that was the size of adders, registers, and the like, that were available in single integrated circuits at the time. And that we did ultimately move forward with. That's what became the Nova, the machine which, to the whole world looked like a slow 16-bit machine, and to the innards looked like a fast 4-bit machine. Obviously there was more we needed to do before we could really get going on this, not the least of which was we needed to raise some money. And so we started by talking to some of the, at that time venture firms, and there weren't a whole lot of them frankly. The venture capital industry was in its early stages.

Hendrie: What year was this?

de Castro: This was 1968, or actually it was-- yeah, it was 1968. It was early 1968. No, I'm sorry, it was 1967, it was mid 1967 when we started on it, because we ultimately actually started in pretty early 1968. We talked to a number of the venture capital firms, and Digital had been financed by American Research and Development, so they clearly had a conflict, so we obviously didn't approach them. But there were several others, and we didn't get a whole lot of interest from any of them.

Hendrie: Do you remember who some of them were?

de Castro: Graylock was one of the ones we talked to in Boston. I think there was a group somewhere in the Midwest we talked to, and I can't recall who that was. But there weren't a lot on our list, because there just weren't a lot at that time. And we then, after talking some more with Herb about it, Herb said,

"Well I know a lot of people in the industry who have done fairly well and are looking for investments to continue on." And so Herb made contact with a couple of people in the industry. The first was a fellow named George Cogar. And George was one of the founders of Mohawk Data Sciences, which at that time was a company that did a keyboard to tape machine, thus shortcutting the need to do punched cards for data input. And George fortunately, was very technical as well as market savvy, and he understood exactly where we were going and what we were doing and what the market opportunity was. We also spoke with Seymour Schweber. Seymour was an electronics parts distributor and was somewhat familiar with the industry, clearly not technical, but an interesting marketing guy. And we had a couple of other individuals who were interested in investing, but really were not the lead. So George decided he was interested and wanted to go ahead and do this thing. At that time we were faced with the need to find a lawyer to put all of this together. We kind of had the bits and pieces, but somehow they had to all be glued together. We had a technical plan, we had investors, we had a marketing guy, but we needed to put it together.

Hendrie: And you had an architecture for the machine?

de Castro: Yes, we had it pretty well worked out by the end of 1967. We'd gone through a lot of different iterations. And it did change a bit as time went on, but we had a pretty good idea of what we wanted to do. The next thing, as I mentioned, was to get a lawyer to put it all together. And Herb was referred, by a friend of his in the financial business, to a lawyer in New York, named Fred Adler, who was interested in working on venture-related kinds of things. So we all met with Fred, and Fred was a high energy individual, I guess is probably the way which we were very impressed with. And he was the kind of lawyer who, at least in our initial views, and I think they were subsequently confirmed, was more interested in getting things done than to figuring out why you couldn't it. And so Fred then talked to all of these investors, including some people that he knew who were interested in getting involved. And we ultimately put together this investment plan, documents and whatnot, to raise $800,000 for the initial funding of the company. And that was to be done in two tranches; the first one would be $400,000, with a call on the remaining $400,000 down the line. And in 1968, that was a lot of money. Clearly inflation has eroded its value today, but back then it was a lot of money. So we basically had the money we needed. We had a corporate organization. Fred, among other things of course, incorporated us. And we decided it was time to move.

Hendrie: Did everyone invest the same amount in the company?

de Castro: No, Cogar was the lead investor, and he had probably half the deal. And there were a bunch of other individuals, whose names I don't really even remember at this point, who had much smaller pieces. And each of the founders also put some cash into it as well. But, you know, small numbers by today's standards anyway.

Hendrie: How did it end up in terms of how much of the company was owned by the investors, and how much by the founders?

de Castro: My recollection is, and I'm somewhat hazy on this, was that the investors got something like forty percent of the equity in the company in that round. Obviously later rounds further diluted that. That was the one and only private round actually the company ever did. So at that point, we decided that we

needed to spend full time at this, and it was time to resign from Digital and move on. And so we decided basically to do that.

Hendrie: Olsen might not take so kindly to this.

de Castro: Well, that's all possible, but that's what we were going to do. You know, we felt that I had given Ken more than what he had bargained for in terms of products that were of great value to the company, launched them into the minicomputer business, and that I'd done my duty and I, as he had done from Lincoln Labs, was free to go try something else, if that's what I wanted to do, without giving him any hard time. So when it came time for us to leave, Pat got cold feet, I guess is probably the way to describe it. And he, I think somewhat with his wife's urging, was concerned that in a new company his income might not be secure, and that all the health care and whatnot benefits wouldn't be there right away.

Hendrie: Too high a personal risk.

de Castro: Yes. Well there certainly was a personal risk, but on the other hand, nothing ventured nothing gained.

Hendrie: Was he older?

de Castro: He was about five years older than the rest of us, but I was twenty-nine at the time, so, you know..

Hendrie: And Dick was?

de Castro: Dick was a little younger than I was. I'm going to say he was twenty-seven or twenty-eight. And Henry was maybe twenty-two. Henry was very young. So the three of us decided to go do it. Pat was hemming and hawing, and maybe he was coming, and maybe he wasn't coming, and this and that. And that went on for long enough that the three of us, with Fred's concurrence, decided we just didn't want to be there anymore, <laughs> and so we told Pat that since he had, you know, postponed doing this, that the opportunity was no longer there. We did allow him to invest in the company some, but other than that we decided that we probably-- we had to move on, and frankly I think we got a different view of his risk aversion, which none of us thought was good for an early stage startup at that time. So we left. We rented a storefront in Hudson as our temporary headquarters, and we got real busy designing a computer and writing software.

Hendrie: Did Herb join originally?

de Castro: Herb did not join at the very beginning, because-- not because he wasn't willing to, but because we jointly decided that, until there was something to sell, that having Herb on board would probably be counterproductive. So, you know, we met with him frequently, and none of us ever had the

feeling that Herb was risk averse, or that he wouldn't join when the time came. <Laughs>. It didn't seem to make any sense to spend money on a marketing guy when we had nothing to sell. So the three of us who were technical basically came on board full time. We developed the product, and when we were ready to go looking for customers then Herb came on board.

Hendrie: How did you split up the work of designing this product?

de Castro: Well I did primarily the logic design, Henry did the software, and Dick Sogge did the memory and circuit design, which were pretty much our areas of specialty that we had experience in, and were able to move fairly quickly on. And that's not to say that there wasn't a fair degree of overlap, to the extent that the logic design impacted the architecture and the software, then, you know, Henry would get involved, and to the extent that some of the timing and the logic affected the memory then, you know, Dick and I would work together. But I mean with three engineers who knew each other and worked together for some time.

Hendrie: It becomes very vague.

de Castro: The boundaries are vague, you don't write formal memos. You just talk to your colleagues and you figure out the answer and you move forward.

Hendrie: One of the things that people have pointed out, was the architecture of the Nova was particularly clever in the sense that many bit assignments for the instruction words were actually micro programmed into the instruction. Where did that whole architecture come from?

de Castro: Well the architecture basically came from myself and Henry Burkhart. And it was very much optimized for low cost of implementation. In those days, hardware cost real money. Times have changed and hardware is very inexpensive these days and software costs real money. So you don't do such things. But we really looked very hard at how this would map on an actual implementation. We also felt that a multiple register architecture made sense. Heretofore, most computers were single register architectures. But with integrated circuits, the cost of flip flop storage was coming down to the point where we felt that a multiple register architecture could be implemented quite inexpensively, and made sense under those circumstances. And in fact, we were able to get blocks of 16-bit register modules that implemented that stuff 4-bits at a time.

Hendrie: Could you talk about some of the other decisions you had to make?

de Castro: Well, as we had talked earlier, on my proposal for the PDP-X at Digital, we felt that the concept of a back plane with lots of wires that were put on, either by hand or by some very complex and expensive machine, had seen its day, and that in fact the whole packaging was moving down a level. Where initially the printed circuit board was a carrier for primitive logic functions like and/or gates and flip flops, the back plane was the mechanism for interconnecting them, that we had now seen integrated circuits being the carrier for the primitive logic functions, and printed circuit boards as being the way to interconnect those to form some fairly substantive function. So we set out to build very large printed

circuit boards, 15 inches square, onto which we could put large numbers of integrated circuits, which in those days were fairly primitive by today's standards, but nonetheless quite dense by the standards of just a few years before that. And thus we were able to do things like put the whole processor onto printed circuit boards in the first iteration, and one in the next iteration, put an entire 4K by 16-bit memory on another printed circuit board, and put a number of I/O controllers on a third, and to then plug these into a chassis which had simply buses, bus connectors on the back, which were again implemented on printed circuit boards. So the whole product ended up with virtually no hand wires. And so that was probably the first such computer built that way, and I think others ultimately followed along. I don't think it was rocket science; it was pretty obvious. But that's what needed to happen.

Hendrie: Did you have any problems in terms of procuring the different parts? If this printed circuit board was a relatively new concept, did that pose problems?

de Castro: It did. There were not a lot of circuit board houses who could build such boards, but when we were at Digital we had in fact built a sample for the PDP-X proposal, which was not quite that large, but was pretty close, and had gotten to understand pretty well what the capabilities were in circuit board houses. And we were able to find a couple of vendors who were capable of doing it, one of which is somebody you know well, which at the time was called Hadco. And they were fairly aggressive, and interested in doing what needed to be done, and it wasn't easy. And, as with many things, the yields were less than a hundred percent initially, but the learning curve was fast, and ultimately they were produced pretty routinely. And the cost implications of it were rather substantial, since we'd basically gotten rid of a whole layer of interconnect, and that also had a fair impact on reliability. It also allowed us to introduce a rather different service, or maintenance concept. As I mentioned, during my experience at Digital, the field service people were very uncomfortable with the use of large boards, because they'd been used to trying to troubleshoot problems down to the level of the gate or the flip flop. And to do that on a large board was fairly difficult without specialized test equipment. But we felt that the answer to that was a good thing, not a bad thing, and that was that it would be unnecessary to troubleshoot it down to the gate or the flip flop, because a service engineer would be able to replace a major function. If the processor was a problem, then the processor could be replaced, and the board returned to the factory or depot for ultimate troubleshooting. And so we moved to that kind of a field service and maintenance concept, which allowed us to get our customers up much more rapidly, since the technician in the field didn't really need to get down to the last nit of what the problem was, but simply replace the major component.

Hendrie: He just had to know in what board the problem was.

de Castro: Exactly. And so all of that kind of came together, I'd say, to make the product very attractive. And it was low cost, it was much easier to maintain, and it looked like a 16-bit machine, which people wanted then, as opposed to 12 or 18-bit machines, even though it was really a 4-bit machine and had a price to match.

Hendrie: When did you actually leave and start working on it?

de Castro: We started on tax day, April 15th in 1968. And we were very busy for the next nine months, more or less. We worked day and night, and we ultimately got our first machine to the Fall Joint

Computer Conference, which that year, we were very fortunate, was delayed into December, for whatever scheduling reasons, which gave us a little more time than the normal November timeframe. We had the machine together, it was running, and Henry had programmed Space War! So we-- that I guess was probably one of the first video games <laughs> in captivity.

Hendrie: By this time you'd obviously added some more people. Who were the early people you needed just to get the job done?

de Castro: Well, it turned out one of the most important people we had to have was a printed circuit layout designer. Needless to say, these big boards were non-trivial to lay out, and it required somebody of substantial capability in that area. And so we brought on board a man named Norm Perryman, who <laughs> was a genius at laying out printed circuit boards, I guess is probably the best way to put it. And we gave him all these schematics for these things and we said, "Go do it." And Norm did it. <Laughs>. So that was a very important hire for us at that time. We also brought on board a technician to help us with the assembly and test of early prototypes. And as we got closer to…

Hendrie: Who was that?

de Castro: That was Dick Mangsen And as we got closer to the time when we wanted to display this thing at the Fall Joint Computer Conference, we felt we needed to embark on an advertising and publicity program. And so at that time we brought on board Allan Clutchman who was and extremely creative advertising and publicity person. And I guess other than that we had a secretary, and that was pretty much it.

Hendrie: Did you build the boards yourself?

de Castro: Well, we did not make the printed circuit boards, but we put the parts in and soldered them by hand <laughs> in the first few.

Hendrie: What else are you going to do?

de Castro: Right, that was something we were quite capable of doing, and we put them together, we debugged them, and after finding all of our design errors, sent it back to Norm to do it all over again. <Laughs>.

Hendrie: Did this end up being a two layer or a four layer board?

de Castro: It was a two layer board. Well double sided, so it was a single layer, but double sided; two layers of edge, one layer of epoxy.

Hendrie: So you got power ground and all signals.

de Castro: Everything. The whole bit.

Hendrie: Had you brought on Herb Richman when you got to the Fall Computer show?

de Castro: Oh, yes. Herb came on I'd say a couple of months before that. That was in San Francisco at the Moscone Center actually, in December of1968, and Herb of course was there selling stuff. And so Herb, as soon as the product was demonstrable, was very active, and he was not only personally selling, but also was recruiting for us a group of manufacturer's representatives, who would represent our products in various areas of the country, and managed to book some orders right after that conference, one of which was going to a university in Texas, which was to be the first one shipped, the first delivery. And so after a fair bit of TLC from the entire staff, we packed it up in February, I believe it was, and shipped it out, and called the customer in a week or so to ask how they liked it and they said, "We haven't received it." Well meanwhile, there was an airline strike, and we had shipped it air freight, and this thing never arrived. And I'm sure the customer figured, "Yeah, right. Of course it's on the way, right?" So we said, "No, you know, we suspect you don't believe us, but we'll ship you another one."

Hendrie: How many did you have at this point?

de Castro: Well, we didn't have a lot, but, you know, we were getting going. And we couldn't have our first customer feeling like he wasn't getting it. So we got him another one, which he did receive, and it worked properly for him. And then come about May, the original arrived. <Laughs>. And in tracking it out, it was clear it had been sitting in some airline warehouse in Chicago for three or four months while they finally sorted out the remnants of this strike. So we recovered our reputation, and the customer <laughs> acknowledged that indeed it had been shipped as we had promised, and-- but some things don't always click.

Hendrie: Who were some of your other really early customers?

de Castro: You know, I wish I could remember that, but I can't. <Laughs>. I may, as we go along, think of some of them. They were generally very technically sophisticated customers in the university or industrial world. They were people who were comfortable using computers and who didn't need an enormous number of people to hold their hand.

Hendrie: Did you have any software at all?

de Castro: Oh, we had...

Hendrie: Did you have an assembler?

de Castro: We had an assembler and a loader, and what more could you want? <Laughs>. That was the starting software package, and we kept right on going from there.

Hendrie: How long did the first $800,000 last? When had you used that up?

de Castro: Well, it turns the second tranche came in without a problem right after we got the machine to the trade show and started booking and shipping orders. And I mean theoretically, we could call that at our behest, but it might have been a little hard collecting it if things weren't going okay. So once things started to get rolling, we decided we needed to build a more formal manufacturing organization, and so we went and looked for a manufacturing vice president, somebody who could put all of that in place and make sure that we got our volumes ramped up to meet the customer demand. And that happened early in 1969, February or March, we brought on a man named Harvey Newquist who had experience at the computer control division of Honeywell, and you may have run into prior to Data General days.

Hendrie: I knew Harvey quite well.

de Castro: That's what I thought. And so Harvey came on board and set up our manufacturing operation and recruited the people we needed, and just made that a smooth running machine, so that as long as the designs worked, Harvey made sure customers got on-time deliveries. <Laughs>.

Hendrie: How did you find Harvey?

de Castro: Good question. I'm quite sure Allan Clutchman recommended him, but I could be wrong. Allan worked at Computer Control before going to Digital and then coming to Data General. And I think he knew Harvey, and I think he recommended him. And we were very impressed with him when we met him, and remained impressed with him during his time at Data General.

Hendrie: I wanted to go back to George Cogar. I remember talking to your partner Henry at one point, and he had mentioned that George was originally investor, but then he somehow backed out, or didn't end up being a long-term investor in Data General.

de Castro: Yes, he was one of the minority investors, one of the smaller investors. George was from upstate New York, from Herkimer, New York and he had, at the original investment, brought in two other people as small investors. And I'd say probably two to three years after we got started, George decided that he wanted to be free of any conflict of interest in terms of funding other startups. And he felt that for him to continue as a major investor in Data General would not allow him the flexibility he might want in terms of doing other startups.

Hendrie: Had he done Cogar Electronics yet?

de Castro: Yes, well yes he had. That existed, but it wasn't doing a whole lot. But he felt that he wanted to be free to invest in the minicomputer area, and thus sold his investment to these other two gentlemen from upstate New York. And George unfortunately not too long thereafter, as you probably know, went off hunting in Alaska and never came back.

Hendrie: I guess I wasn't aware of that.

de Castro: Yeah, so that ended that saga. But it was several years before that he had sold his investment to these other two gentlemen, so as to be conflict free.

Hendrie: He thought that to be conflict free was worth more than the Data General stock?

de Castro: Well I think he probably did, because we were public by then, and there was a market price, and I don't know what he sold it for, but I assume he got pretty close to market price for the large block.

Hendrie: You've announced the product, you're in manufacture, have your first few customers. What next?

de Castro: Well, what next was we started to do a fair bit of business. We got a bunch of orders, and we needed to get geared up to fulfill them, and Fred Adler came around and said, "I think you guys need some more money." And we said, "Yes, it does look that way. We really need to get into larger quarters, we need to put in place more test equipment, more manufacturing equipment. We need to automate some of our processes for soldering and things like that. And we could use some more capital." So Fred said, "Well, the market's looking pretty good these days. Why don't you go public?" And we kind of said-- swallowed hard and we said, "You know, we really hadn't thought that was going to be possible for us quite this soon, but you're much more financially in tune than we are. If that's doable, we won't complain."

Hendrie: Were you profitable yet?

de Castro: At the time we went public, we had just crossed through the profitability threshold. So we were right at the breakeven level. And we went public in November of 1969, which was about a year and a half after we started the company. So it was very quick, but as Fred advised us, and we soon came to understand, the capital markets were rather fickle, and you raised money when you could raise the money, <laughs> and not about waiting if it was there for you. So we did a public offering, which at that time was underwritten by a company called Bache, which was later acquired by Prudential Securities, and a bunch of others obviously in the syndicate. It was very successful.

Hendrie: Do you remember how much money you raised?

de Castro: I think we raised five million dollars or something of that nature.

Hendrie: A substantial amount of money.

de Castro: Yes, substantial in those days anyway. I mean right now underwriters would sneer at a five million dollar public offering, but inflation has taken its toll.

Hendrie: Now you had enough to finance your ongoing operations.

de Castro: Exactly, so we leased a building which actually was built for us in Southborough, which was initially 10,000 square feet. And as soon as that was finished, we signed on for an additional 20,000, to make a total of 30. And we kept building onto it as time went on. And that was all of our operations basically, R&D, manufacturing, sales and everything. Things were going well. Customers were buying product, but competition was out there. Digital was a bit annoyed that we'd managed to do some business, because, you know, Ken had predicted we would fail, and the prediction was not coming true. But there were rumors that Digital had belatedly decided that indeed there was a real 16-bit market and that even though it would probably do bad things to their 18-bit products that they probably needed to move on with it. And so we decided that it was time for us to move on to the next product. The technology had advanced, semiconductors were getting faster and denser, memories were getting smaller and faster, and new things could be done. So we brought on board another senior engineer, a fellow named Larry Seligman to work on the next family of equipment. And I guess the first one was called the Nova, and actually the next one would be called the Supernova.

Hendrie: About what time did you hire Larry?

de Castro: This was right after the introduction of the original Nova. I'd say it was in late winter or early spring of 1970. And so he came on board, and at that time, the semiconductor guys, Intel in particular, and Bob Noyce, were starting to make rumblings about building memory out of semiconductors. For that of course we were using ferrite cores, which was the technology that everybody used at that time. And Bob Noyce told me that they were going to be able to build very dense parts; that they thought they could probably get a thousand bits on a chip that we could use as memory in our computer. And since the mission for the Supernova was to build a very fast machine, with the Nova we had, as I mentioned, basically built a 4-bit machine with a 16-bit exterior, the Supernova would be a fully parallel 16-bit machine that could utilize rather fast memory.

Hendrie: How fast was the memory in the Nova?

de Castro: 2.6 I believe, or something like that.

Hendrie: It was fast, but...

de Castro: Not real fast.

Hendrie: You could easily buy a one microsecond cycle time memory at this time.

de Castro: Right, exactly. And in fact, the innards were running at that kind of speed, but it was just that we did it 4-bits at a time. <Laughs>. So that kind of slowed it all down. Anyway, Larry got busy on this design and we decided that...

Hendrie: Now he was from Digital?

de Castro: He had worked at Digital, but at the time we hired him, he had gone back and was at MIT, so he was not actively working at Digital at the time that we had him.

Hendrie: He'd taken some time off.

de Castro: He was back studying at MIT, and I don't remember exactly what he was doing there.

Hendrie: Doing his masters or whatever?

de Castro: Something of that nature. Anyway, we decided that we had ought to prepare to accommodate this semiconductor memory, that while we didn't want to totally depend on it, since it was fairly early stage, we thought that the right approach was to allow for the use of either core or semiconductor memory in the design. And we did that. Unfortunately, these 1 kilobit parts were made out of bipolar technology and they absorbed a fair bit of power, <laughs> and they got very hot, and when they got hot they didn't work, and there were numerous problems with it.

Hendrie: You probably didn't have enough room in the package to put some huge high speed blower on them?

de Castro: Exactly. So while we initially did offer the semiconductor memory, the problems associated were such that we really didn't sell any. There were a few customers, who ordered a very small chunk of semiconductor memory, and we were able to make that work, but in larger pieces, given that technology, it really wasn't practical within the context of our design. But we did design a pretty high speed core at 800 nanoseconds to go with it. And so it was a respectable performing machine.

Hendrie: How fast would it have gone if the semiconductor memory had worked? Do you remember?

de Castro: I don't, but it was somewhat faster than that at a semiconductor memory. And...

Hendrie: How big a semiconductor memory could you get working?

de Castro: 1K. Yeah, 1K.

Hendrie: 1K was buildable.

de Castro: It was buildable, but it was hot. <Laughs>. And so that product was successful, but it was also fairly expensive to build, because we had really focused on speed. And it was built, I believe, on

three printed circuit boards, three of these big boards for the processor. And at that point, we decided that we needed to go for the next generation of low cost machines. And well, at that point, we also felt that we needed to offer a compatible high speed machine, one where a customer could, by simply swapping out processor boards, upgrade an install machine from this economy version to a high speed machine. So we really had two designs to do at once. And Larry was signed on to do the high speed one, but we were looking for another engineer for the low speed one. I got a rather interesting letter from an engineer who at that time was working for General Electric. And he said, "I've read about your product, I've read your ads, and I'm going to work for you. And I'm going to be at your offices in a week to talk to you about that." And this was a man named Ron Gruner. So I called him up and I said, "Gee, we're looking forward to seeing you when you get here, but it would really be helpful for us if you could send your resume in advance so we could be a little more knowledgeable in talking to you about what might work out." So he said, "Okay." So he sent us along his resume, and sure enough showed up on schedule. And Ron was a very bright, very aggressive, very high speed kind of individual who we immediately made an offer to. And he came on board to design the economy version of this machine, which we decided we would finally fulfill our original desire of getting the processor on one board. And so he proceeded with that, and Larry proceeded with the high speed version, and they were introduced as a Nova-800 and 1200 to indicate their memory cycle times.

Hendrie: I've actually seen the letter that he sent.

de Castro: Okay.

Hendrie: As I remember, there was a newspaper clipping about the computer he built in high school, and he was just dying to be a computer person.

de Castro: Yeah, and he was an amazingly <laughs> good hire.

Hendrie: He dropped out of University of Oklahoma.

de Castro: Yeah, so, you know, sometimes good things just drop in your lap. Not always. You've usually got to go looking for them.

Hendrie: It would be very hard to find a designer as good as he was.

de Castro: Absolutely. Absolutely. And Ron just worked day and night and did a great job.

Hendrie: And so that's how you got the 1200?

de Castro: That's it.

Hendrie: What were the peripherals you originally had on the Nova?

de Castro: Well, originally the standard peripheral was a teletype ASR-33, which was a paper tape reader, punch, printer and keyboard. And those were kind of the standard of the industry for a number of years. In addition to that, we began to offer other peripherals. We offered interfaces to high speed paper tape equipment, and ultimately an IBM-compatible magnetic tape, and to a disc drive with a fixed media and fixed head disc drives. Yes, all fixed which we bought from-- I'm trying to think of the name of the company who did the drive. In any event, we...

Hendrie: Bryant?

de Castro: No, it wasn't Bryant; it was a small upstart company.

Hendrie: Vermont Research?

de Castro: Somebody in California. Anyway they were alright.

Hendrie: You had hired some other engineers?

de Castro: We had. We'd hired other engineers to do some of the interfacing work. And these disk drive guys built a decent product. Thirty or forty percent of them worked, and the rest we sent back <laughs> and ultimately got them to work. And so that obviously upped the capability of the product. And along the way, we decided that we really needed to start building some of our own peripherals in order to be able to offer them at a lower cost. And we hired an individual who had some experience with the then ubiquitous IBM removable disk packs, which were oxide-coated disks with moving heads. And he came on board to build us a product similar to that called the Nova disk, which had its problems. <Laughs>. It worked most of the time, but probably was not the world's most reliable disk drive. But we did go on from there to build a number of different disk products, many of which were very good.

Hendrie: But the first disk was the Nova disc?

de Castro: Yes.

Hendrie: Was it removable?

de Castro: It was removable. I'm sorry, the pack was not removable, but it was built using a pack which was designed to be removable, but it was not removable in a Nova disk implementation.

Hendrie: So you didn't have to deal with exchanging packs.

de Castro: Right, we did not have to deal with all that issue. But it was built out of the standard stack and I don't remember how many disks were in it, that IBM used in their removable pack.

Hendrie: By the time we get to designing the 1200 and the 800, do you remember anything about how big Data General had grown to in terms of revenue?

de Castro: Well, we had a fiscal year that ended in September, and in the first fiscal year where we were shipping product, and that was the year that ended in September of 1969, we did roughly a million dollars. The next year we did seven million, and the following year we did fifteen. So we were growing pretty rapidly.

Hendrie: You had an initial public offering in late 1969.

de Castro: Yes.

Hendrie: Did you raise any more money from public offerings?

de Castro: Oh, yes. We did a number of public offerings. We probably did maybe three or four more after that as the company was growing, because to grow at the rate we did, you're really not self-financing. The need for working capital, as well as capital equipment is such that you do need outside financing. And frankly, capital was available to us from the equity markets fairly cheaply. And so we ultimately owned all of our own real estate, because it was the least expensive way to finance it, given we could tap the equity markets at the kind of rates we were doing.

Hendrie: After the 800 and 1200 got introduced, you had done at least one peripheral, presumably sort of in this general timeframe that was in-house.

de Castro: Yes.

Hendrie: What were the next thoughts?

de Castro: Well, we started looking at how to expand our market presence. And we felt that one of the keys to that was to have more software, and that at that point people were predicating their purchases on availability of software tools. And since we were initially in a scientific and industrial market, the tools that were required were basically a basic interpreter and a FORTRAN compiler. So we did the basic interpreter. I believe Henry did in-house, and I believe we had some contract help on the FORTRAN compiler, which we ultimately brought forward for the computer. And that helped us to be a pretty full line player in the scientific and industrial markets, not in the commercial markets. That was later, and I'm not sure we ever really penetrated them in any meaningful way, but we did offer product there down the line. So software became a significant focus as we went along.

Hendrie: Do you remember when you first offered an operating system or an operating environment?

de Castro: Very soon. We offered a rudimentary disk operating system, and that was I'd say within a year after initial product shipment.

Hendrie: Did Henry do that?

de Castro: Well, Henry did the basic architecture and supervised the coding, but we did have some other programmers on staff. I'm trying to think-- John-- I can see the guy's name who actually wrote the code. He, after working for awhile, went off and wrote a book about hiking in the Appalachians.

Hendrie: Is that right?

de Castro: Yeah, I'm trying to think of his name. It may come…

Hendrie: Oh, yes. He worked for Larry Seligman for awhile?

de Castro: Probably. Possibly.

Hendrie: I think I know who you mean.

de Castro: Okay.

Hendrie: Yes, he did write a book. Why don't we continue with the story of the growth and expansion?

de Castro: Okay, about that time, Digital finally got the PDP-11 out the door. <Laughs>. And the PDP-11 had a significantly richer instruction set than the original Nova. And so we were beginning to feel some competitive pressure for a richer instruction set, and the costs of integrated circuits had continued on down at a pretty high pace, which made hardware less of a factor, in terms of the ability to implement such an instruction set. And so at that point, we sought to put in place a design which would be upward compatible with the Nova, but would incorporate a richer instruction set, the ability to address a fair bit more memory, and effectively give the customer higher performance. And so Larry Seligman was tasked to architect this machine, which we ultimately called the Eclipse. It was still a 16-bit machine, but with a significantly upgraded instruction set. And the instruction set had some variance in it which could be implemented or not, that either were valuable for scientific or commercial applications, when you put in some instructions which would allow it to perform better in each of these areas if they were implemented, and went on to implement a whole series of Eclipse machines, some of which had S and some of which had C designations, depending on whether they had the scientific or commercial instruction enhancements. And for the commercial version, we ultimately wrote a COBOL compiler. And all of that competed reasonably successfully with the PDP-11, which was the major competitor. Hewlett-Packard was also there, but not as much of a factor as Digital in those times.

Hendrie: I remember that eventually Ron Gruner got the job of actually implementing the first Eclipse machine.

de Castro: He implemented some of the Eclipses. I'm not sure I recall which ones he actually implemented, but he certainly did a bunch of them. Yes.

Hendrie: I remember that there were some forays into some other potential business areas too at this time. My memory recalls a supermarket system and a milling controller system and I'm not sure what else.

de Castro: Those are all true.

Hendrie: Can you talk about how those got started and what the thinking was?

de Castro: Well, we did try to do some industry specific solutions. And with respect to the supermarket system, we ran into a group at a company called Dymo, which is a company that made label makers. They're still around. They still make label makers, though they're more advanced obviously than they were back then. And they had a product which printed barcode labels to go on merchandise that could then be scanned at checkout. And we purchased from them all of the rights to this system they had developed for a handheld tool to print barcode. And at that time, the grocery industry was going through the decision process, is probably the right way to say it, and had asked a number of people in the industry to make proposals for the barcode that would be used on grocery items. And we, among others, submitted a proposal, and the proposal was based on the barcode that was being used in these Dymo label makers. And we were the only submitter who had a handheld tool to actually print these things. Everybody else was relying on them being printed on the boxes and the cartons by the grocery manufacturer, which clearly was the approach of choice for the vast majority of them, but we felt that the industry might be taken by the ability to label those items which didn't come printed that way.

And so we submitted this, and ultimately the industry chose an IBM approach, which was a somewhat different barcode, but it was not printable on a handheld device, primarily because it was way too tall. And so we then, in order to continue to compete in that, had to build a laser scanner, because the theory of all this was that it was all going to be scanned by a fixed scanner rather than a handheld scanner. And we had a handheld scanner which we thought might be useful as an adjunct. But we built the laser scanner and went to the market to try to sell this. And we did in fact get several installations. Shaw's, which was the local supermarket in this area, installed a bunch of our systems for grocery checkout. And this of course was all based on the IBM code, which they had won the competition and became the standard. But it soon became clear to us that we could not effectively market this ourselves, that there was a whole industry and infrastructure of point of sale terminal manufacturers who were better able to get to the customer than we were. So we ended up selling this business to a company called Sweda, who at that time was a viable point of sale company in competition with the likes of NCR, but ultimately left the business. <laughs>. So we sold that business to them.

As you mentioned, we also did have a system for computer numerical control, which we attempted to sell into the manufacturing industries, but ultimately were not successful, primarily because each of the

vendors of this type of equipment had their own that went with the tool. And the customer was really not looking for a separate supplier of numerical control hardware.

Hendrie: Were there any other industry specific products that you tried out?

de Castro: I can't think of any others. We kind of thought that was one of the approaches that the marketplace would go in, where people were buying things which were specifically tailored to their industry, and indeed that was true. We just weren't successful in penetrating any of them. <Laughs>.

Hendrie: There were barriers such as relationships, sales forces that are focused and all sorts of things like this.

de Castro: Yes, in the point of sale area, we just didn't believe that unless you had a much broader presence there we could be successful, that we were competing against NCR who, you know, had a huge cash register business and a salesman on every corner, and IBM, who owned the back office computing of all of these retailers. So as a stand-alone it just wasn't going to work, and that's why we ended up selling that business.

Hendrie: In the main product line, the major source of revenue was the Nova and the Eclipse line. At one point you started a project that eventually moved down to North Carolina. Could you talk about the genesis of that?

de Castro: Yes. Well, we were beginning to see an opportunity for even larger higher performing machines, machines which were generally 32-bits in word length. And at that time, rumor had it that DEC was working on a 32-bit machine which would be an upgrade to the PDP-11, and we felt we needed to get going and…

Hendrie: Which was certainly accurate.

de Castro: Yes, felt we needed to get going on one. So we got a group of people together, it was headed by Ron Gruner, to work out the architecture for an advanced 32-bit machine. And they met over a rented an apartment over the Fountainhead complex and started to work on this project. And they came back with a rather advanced architecture. It included many new concepts in computing that were just beginning to be developed. And we decided that in order to implement this we really needed to give these people a laboratory of their own where they would not be disturbed with a lot of the past, and could focus on just doing a good job of building this new machine. And so since it had been developed at the Fountainhead apartments, it became known as the Fountainhead Project or FHP for short. And Ron, looking around, decided that he liked the environment and the Research Triangle Park in North Carolina, and we, at that time, were putting in place a manufacturing facility in that area anyway, and so he, with his group, moved to the Research Triangle Park, and began work on the implementation of this machine. Unfortunately, the architecture was probably more advanced than it should have been at that point in time. It had a number of concepts, including segmentation and things like that, that I think, in the real world, only ultimately appeared in one machine, and that was the IBM System 38, which was originally

designed by IBM to be a replacement for their whole product line, but they ultimately determined that it was too aggressive and relegated it to one particular segment. But it was a very advanced machine and turned out to be quite successful for them ultimately. But implementation of that was, to say the least, non-trivial. And the project began to go on and on and on and on. And the need to get a 32-bit machine to market was much more immediate.

Hendrie: It was not going on and on and on.

de Castro: It was not. <laughs>. It was not. So Tom West, who had worked on a number of the Eclipse products with Ron, came forward and said, "Let's do something much less aggressive. Let's get out a 32-bit machine which is Eclipse-like with extensions, but something we can get done in a reasonable period of time." And at that point, we really needed to get something done quickly. So Tom got the charter to go ahead with the project which was called Eagle and is extremely well chronicled <laughs> by Tracy Kidder, and did indeed bring us a product which, although not as technically exciting as FHP, worked.

Hendrie: And could be shipped.

de Castro: And could be shipped, and people bought it. So ultimately, the costs of finishing FHP, and the likely upside of it, given that we already had a 32-bit machine, were such that we decided to cancel that project. Out of that, we did manage to salvage one piece of software, which was a symmetric multiprocessing operating system which ultimately got incorporated into Data General's UNIX implementation.

Hendrie: You did get some software out of the FHP.

de Castro: We got some software out of FHP. <laughs>.

Hendrie: What did you use the multiprocessor product in?

de Castro: In the latter days, we built a product around the Motorola 88K processor. And that ran UNIX, and it was available in multiprocessor configurations, which incorporated an operating system called DG/UX, which was a UNIX version that had symmetric, multiprocessing on it. And that was the AViiON. But that was much later. The other thing, interestingly enough, that Data General got out of all of this, was a lot of patents. And at the time when EMC acquired the company there was a piece of litigation ongoing with IBM over a number of the technologies used in the System-38 which we felt had been patented. For better or worse, that litigation died when it was acquired by EMC, because EMC had a cross-licensing agreement with IBM. <laughs>. So-- but the thought was had this been, you know, carried on independently that there was a big royalty bill due from IBM, <laughs> because of these patents

Hendrie: You'll never find out now.

de Castro: We will never find out.

Hendrie: The Eagle proved to be a very successful product. Could you talk some more about how the company was developing?

de Castro: Sure. Well, as I mentioned before, we had started toying a bit with the commercial marketplace with the Eclipse C-series, and had written the COBOL compiler, and were generally interested in that market. And at that time, our software people were getting intrigued with the possibilities of doing office automation, handling things like calendaring and electronic mail based on, at that time, the use of a central computer and fairly dumb terminals. And they developed a product which incorporated pretty much all of the capability that's in today's office automation systems, albeit configured quite differently, with the exception of spreadsheets, and started marketing that. And that actually was quite successful for the company, given the limitations that were inherent in the technology and infrastructure of the day. The fundamental problem was that it did a great job for one corporation, but there were no standards for interchange with other people. So we had a fair number of customers who were very early adopters of electronic mail and scheduling who used it within their corporations, and not just within one building, but within the entirety of the corporation. But you could not sit down and send an e-mail to somebody in another organization. The Internet was not deployed to any degree at that time, and the standards for all of that were not in place. So I think we were a little early to the party, and we also didn't quite have the architecture right. And I think that that was strictly a function of timing, where at that point there was still a certain semblance of authenticity to Grosch's Law, which has been totally decimated as of now.

Hendrie: As hardware became free.

de Castro: Free, yes. Well I think it was-- basically what happened to Grosch's Law was that computer science theorem is right, but it ran afoul of the mass production economics. Basically, even though from a computer science perspective, it's less efficient to use a whole bunch of small processors, mass production says it's a hell of a lot cheaper to build a million of the same thing than it is to build a few hundred of something else. <Laughs>. And so that's kind of brought then, and has totally changed the configuration that people use for office automation systems where there was just lots of small processors. Everybody's got their own. You run your word processor locally, not on some central machine.

Hendrie: Well it was the age of time sharing that eventually evolved into everybody has their own computer.

de Castro: Everybody has their own, because mass production economics said that was the cheap way to go.

Hendrie: PCs and workstations.

de Castro: Yes.

Hendrie: More or less about the time that the integration got to the point that the central processor is not a single board, but is on a single chip.

de Castro: But there was a fair bit of good work done, although I don't think it ever benefited Data General. You know, if you look at the original MS-DOS, it bore a strong relationship to Data General's DOS operating system, and their COBOL compiler was virtually identical.

Hendrie: Is that right?

De Castro: Yeah. So there was a lot done to us that we did to the mainframers, basically taking a lot of their good ideas <laughs> and implementing them in a new and less expensive kind of paradigm.

Hendrie: Well there was certainly no lack of talent. There was Jonathan Sachs, who worked in that group, and ended up writing Lotus 1-2-3.

de Castro: That is right. There were a lot of very talented people who went off and did great things afterwards. The lead programmer for the symmetric multiprocessing system was a guy named Craig Mundy, who is now [a] vice president of Microsoft.

Hendrie: Exactly. At some point during the evolution, I know the company moved away from selling big processors, and started doing some work on the AViiON. Could you carry us through from the Eagle to AViiON?

de Castro: Yes. Certainly. Well, a number of similar events happened. We indicated earlier, in my talk about things at Digital, that IBM's introduction of the System 360 had a salient affect on the marketplace. Well IBM's introduction of the PC had a similar effect, in that it established certain standards around which others rallied. And it's not that there weren't personal computers before that, there were. And the ones that were there before were probably every bit as good as the IBM PC. But IBM, with their market power, was able to establish a standard. And this had a major impact on the software industry. Software, which is the kind of product where all of the investment is up front and there's virtually no investment on a per unit basis, is obviously done most efficiently in a large market. And so to the extent that a single standard can be established for the instruction set, then software can be written that can be sold many, many times over, and that's going to be a lot more effective and inexpensive. So the coming of the IBM personal computer began essentially a revolution in the way the industry was structured.

There were clearly some approaches which did not run directly down that line. Sun, for one, did not adopt that and has been successful. I think there's some questions today, but at least for the last twenty years have done pretty well. But there were really some I'd say fundamental tenants which characterized this change. First off, the monolithic integrated circuit processor on a chip became effectively the only economic way to build a computer CPU, as a result of the constant advancements of that technology, and the ability to get more and more transistors on a chip, and to make them go faster and faster and not absorb levels of power which made the thing too hot to work. The other was the standardization of operating systems.

And there really were two standards, and frankly still are two standards. One is the Microsoft standard, which started out as DOS and was morphed into Windows, and the other was UNIX, which was developed many years ago at Bell Labs and exists today in a number of forms, Linux probably being the most viable at the moment. But it has passed through a number of iterations. And it appeared at the time we were considering what to do with the new architecture that we were going to have to adopt those two approaches. We were going to need to build our processors based on a high volume commodity processor on a chip, and we were going to have to utilize a commodity operating system. And in looking at the alternatives, I put together a group of fairly senior people at DG to examine all of the options and opportunities, with the fundamental premise being, forget about the past, it's over. You know, it's probably going to be an expensive transition, but it would more expensive not to make the transition. And so the outcome of that was what turned out to be the AViiON, which was based on the Motorola 88K chip. At that time, there were really two mainstream providers of processors on a chip. There was Intel, which had dominated the low end, and Motorola, who had the high end, as well as Apple with their 68K. RISC architectures although probably could trace their lineage back to the very beginnings of the industry had finally been mathematically proven to be <laughs> more cost effective than complex architectures, primarily through a lot of work that had been done at Berkeley. And Motorola had decided to offer a RISC machine in addition to their 68K which had been very successful as a complex instruction set machine.

We made the decision which ultimately probably was not the right decision, to embrace the 88K, the Motorola RISC processor, as our processor of choice, and to build a product line around it. At that time Motorola had led us to believe that they were going to do cost-reduced versions and enhanced versions and all kinds of things and get a lot of market share, which ultimately they never did. And so we took this 88K and built a new product line around it. We decided to use the UNIX operating system, which was much more suitable for the higher end of the market. The DOS operating system at that time was still fairly rudimentary and was appropriate at the low end, but really did not have the horsepower to get into the server class of machine. In addition to the standard UNIX, we took some of our own internal technology for symmetric multiprocessing and combined that into a product called DG/UX, which was announced with the AViiON. The major competitor in that area at the time was Sun, who was using a product called the SPARC. And there were a bunch of other using a RISC architecture made by MIPS, Silicon Graphics, and I believe a few others. I'm not sure exactly who they were. So there were several RISC architectures kind of vying for attention.

And I think that from a computer architecture point of view that Motorola really let us down, never really followed through on what they had to do to turn this into the dominant architecture at the high end, and ultimately ended up abandoning the 88K. They did pick up an architecture from IBM, which was originally IBM proprietary called the Power PC, and was ultimately adopted by Apple as their processor. But in the meantime, the Intel architecture machines were growing in volume and speeds and capability, and it really got to be a critical mass phenomenon. Once there were enough of them, they could be produced inexpensively enough, that was very attractive to software developers, who developed great software to run on this architecture, which caused people to buy more of them, which made the market bigger, so it all kind of cascaded up and is now to the point where Intel architecture is in fact viable in server configurations, albeit not before. But that's all good hindsight.

In the meantime, I ran into some problems. The move towards the AViiON, I felt was what the company had to do, that the MV architecture of the Eagle or whatever you want to call it had really run its course, that customers were not going to buy proprietary systems, and that we needed to put major investment into the development of the AViiON, most of which was going to go into software. And we were going to

pour all of our office automation there; we were going to do a decentralized version which would have used PCs as the workstations as opposed to the dumb terminals. The problem with all of this was it was very expensive. And the company's market for its proprietary systems was on decline, and so were profits. And when I presented this to the board, they basically told me we couldn't do it, that the company had to stick to its knitting, that you can't abandon your past, you have to keep up with what we were doing. And I never believed it. I always thought that this was really an industry that was changing, and that the change was inexorable, and that those who didn't change were going to perish. <laughs>. And so I kept doing it anyway, even though the board didn't want it done. And we also were doing a version that was fault tolerant.

Hendrie: The AViiON or the MV?

de Castro: AViiON. Yes, that would have been UNIX transparent, that you could have taken a UNIX based program and it would have compiled right onto the fault tolerant version. And it incorporated a fault tolerant disk system called the CLARiiON, which you may recognize as now the growth part of EMC. <laughs>. And so the board got more and more disgusted with me, because I told them we weren't going to make any money for two or three years when we made this transition, and decided that they needed to get somebody who had more sense than I did in there and move the company into a profitable position.

Hendrie: And forget about keeping up with the transitions in the marketplace.

de Castro: Right. As a matter of fact I was told by one of our board members that continuing with a fault tolerant UNIX machine was a no-brainer, dumb idea. So, <laughs> and this was a guy who'd spent all of his career in the insurance industry. <laughs>.

Hendrie: Yes, so of course he had all the qualifications necessary to make that judgment.

de Castro: Absolutely. So I don't know. One clearly makes lots of mistakes. As the old saying goes, "the only one who never made any mistakes never did anything". <laughs>. And I've made more than my share.

Hendrie: You certainly did more than your share of things though. So at that point the company did end up still doing the AViiON and the CLARiiON product lines?

de Castro: Right. They took the CLARiiON out of the fault tolerant machine and did it as a separate disk system. And that turned out to be a successful product.

Hendrie: I don't think the company would have gotten sold to EMC if it didn't have that.

de Castro: Right, if it didn't have that. That's probably right. And despite EMC's original disdain for it, it's now doing very well for them.

Hendrie: I've kept in touch with Mike Feldstein.

de Castro: Yes.

Hendrie: Who is V.P. of Engineering over there.

de Castro: Oh.

Hendrie: It's the growth part of EMC.

de Castro: It is. But, you know, there was really no effort or thought given to the AViiON product line after that. They kind of just kept making them. But when it became crystal clear that that processor was not going to be the standard, something needed to happen. And the something didn't happen.

Hendrie: So there was never an attempt to transition to another processor.

de Castro: Right.

Hendrie: But keep all the higher level languages and all of those things there so people could compile to a new processor.

de Castro: Yeah. I mean clearly in retrospect the right thing to do was to go to Intel architecture. Whether or not I would have figured that out under those circumstances, I don't know. Hard to say, but I mean hindsight's easy.

Hendrie: It really is. What have you been doing since you left Data General?

de Castro: Well, a little of this and little of that. After leaving Data General I got myself really interested in the biotech industry. And I ran a small biotech company for about a year and a half out in Boulder, Colorado, and learned a lot. I'm not sure I made the company successful; it ultimately got sold. But it was a company that was using biotechnology to help determine whether or not compounds were toxic, rather than having to feed them to animals to find out. So it was a rather interesting technology that used gene expression. And I learned a lot. Among other things, I learned that the average length of time from first development to product on the market is fourteen years <laughs>.

Hendrie: It doesn't sound like the kind of business somebody who's impatient should be in.

de Castro: Right, which is rather daunting number, especially after coming out of the computer industry where products had a one year to eighteen month life cycle. <Laughs>. Also that the science really is

not developed to the point that electronic science is, and the system, per se, is not as well understood. Clearly that's all progressing at a very high rate and ultimately I'm sure that it will be well understood, but it's not there yet. So that as it turns out is a very different industry. It's also one that's very heavily regulated and the computer industry really never was which I think helped in its kind of rapid growth. So dealing with regulatory bodies takes time and necessarily slows things down. The FDA has a difficult task. I'm not a critic of the FDA. I think they have a meaningful position and they don't do everything perfectly either, but if you're going to feed this stuff to people then there probably needs to be a fair bit of research to prove that it's safe. <laughs>. I've also continued on the boards of a number of companies in the computer industry. And have gone through the usual cycle of some companies starting, getting sold, one thing or another. <Laughs>.

Hendrie: Okay, good. Well, thank you very much for your time.

de Castro: Oh, you're welcome. It was enjoyable.

Hendrie: This is wonderful to get some of your history, preserve it for posterity, and get all your thoughts on lots of subjects. I appreciate it.

de Castro: <Laughs>. Oh, you're welcome.

END OF INTERVIEW TWO

