KEN OLSEN
ORAL HISTORY

COMPUTERWORLD HONORS PROGRAM
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Transcript of a Video History Interview with
Ken Olsen
Founder & President,
Digital Equipment Corporation

Interviewer: David K. Allison (DKA)
Division of Information Technology & Society
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DKA: I'm interested in how you first became interested in electronics. I read that you set up your own radio station. Whether that's true or not, how did you first get interested in electronics?

KO: When I was a teenager in the late 30's and early 40's, electronics wasn't a word. You were interested in radio if you were interested in electronics. Most of the information came from *Popular Mechanics* and *Popular Science* magazines. The books in the library had very little on radio. I remember very clearly they stopped at a, the spark transmitter, which was approximately World War I time. Anything I could get hold of I seized and studied and read. And any chance to experiment. If anybody threw out a radio, which they didn't do very often during the Depression, I, of course, stripped the parts and used it to do experiments. The experiments were limited because we could never get enough parts to do anything very exciting. The war helped.

DKA: Ken, was this something that you did alone? Did you do it with other members of your family? Or was there a club?

KO: Most of this I did alone. I had a brother who was two years younger and we sometimes experimented together. One thing we did was make a one tube radio. Before that we made all kinds of crystal radios, which were very limited in their selectivity. You could only get one or two of the local stations. We made a one-tube radio. With this we could buy battery cells for a penny a piece on sale. And get up to twelve volts. The normal voltage of 200 volts or so was beyond our budget. But we made a one-tube radio. It worked very well. We built it and rebuilt it and rebuilt it again. And learned a lot on the way.

DKA: Where was this, Ken?

KO: I was brought up in Connecticut, outside of Bridgeport. It was an area where machine tools were built, where you were normally expected to learn machine shop practice. And I did. But there wasn't much in the way of electronics going on. When I was drafted for World War II, I had the enormous opportunity to go to electronics school in the Navy. It was a great school. It lasted a year, or at least eleven months. It was set up by competent people and they gave an excellent education in electronics. They taught us all the tricks, manipulating, calculating circuits, the rules of thumb for electronics, and went through all of the gimmicks and tricks and things one should know about radio. And then radar, and counter measures. It was the most exciting thing a young kid, a lot of the electronics could go through.

DKA: How old were you when you went to school?

KO: When I was 18 I went off to the Navy.

DKA: Where was this school?

KO: After a few months at Great Lakes at Boot Camp, I went to downtown Chicago for two months. I lived in the high school [where] they taught us the basis of electronics. I'm not sure we even used the word electronics at that time.

The program was set up for the Navy by someone named Captain Eddy who was, before the war, the one who set up television in Chicago. The Kukla, Fran and Ollie stories were, I think, one of his projects. We then went out to Monterey, California for three months, nine months in the middle of San Francisco Bay on Treasure Island. It was a dream for someone who loved electronics.

DKA: Ken, was this the first time you really had a group of people around you that you could talk to?

KO: Oh yes, yes.

DKA: What was that like?

KO: It was just exciting because everybody was thrilled with what could be done with electronics. Vacuum tubes were largely just for radio. The development of radar opened up the use of vacuum tubes in such wonderful ways that we never conceived of. We'd known what radar was in very general terms. But not in exactly the detail which how everything was done. And some of the inventions in radar just thrill me today to think about them.

DKA: Ken when were you drafted? You were drafted because you...struggled to get into radio electronics?

KO: The Navy gave tests to people ahead of time who wanted to go into this program. And if you were accepted you were then drafted. But my serial number always had on the end of it, SV, Selective Volunteer. That is selected ahead of time and then volunteered. So we went in a special program right away. And stuck with electronics all the way.

DKA: What were they grooming you to be?

KO: Oh technician...technician. Their goal was to train enough sailors to maintain the vast amounts of electronics that were being put on shipboard. The war demonstrated the importance of electronics. The radar, the radio, the sonar, the navigation and countermeasures were all very intensive use of electronics. There also were analog computers for antisubmarine work. And all of these needed large numbers of technicians. And so they set this massive program up to generate thousands and thousands of technicians. The result was, I believe, a major influence on the development of electronics in this country. After the war when we all went to school, everybody wanted to be in electronics. And out of that came I think the success this country has had in electronics.

DKA: What happened to you in particular? You went to your school in Illinois then out to the West Coast, and then what happened?

KO: We went through the usual red tape of sitting in camp and going on a troop ship. And by then the war was over. And I ended up in China and was assigned then to an admiral's staff and we lived on one cruiser and then another, maintaining communications for the admiral. While we were there we had an opportunity to see China and Korea but we had enormous time for experimenting.

In the radio shack where most of the time we were on duty with nothing to do, the crew was broken into three groups; the card players, the sleepers and the experimenters. It sometimes rotated. We had access, one way or another, to all kinds of electronic parts, and we did some fascinating experiments.

DKA: Why do I not have to ask you which group you were in?

KO: [LAUGHS] Then there were things that always had to be done somewhat illegally. The bureau ships laid down rules on how things were to be done. But they didn't know what things were like 8,000, 12,000 miles away. And we had to make things and redo things and get our major projects and...

DKA: What's an example, Ken?

KO: Oh... the communications suddenly, within a harbor, were done on radios that were made for tanks, and ran on 12 volts. There's no 12 volts on a ship. Well, we could listen with 12 volts, all right, [but] when you transmit we need a lot of power. Every time we went to transmit, we had to turn on a motor generator set. You couldn't call a technician in to turn it on every time you're going to transmit. So we had to make a major switching system to allow an operator far away to turn on the ______ system automatically. None of this was legal by the rules but we got the job done.

DKA: You mentioned a while ago growing up, Ken, [about] machine shop practices. I wondered if that began to pay off in your work in the Navy and later on.

KO: My father was a machine designer. He said it was okay to go into radio but it was a business you went into because you loved and therefore you starved. People in the radio business or electronics then really didn't make a reasonable living. So he insisted I learn machine shop practice first, and I did that afternoons when I was in high school. It paid off very well, in the Navy, because I was the only one who could sharpen a drill and do simple things like that. [And] when we started Digital I was the closest thing we had to a toolmaker, not a good one, but I made the original tools. We used cutting sheet metal in making parts. I can at least carry on a conversation with people today.

DKA: When you were in the Navy and had all this time, were you prepared when the war ended? Were you ready to function? Were you ready to go to work in a big way? Or were you still in training?

KO: The plan was obviously to go to college. After the war, we had developed a lot of self-confidence that we could fix anything. Part of it was true because we were trained in a way. And other parts were very naive. But we didn't understand. We had to go to college. The government did wonderful things in encouraging people to go to college with the GI bill of rights. So almost all of us had the ambition to go right into college.

DKA: The feeling must have been very strong to see all this development in a field that you loved. And we'd won the war. How did you feel coming out? Did you feel about opportunity?

KO: Oh, yes. We felt a lot of opportunity. We felt electronics was going to revolutionize industry. We could see so many opportunities for electronics. It was discouraging to see how slow it picked up. After I had been in college I thought I'd find a summer job that could be useful. Electronics just was not finding a place in industry. It took a long time.

DKA: I want to go back to that transition from training when you were in the Navy to your working. Was going to China the first work? That admiral's staff, was that the first time that you were deployed?

KO: Yes. Being on shipboard was the first time we really had an opportunity to practical measure use our training. We probably learned technology but also learned enormous confidence, maybe way out of line for our skills but we'd tackle anything. Except once. I remember that the ship's navigator wanted me to fix this flashlight. And I said, any electronics, yes, but a flashlight, no. [LAUGHS]

DKA: What were you good at in the Navy? I don't really have a picture of what you did. I know you were fascinated by all the stuff, but what did you find yourself doing individually the most?

KO: The job I had in the Navy with a group of two dozen people, was to keep all the electronics going. And we always had someone on duty. When transmitters had to be changed, we had to do the changing. When anything went wrong, we had to fix it. When preventive maintenance was needed, that was our job. When there was some logistical problem in the operation of electronics, that was our job. So the area of troubleshooting particularly fascinated me because it was an interested puzzle. Finding out was wrong and fixing it as soon as possible.

DKA: What did you think of the quality of Navy equipment?

KO: Most of it very good. At that time, now looking back at it, it was heavy and somewhat crude. But that time it was beautiful, elegant, magnificent, with a few sad exceptions.

DKA: Was it well organized?

KO: Yes. Very sturdy and very well built, with a few pieces that they should have left on shore. I was still in school at Treasure Island when the war ended. I finished soon afterward and after a number of stops on the way, I went to sea for eight or so months.

DKA: What were you on? Was it a destroyer or battlewagon?

KO: I ended up on a cruiser because that was a cruiser because that was a flagship. And when the war was over we didn't really think about going out. We knew we still had a long time to go.

People joked about the war lasting many, many years. [I] never really thought about getting out, you know you're just there forever almost. When it was time to get out the first idea was to relax for a while and then get ready to go to school. But I think most people really planned to go to school. Some people had no preparation for it at all. Tried... because the spirit, because of the GI bill, was unique, I think of all previous wars the drive was to go to school and get education. And I think it made that generation of, from that war, different from all others. People really drove to go to school.

I went to work at General Electric, which was in town, where they were making radios. We made very expensive FM radios. I was a troubleshooter on the end of the line, [doing] mass production troubleshooting. I loved it, it was fun. This was in '46. My folks were still in Connecticut. After they mustered me out I went home and spent a month or two going to the beach and then went to work for General Electric who were hiring anybody they could get who could do work in electronics. They had a whole wartime of backlog to catch up with. They were making very expensive FM radios. I enjoyed it and learned a lot. At the same time I was studying for a college entrance exam. I applied only to one place, MIT, took the exam and was accepted.

DKA: Why did you only apply one place, Ken?

KO: There was only one place I wanted to go. My grades weren't all that great but I... [PAUSE] didn't think far enough ahead to think of an alternate.

DKA: What did you know about MIT to have made you want to go?

KO: It had a good reputation in electronics from the war and I suppose that was all.

DKA: And what was it like to be at MIT as a student compared to today?

KO: We were an extra class brought in February. Largely of veterans so we fit right in. And we kind of ran the place.

DKA: What does that mean?

KO: Well there was nobody who was young and scared, you know. It was very serious in a way and yet very carefree also. I went there in February of '47. And then went four terms straight without vacation. The first two years were a standard course for everybody.

Interestingly, when it came time to select the major, many people went into electronics, wanted to go into electronics because they had exposure to it during the war. MIT set about to interview everyone with a goal of talking a certain percentage of them out of electronics, because there really wasn't room. They had calculated that there wasn't going to be that much future for electronics, so they tried to talk people into going into chemical engineering. I remember the questions in the interview, and I remember the professor who interviewed me. I was accepted to stay in; course six of electrical engineering. Electrical engineering was particularly useful for the future, our future in computers because many of the people who laid out the course of study came from the radiation lab and the wartime experience.

One of the things they clearly said they had in mind was that if another war started, there was going to be somebody able to design magnets. Because when they tried to use the magnetron in World War II, they couldn't find anybody to design magnets. So, out of these classes came a large number of people who had some simple basic theory of magnets. And out of that came very useful knowledge for us in the development of the core memory, the key part of computers. People who came from other schools without that background were at a serious disadvantage.

DKA: Did you study from the radiation laboratory textbook series that became so famous, Ken?

KO: No, I don't think there were ever classes. There may have been. They did develop a number of classes, though, where you could see the influence of the people who wrote the rad lab series and who took part in their work.

One interesting experience, when we studied circuits, probably the first course in electrical engineering, I had learned all the tricks and all the ways of doing fast computation. And manipulation in...in one's head in the Navy. We could do X, Y transformations and do parallel series networks of components and do it very quickly. And for several weeks [in] the MIT course, I could do all the answers in my head. Suddenly it got beyond what I could do in my head. And with a panic I had to go back and learn the systematic approach to it that I had just lost in those weeks. Fortunately I caught up and I was able to do it.

But I almost lost out completely because I had learned so much before I got there. But I didn't learn the systematic approach that would take you to the really complex questions. There was quite a bit of laboratory work at MIT at this time, very much so in physics and in chemistry. The most memorable laboratory which I feel badly has disappeared is the motor laboratory. They had a very large room, very high ceiling; quite dusty and dark, with large generators and motors. Oh, six feet in diameter that you'd set up and run and learn by the sound of them and by the sound of the sparks and the dramatic result of making a mistake and the wire would evaporate. A feeling for electricity that too many students missed today because it's all simulated on a computer. It's not quite the same as hearing a motor run away and about to explode if you don't dive for the switch and turn it off. So we did learn some things there that are missing in today's education, I think.

DKA: Are you the kind of guy that liked to spend lots of time in the lab at this period?

KO: Oh, I enjoyed it. The electrical engineering laboratory experiments took a lot of time. Many nights we literally stayed all through the night working on the experiment, writing up the experiments. So you never went and did any more of those than you had to because they were so time consuming.

DKA: I haven't heard anything about what you were getting interested in.

KO: [My interest] was still in electronics. Oh, I didn't know what a computer was. One of the fascinating things was electronics were medicine and healthcare, also machine tool control. Being brought up in the machine tool industry, the control of machine tools with electronics was interesting.

DKA: It's numerical control.

KO: Numerical control, the like. MIT was making a numerical control milling machine. When I was out looking for a job, I went to the head of that project who later became head of the department and I said, I'd like to go to work here. And he said, "Well, we don't have a contract. We don't have any money, so we can't hire you." About then I got an invitation to come join the computer laboratory. They hired only the top ten percent of the class to the computer laboratory, which I think I wasn't quite there. But my love for electronics had caught the imagination of one of the professors and he recommended me even though I wasn't the top ten percent. And I accepted. And a day later Gordon Brown, head of the numerical control machine was running down the hall and saying, "Ken, Ken, we got money." I said, "It's too late. I've already got a job."

DKA: Probably the most lucky lack of funds in the history of computers.

KO: Yeah. At least for me.

DKA: How'd you feel to be able to go? What did you know about the computer lab?

KO: Oh, I knew nothing, nothing at all. It was classified. It was military. So no one knew what was going on inside.

DKA: Did you know it was Navy at that time? Was it still Navy?

KO: It was Navy but nobody outside knew what it was except those who had legal access to it. I was graduating and going on to graduate school and needed a job as a research assistant. That was 1950.

I'll make a few more comments back in the undergraduate area. Some of the things that I found particularly exciting and fascinating in the undergraduate study is the technology or the techniques for testing, proving or learning things. In physics they would say, suppose you looked at an area like a pillbox and it got skinnier and skinnier and skinnier. What would happen? Or in the shape of a tube and it got skinnier and skinnier and skinnier, what would happen? Or suppose something went to zero, what would happen to the rest of it? Or went to infinity, what happened to the rest of it? And looking at problems this way. It is ingrained in you.

[It] is surprisingly useful all through engineering and also in business. That part of the undergraduate training is still one of the most fascinating and one of the most useful mathematics. A lot [of] time was spent in complex mathematics. But the key part of mathematics is the simple concepts of calculus where one looks at everything in terms of slopes, simple derivatives. It gives insights into so much phenomena, including business phenomena. You never talk of business in terms of calculus, but it sure is a handy way to look at it because the balance sheet is an inner glow of the P&L statement. You really have to look at the derivative of the P&L statement in order to gain knowledge -- and sometimes a second derivative. All of this helps in looking at phenomena we work with every day outside of the academic world.

DKA: Are you [saying] that calculus gives you a sense of trends in business? I'm not sure I get the parallel.

KO: If the company is growing, you look at the derivative of the P&L statement. There are factors there that, for example, show that it costs to grow. You stop growing, the cost disappears. And the usefulness is, for example, if you stay at a constant growth, that cost should stay constant. But if that rate of growth is changing you have to take another derivative. And there's another cost which should go up and down. Looking at it that way you can draw conclusions, simple conclusions on a financial statement which are not immediately obvious unless you think of it in those terms.

DKA: So it's a kind of discipline of thinking?

KO: It's just mathematical tricks at looking at things. Now that's of probably no general interest but... There are a number of things that are taught in engineering and science that sometimes aren't taught very much today and I think are lacking. One thing still taught in many places that's still very important is that every engineer keeps an engineering notebook. Everything you do, everything you learn, everything you run into, even if it's a phone number or a piece of data you collected, you write in a notebook. You never correct it. If it's wrong you cross it over and do it again but leave record of what you had there. Everything is kept there permanently. It may be written poorly, but at least it's there. Then there is the belief that [there is] absolute honesty in what you're doing. If a piece of data doesn't come out right you flag it as it didn't come out right. But you never adjust it so it looks right. In any experiment, you may have mistakes in it. But no one would ever waiver or even, the thought of having any dishonest is...the tradition.

Part of the ideas of science were traditional [and] came from many years past and from reading and being exposed to scientists. I bought a recording barometer and a recording thermometer a few years ago, and I felt this overwhelming obligation to keep all the records of temperature and pressure perfectly dated and filed. For no reason. It's just that if you're taking the data, you're just supposed to do that. I knew it was foolishness because there was never any need for me to have it. But it's just part of that tradition. This comes about from reading of scientists and how things are done. The other idea that I developed before MIT and afterward is the parallel between Christianity and science. The books written before those years often were about the conflict of Christianity and science. But it's obvious that the main theme of both is the same, which is searching for the truth, which implies a certain humility.

This has turned out lately to be a very important idea, I believe. The traditions of the church were never absolutes, but searching for the truth. The scientist says there are very few absolutes but searching for the truth. Today the scientist, because he's on some kick for ecology or something, will talk about absolutes he knows nothing about. And we've been exposed to so many people in the church who are absolutely sure about things they know nothing about. It's interesting to see how in both cases we've deviated from the original traditions. Some of the people in the church today would say by the way they act. St. Paul and Christ were of course, in ignorant times, but we know. And scientists today will say, "All those old scientists who always cautioned that they didn't have the final truth." That was the old times. Now we know. It happens all the time today.

DKA: I guess I'm curious that you talk much about scientist and not about engineers in your training. Do you see a distinction there, Ken?

KO: They blend together. Engineers should follow the tradition of the scientists. The engineer is the more practical scientist based on data. Very few people do much philosophical thinking after they leave school. When you're in school you think, when I have time, I'll think about these things. When I was ready to graduate and I was accepted into graduate school, I had to find a job as a research assistant.

DKA: You were going to graduate school at MIT?

KO: At MIT. Do you remember [in] "Fiddler on the Roof," they asked "Why do you stay in this town?". He says, "It's home." That's part of it. Interestingly, the class in those days didn't like MIT. Afterward they did, but I never thought of leaving and going anywhere else.

DKA: What do you remember about learning about what was going on in the computer laboratory? What had you heard?

KO: We heard nothing about the computer laboratory. No one knew anything about it that I had any contact with. Students tend to know a lot about what's going on. We had the equivalent of hackers who had access to the telephone system. People had access to all sorts of things. We knew nothing about the computer laboratory. There was nothing particularly military going on there. There was no real project except make a computer. But we knew nothing about it because the security was that good.

DKA: Was there any doubt in your mind what the computer was?

KO: Oh, I had no idea what it was. The concept of the computer, I had no idea. Entering the laboratory was a little bit like going into a religious order as a neophyte. They had an attitude about reliability and how you build electronics, which they believed religiously. You had to follow the rules. It was almost a fixed procedure that you had faith in rather than something you knew worked.

The problem they had is very obvious. They're building a ten thousand vacuum tube computer with vacuum tubes that had a design life of 500 hours. So, if you do a simple arithmetic, you could easily conclude the thing should never work under any circumstances. Very special care had to be taken to make things work. The vacuum tubes were never turned on. They were slowly turned on. They were never turned off then. The designs were done with utmost care. Everything was tested and wide margins were held in every component so that anything could vary and the thing would still work.

Then to top it off they built this whole computer with ten thousand vacuum tubes in a room, oh, twice as big as this one, [THE INTERVIEW SITE IS 2500 SQUARE FEET] with long racks. The racks are 22 inches wide, 11 feet high. Each rack was a digit, so there were 16 of them plus a couple on the end, filled with vacuum tubes. Every vacuum tube had one grid, the screen grid, which was brought back to a large telephone switch. So any tube or any collection of tubes could have that screen grid voltage varied until the computer failed. You could tell in that grouping if anything was deteriorating. That way the beginning of the day you could replace any tubes that were turning weak. The utmost care was in reliability. That was one of the secrets [of] Whirlwind, and it was one of Whirlwind's contributions to the world of computing with that extreme care for reliability.

DKA: So you got in the Whirlwind project and you began to see the whole project. What was your feeling about recognizing what they were attempting to do? Was this brand new to you?

KO: Oh, it was brand new. I was awestruck. And I loved it. Anybody who put 10,000 vacuum tubes together, I used to tell my wife it was a bridge builders personality that would build anything that big. Imagine 10,000 tubes in a room.

DKA: Had you ever seen anything that big electronically before?

KO: Oh, no, you see, during the war a radar set with 150 tubes was amazing. 150 tubes was just out of this world. You couldn't conceive of that. That building, what with 10,000 tubes, that just was way out. Now a large part of it was war surplus equipment. Many of the tubes were war surplus. It was one way of getting large numbers of things at an inexpensive price.

The history of Whirlwind goes something like this. I joined there in 1950. It started during World War II. The government wanted a computer to run a wind tunnel. They started off, [while] the war was still going, to make an analog computer. I have one of the parts of the analog computer in my office. Analog computing was too slow and they built a serial digital computer. In time it was discovered it was too slow. So they built a parallel computer, which is what Whirlwind ended up to be. It had to be exceedingly fast.

Whirlwind had just [a] 16-bit word length, which in those days was considered ridiculously small. But they were working on physical phenomena which 16 bits described as very well -- people doing mathematics had 48-, 64-bit word length. But the circuits were made very fast, exceedingly fast. Each circuit was intensively engineered and put together in very simple logic to maintain the speed. The thoroughness to the engineer and the insight into how he did use vacuum tubes, I found fascinating. I found out who the smartest designer was and sat on his side and learned from him immediately. It was Dick Best, now at Digital. [Dick Best] would design things in a way that everything was tested, and then draft in a way that anybody could see how it worked. Instead of having drawings made, all the data is there and then forget it, he would study it until it was in the form that anybody could look at it and figure out how it worked. He was exceedingly objective.

One of the problems we had in those days was that there were no oscilloscopes to look at high-speed circuits. Tektronix was not yet in business. We had war surplus, Sylvania cyncroscopes which were quite a large box with almost nothing in the box. The five inch cathode ray tube, and in order to use it we cut a hole in the top. Every engineer did his own. I learned from Dick Best how to do it. Cut a hole in the top and put the wire right into the deflection plate with no amplifier. The deflection plates had sensitivity as 60 or 70 volts per inch. So if you were looking at 10-volt pulses, you would see about a sixth of an inch high pulse on the screen.

You also had problems, if you used wire to do this it would ring and you'd get all sorts of spurious signals. But with that we developed a technique, or I probably learned it from others, where we could measure a fraction of volt and amplitude even though the picture was that small because it was all technique for making measurements, and there being no amplifiers available to make a bigger picture.

Dick [Best] was a great designer of circuits. When he was working I'd look over his shoulder and learn from him. Others were logic designers and there was something to learn from [them]. The difference between Whirlwind and the other computers at the time, there were about three or four being built, they were all six months from completion. Every year they were six months from completion -- all three or four of them.

There's a story which my friends at Harvard say was apocryphal. But the story says that, Professor Aiken at that time said, "When all the computers then being built were complete, they take care of all the computation needed in the world." And he, or whoever said that, was, of course, looking at the computation then being done and divided that into the capability of a computer and [it] look[ed] like you didn't need very many. Nowadays we have thousands of times more computing on a desk and we're still looking for more because as we get it we find more uses for it.

[The logic for] the computers then being built was designed by using Boolean algebra. It was the mathematics used to design large networks and switches. And it was directly linked to computer type work. However the people doing Whirlwind, Bob Everett, probably being the leader, approached it differently. They approached design of mathematics and the logic of the computer as if it were a puzzle, considering all possibilities and picking out the best ones.

The result was exceedingly simple, elegantly simple way of building a computer. The Boolean algebra people ended up with very complex computers. They had simple circuits and complex logic. Bob Everett's approach was very complex, thoroughly engineered circuits, but very simple logic and very fast. I like to think that we, Digital, were missionaries to the world to convince them that the MIT way was the best way. Because the MIT way is what's commonly accepted today. And I like to think we helped sell the idea. But it definitely was unique. When we started Digital, we sold modules, little blocks of logic that people could use. People would ask us how many levels of logic we could do in the speed we said we could do arithmetic. We couldn't answer that because we followed the MIT tradition where you did it all in one step. Everybody else did it in several steps and therefore it was a lot slower.

DKA: You mentioned that sometime in this period you got married. Do you want to say a word about that?

KO: While I was still an undergraduate, before my senior year, the neighbor next door to my parents had a Finnish girl visit them for the summer who was a student in this country. I didn't make out well with her at all. She went back to Finland and the summer between undergraduate school and graduate school, I got a job in the ball bearing [factory] in Goteberg, Sweden, as an excuse to go to Finland and see how I would do with her. So that summer I got there and in two weeks, became engaged to her.

My approach to things often is [to] be somewhat systematic. I kept a notebook of all the things I wanted in a wife for a number of years. Every time I heard a preacher preach on the subject, when preachers used to preach on practical things, you see, not like today, or anybody would have a lecture, or any ideas [would] come, I'd write down what I want[ed] in a wife. And when I found her, she kicked off perfectly on every point; I knew she was the one. She didn't agree that quickly. She was a Finn, [a] very nationalistic Finn. Leaving Finland was a just strange idea.

When I went there that summer, her brother wouldn't shake my hand because Finns are Finns and they don't leave. But she agreed to marry me. Then we had a terrible time getting her into this country because the rules were very strict. We couldn't get her in as a tourist or as a student or any other way. The Iron Curtain was expected to come down and then close. The Korean War was on and I had a friend from MIT who went over to Europe with me but couldn't get his wife out of Poland and [was in the] terrible position of being engaged [with] no hope of ever getting his wife out. So I went home, engaged, with a concern whether I'd get my fiancé out. I went back in December at Christmas vacation, and stayed six weeks til I got permission to bring her in. And got behind in school. [But] with the generosity and patience of MIT I kept my job there. And with her patience, [I] got the work done at MIT. It was an important part of getting anything done I got done.

DKA: Is it true that the term Whirlwind came from your romantic affair and that was applied to..[LAUGHTER]

KO: Oh, no, see Whirlwind was well underway by the time I showed up. The story, before my time, was that its military code name was "tricycle" or "kiddy car." Something trivial like that. Jay Forrester, the boss, one day came by and said, "That name has to go. From now on it's Whirlwind." So that's the only story I know. And it was a good name for it.

DKA: Your fiancé must have been amazed. Did she know you were coming over to work on?

KO: Oh, we exchanged mail so she met me there, yes. We bicycled around Finland together.

DKA: She must have known you were serious if you'd come across the world for her.

KO: Yes, yes. She never went back to Finland for 16 years. People can't understand why, [but] if you saw the film, "Dr. Zhivago" you realize that in wartime you had idea[s] never to leave your family. Once she had a new family she wasn't going to leave. Once she got back she saw the world was different and she went back every year to see her mother. But when the memory was of wartime Finland, she wasn't going to take any chances with the military or immigration people of ever getting separated again.

DKA: Back to work in the lab, what was your work? What were you doing yourself?

KO: First I was doing small projects. My first job was to make a digital to analog converter to drive the cathode ray displays. This sort of thing we take for granted today on our personal computer[s] where we have pictures on a cathode ray tube. At that time [it] was a rather unusual idea, one of the developments that came out of MIT and influenced the world of computing. Converting the signal from a Digital number to an analog voltage to drive the cathode ray tube was one of the devices I'd had. My contribution was to, here was a clever little circuit that used very few vacuum tubes and made a precise unit. This circuit then became a very important part of the core memory.

The core memory was invented by Jay Forrester, a brilliant idea. The core memory idea was not the idea of storing information in a core. That had been done before. The clever idea of Jay Forrester's invention was the way of selecting the core. So you could put thousands of cores together and select them very quickly and easily. It still took a large number of current sources to drive it. The number of current sources stifled the future development. No one had the nerve to build that many current sources. The [original] memory for the Whirlwind computer was a storage tube. The storage tube was quite large with a neck coming out of it about 8 inches in diameter. It was really a cathode ray tube with two guns coming into it. Stored on the face, on the form of dots on this, were the ones and zeros. And when it was working well, (and it was hard to get 32 of them ever working together, all you got was 256 bits per tube which meant when the whole thing was working), you had 512 bit words of memory which is a joke today, [and] even then was marginal.

It took great cleverness to solve problems without much memory. The pressure was really developing more efficient memory. Jay Forrester came up with this brilliant idea of using cores. His first idea was a gas discharge where you have a big bottle of neon and near, crossed wires a spark would develop. Would stay there for one and would disappear for zero. This idea then was to put a core at each intersection. And use that for memory. And this progressed as great excitement.

The laboratory had some very productive ideas, or ideas that made the laboratory very productive. There was a lot of trust, a lot of freedom, a lot of competition between very bright people -- but a lot of openness. And with that communication was free. And we all had to write a report every two weeks, maybe only one paragraph or a few sentences. Even if we did nothing we had to write down that we did nothing. With that the communication was very open. When you had an idea you immediately had everybody knowing about it. And if it was a good idea you had support. And if it was a bad idea you quickly realized you should just quietly go away with it.

So with the idea of how to do a memory, there was no problem of getting it across. We started a single plain memory, 16 by 16 cores. Each core was a ceramic bobbin, about a quarter of an inch in diameter, maybe an eighth of an inch diameter inside. Wound on that was a very thin foil of magnetic material and then heat treated to make sure there were no tensions in it and that was the core. There were four wires strung and then in order to drive it, it took 16 current sources times four. Two for each coordinate and that same thing again for reading and writing. The idea worked but it still had so many vacuum tubes in it scared people. People still didn't feel bold enough to build a big core memory.

I had an idea for using a magnetic switch to eliminate all the current sources. Get rid of all the tubes and drive them with magnetic switch or drive them with cores, which were selected the same way memory cores were selected. So when I quick changed my thesis, somebody else finished the original one. And it worked. It never was a great success. It never really contributed an enormous amount to anything except for one thing. It was a great academic interest. At least to me. But what it did do was, for a while, got rid of the hang up people had about having too many tubes. So there was a spurt of interest in core memories. It solved the problem in people's heads. They went off and built it with vacuum tubes.

But the contribution of the core switch was it got people's hang-ups to disappear long enough to get enthusiasm. The story [that] goes parallel with that is (and I didn't know about this until just lately), IBM's next generation of computers use core memory switches. But I never knew that. The problem we had with the core memory, (the first one was going to be 16 by 16 or 256 words, and 16 digits long), was how to test it. We understood from experience that you really had to test every possible combination. Because [no matter] how thoroughly you designed things there's always something that might go wrong or some combination of things that might be wrong. And people were not about to trust the core memory unless it was truly tested in an environment that was tested. So we set about to build what we called a memory test computer. It was supposed to be an honest to goodness computer that would really run and test the memory, but not a computer that designed to be useful.

I was given the job of building the computer just as soon as my thesis was done. I think I was still a graduate student and it cost a million dollars. I can remember being impressed of how much a million dollars was -- how much work it took to spend a million dollars. Now I'm impressed at how little effort it takes to spend a million dollars. So we built a 16-bit machine. My way of showing off was to build it in a room in a straight row of racks with a console in front of it, with enough room for the photographer to stand back and take pictures of it. We naively showed off by saying, look how easy it is. That's kind of the young academic approach. The problem with that was that people believed it was that easy and never took it seriously. We learned later, for the next machines I was responsible for, to do it with a little more flair than that. We made a homemade wooden console with cabinets from the local distributor. Afterward we learned to put color in it.

The machine ran well. The first night it ran, my wife was out of town, and we stayed late at the lab and it finally worked. Everybody else went home and I stayed there and listened to it work. We put a loud speaker on every computer we built because you always wanted to be able to play music or make it do things. So I had the computer on the loud speaker and as long as the tone was constant I knew it was working. So I went in the ladies room and laid down on the sofa with the door open and fell asleep with my ear tuned to that sound so I knew that it went all night long without a glitch and that was a significant test. As soon as the machine was truly completed and within one day of it being working, the people in charge made the decision to shut down the storage tube lab and switch everything over to the core memory. The second memory was started immediately. The first one, we painted everything. The second one was bare aluminum because we weren't going to take the time. So we had two memories there. Whirlwind, the memory test computer was there without a memory. The machine we worked so hard on suddenly, instantly was sitting there with no memory, and therefore quite useless for a while.

Today we tend to build computers by putting them on a small board and designing everything right there. But an important part of the early development of computers was to make them modular so that things that were used many times were made identical and used over and over again. It wasn't always obvious. Not everybody agreed with it that way, but one of the first modular approaches was Whirlwind. This is one of panels of Whirlwind. [HOLDING RACK FROM WHIRLWIND COMPUTER] There were probably 16 of these all in a row, all identical. The original theory was, if one went bad, you took it out, replaced it.

At Whirlwind it never quite worked that way because it was easier to troubleshoot in place because you could reach behind, take out a vacuum tube. Those tubes had the advantage because they didn't fall out easy, but they didn't come out easy either. You could change a part and troubleshoot without turning off the power. There was 250 volts positive, 150 volt negative. You could learn by touching it, approximately [what] the voltage was. But shutting it down was such an operation you never thought of shutting it down. You did things carefully, you never thought of hurting yourself, but [because] you could ruin something if you did it poorly. The parts today looked antique. The capacitors were mica with foil between them embedded in Plexiglas. The resistors were carbon and normally not very precise. The terminals were, for some reason I can never explain, silver-plated. It sounded quality. But they corroded, were impossible to solder and created all kinds of problems. But that was the tradition of the day.

The Whirlwind was made up of these modules. I don't know what this one did. This one was a program counter. This was one digit of a program counter. So, as your program went step by step, it kept track of what the last step was and set up the next step. I think there were twelve digits of the program counter so there are twelve identical units. They're put in a row and they would keep track of how many steps the program went through. Supposedly there was a spare and you could have swapped it. It just happened to never to be done. The next step in modules development at MIT was to make true modules where there was a large number of the same thing and they look something like this one where you not only made it easy to swap units that were defective, but you also gained density in the third dimension so that you could get a lot more stuff in a much smaller area. This was a module used for building MTC computer out of...

DKA: How many tubes did the MTC have?

KO: Thousands of tubes.

DKA: And this was the reason why because you had thousands of these components?

KO: Yes. So there were hundreds of these components. Most of them had just two tubes in them. With transistors it was much easier because with these, each tube had approximately five, ten watts of filament power. That meant that every time you built something, you had huge transformers just to drive the filaments. The voltage on the plates were 250 volts. Any current of 250 volts had a lot of power. With transistors, life became easy. The first transistor computer we built at MIT was the TX-0 computer. I didn't have faith in putting

[transistors] in circuit boards. Maybe it was poor judgment on my part. But we built them into a tube like this. [HOLDS BOTTLE FROM TX-0]
There was one transistor. They were fit in a small socket. Then you could have a high density, and they had color codes on the top so that if a red one went bad, you'd just put another red one in. These transistors were made by Philco. They were the last of the high-speed transistors. No one else could make high-speed transistors. So we grabbed hold of and designed circuits to match their characteristics. They were so delicate that if you combed your hair and touched one, you burned it out. It took a special set of circuits to do it. They cost several dollars each. The next computer module we built was the TX-2. We had printed circuit boards. [HOLDS TX-2 MODULE] This module we designed for high density. We had real solid, secure sockets we thought at the time. The printer circuit boards were here in special metal size. It looked quite attractive. It also was color coded with colors on a handle. The transistors are through that hole there and other components are laid out and you can see the components become more moderate now. They're more compact. They look a little more professional. The connector is solid and rugged and shows our lack of faith in connectors at the time.

DKA: Ken, is this again something that you designed all the circuitry on?

KO: In general [the design of] the circuits involved many people. The idea [of] these circuits, I probably did when I was all alone on a project. But in time many people got involved. One of the ideas they had at MIT before I showed up was to make what they called test equipment. It was a set of modules that would do single operations like a flip flop, a gate, a delay unit. With those you put on your experimental bench, develop an environment for testing a circuit. That detail[ed] testing of circuits was possible because of testing equipment. When we started Digital, the first product we had was the equivalent with transistor computers and this is one of those. [HOLDS DEC LAB MODULE] You could arrange these in a rack and do specific operations at a speed that no one else could accomplish at the time. But you would wire them together with these pigtails and make a counter, set up pulses or anything you want to do for testing. That was our first product. It allowed the rest of the world to design the logic they needed for military projects and other computer projects.

When we wanted to make something permanent like a computer, our first computer, we took the same circuits and put them into a frame, which could be stacked quite densely without the cover. These we called our system modules. They were a key part of the business for many years. The transistors had changed by this time. The components had gotten smaller. We had a unique idea in driving these. We said we would make a simple rugged power supply and design the circuits to tolerate the variations in the power supply. We also used diodes to generate three volts, the base voltage right on a board which meant this was almost completely tolerant of noise on the power line, lightning or anything else that wiped out computers at the time. That made our computers very rugged. When some of the space programs, everybody's computer was down. Ours was still running because we generated our base voltage right on the board.

DKA: You were talking about what service that component provided. Could you go through a bit of that again?

KO: We had a box for every circuit you'd want to build a computer or computer environment. This one happened to be a pulse amplifier.

If you look at the diagram, there's a gate and an amplifier. So, if you put in two signals here and they were in the right combination, you'd get a pulse out here at a standardized size. Other boxes would be a flip-flop that would store information. A complex set of gates which would allow you to do logic and delay units that would allow you to accomplish other activities. With that set of pieces, people could do almost anything they want to do at high speed.

DKA: The degree to which you did modular thinking, was that unusual in this business at this point?

KO: No, no. By this time it was quite commonly done.

DKA: And what's unusual is the ruggedness with which your components were designed?

KO: On almost anything someone does in the computer business, you can go back in the literature and prove someone had done it earlier. In the case of going in the business selling modules, there were 45 people doing it at that time we went in business. All doing poorly. Our contribution was first of all we had the circuits we took from MIT which were fast. No one else could do fast runs. We also had an interesting business idea. Most of them went into the customer and said we will charge you ten percent less than what the other guy offered to sell the same thing for. We went in and said, here's our literature, tell us everything we know about the circuits and here's a fixed price list. And there's no dickering. With that we changed the industry in a year. Everybody had a set of literature and everybody had a price list. That was our main contribution besides speed.

DKA: You had good circuits but you also had a winning strategy.

KO: Yes. The chronology, as I remember it, this [HOLDING WHIRLWIND MODULE] was probably designed in '48 or '49, well before I came to Whirlwind. Probably [at that time] the first module was built as part of the control element of Whirlwind. This module then was designed about 1950, '51, for more or less high production. The transistor work, the transistor computers we started '55 or so, '54. We were working on air defense system. I spent a year at IBM representing MIT. As a rest cure, they allowed me to work on transistors, outside of the defense part of the business, which everybody else was working hard on. I could have no staff or space. And then these came [HOLDING TX-0 MODULES] probably '54, '55 and this one '56 [HOLDING TX-2 MODULE]. And then as we started Digital, this one [HOLDING DEC LAB MODULE] was '57, '58 and then on.

We felt quite confident with the way we were building computers. We knew we could do almost anything we wanted to do, but the big limitation was the memory. Storage tube memories weren't reliable, worse than that. And they would never be big or fast. [When] the idea of the core memory came along, it just raised the possibility of making real computers. Here's a plane from one of the first ones we built. [HOLDING WHIRLWIND CORE PLANE] You can see there's a thousand-twenty-four [1024] cores arranged in a square array.

The way it worked was quite simple. The direction of the magnetization in a core decided whether it was a one or a zero held there. If you put current on one line it never was enough current to switch the core from one state to another. But if you put current in two lines, where the current went from two wires to the same core was enough to switch it over. With that you could select a core and read a one or zero into it. This meant, however, 32 drivers on this side and 30 drivers on this side for just one direction of current. Plus another 32 and another 32. That meant 4 times 32 drivers. You can see those on the memory here. Here's 32 drivers. And here's 16 drivers times 8 around here which ended up being able to drive 32 lines, 4 directions. Each driver just contained one tube and one small tube. That drove a good half-ampere into each wire. This plane comes from one of the first two core memories built. And right here we have a complete memory, which happens to be the third one. [POINTS OUT WHIRLWIND CORE MEMORY STACK] By the time we made the third one, the plane's a little smaller. But you can see there was one plane for every digit of the memory stacked up here. The drivers going in each direction came from these four sides top and bottom. There's a wire for each of the digits here. This made a thousand twenty-four [1024] quite reliable core memory, and this made computing truly possible.

DKA: How many numbers could you store?

KO: The 16-bit word, they called two bytes. So there's a thousand words, or 2,000 bytes, which then was a large number. Today a kid with a personal computer would laugh at you for having that small a memory. The core memory revolutionized computing because it gave the promise of great things. At the time we never dreamed of large memories because every core has to have five or six wires put through it. But in time, as the demand grew, the capability of making them grew. People invented all kinds of machines to do this automatically. But to the very end, the bulk of it by far was done by girls stringing wires with long needles.

We at Digital at that time were a small part of the computer industry. But at the peak of the core business, we alone made four billion cores a month. We had girls in Taiwan string each one of those with five wires through them. Now I have in this little saltshaker some of the cores we made. [HOLDS SALT SHAKER CONTAINING CORES] When it was full it held a million cores. They are so small that I can't see the hole in them, even with my glasses. I think they're about 8-thousandth of an inch in diameter, and the hole is about 4-thousandth. And they're the size of pepper grains. I can see the hole, but the idea of putting four wires in there and doing it with 4 billion a month is just astounding. Here are the specifications for its size and its chemical mixture.

Now with that, people made big memories. And the computer business spurted forth. The minicomputer business became practical because we could make inexpensive, very powerful, quite large machines for very little money. Since then, the semiconductor memory has taken over. It is just so much easier to use. It's so inexpensive and when you hear about one, four, eight, sixteen-megabyte memories, they're made up of little tiny chips of ceramic doing the things that we used to do with cores. So as miraculous as these little cores were, the miracle of the semiconductor memory is much more so. And it continues to get better every year. The prices go down, the size goes down and there seems to be no end.

The little things that we take for granted, now we have computers in our automobiles and computers, in our microwave ovens, and computers in our washing machines. It comes about because the memories now are so cheap. But a key part in the history of computers was this ceramic core memory. The first core memory we made, we only made an experimental one plane one. It had metal cores. It made a very thin foil to make them fast. We knew that it was possible to get magnetic ceramics called ferrite that would have the characteristics we wanted, but the builders of ferrites didn't think it was very promising.

One day a company in New Jersey brought some samples made on a washer dye, about a quarter-inch diameter. We jumped at those. My thesis came out of using those. And with that small, then very large, about a quarter - we call[ed] them Cheerios because they're the size of the breakfast cereal ring. From that came smaller and smaller ones and the small ones I still get stuck to my hand, are the limit in how small they got. But developing the material was a different story. MIT set about the traditional scientific way to pick the best mixture of materials to make these. There were three components to the ferrite; ferric oxide, ferrous oxide and magnese dioxide I believe. They all cost about a dollar a pound. But the mixture of the three compounds took a long series of experiments. They tried every combination, plotted them out, fired them, tested them, and decided what the mixture was. The ceramics company in New Jersey, an old German ceramicist who by guess or by intuition, or years of experience, mixed up his first mixture and hit exactly the same spot as all the research done at MIT. It shows a place for science and there's also a place for intuition.

[STANDING AT THE TX-0 COMPUTER] When I was given the opportunity to work on a transistor computer, the idea was kind of new, it was exciting and we had knowledge of the very fast transistor, which we had built a very fast computer. The rules were, I could hire nobody and have no space. I studied the rules carefully and found all the loopholes. I somehow was able, one way or another, to get three or four people to work with me. We discovered that hallway was not space. So we moved my office into the hall and put walls around it. We then traded that space for a space in the basement, which was less desirable but bigger. With that we were able to do our work.

We discovered that part of the basement in Lincoln Laboratory was non-finished. It was just dirt. We talked people into pouring concrete floor there and then we talked people into putting a light colored floor. When they discovered what we had done they said, never again. We talked them into twice the light level of anyplace else in the laboratory. And when they found that out they said, never again. And then we had the walls with different color. The walls there are just normal military type. I can't remember if it's beige or green, you know it was just a bland color. We had a bright color. And then we set about to make a computer that would attract attention.

We discovered with the MTC [MEMORY TEST COMPUTER] computer, that blah looking computers, never really attract attention. People, you'd think, particularly scientists, would be interested in the specification, the capability. But things have to be colorful to attract attention. So we set about to make as modern a design as we could. Now it looks quite naive. But this is it. You know it had rakish lines like racecars were supposed to have because of the way they took pictures of them. And we picked a color which is just as opposite from the traditional black wrinkle finish which was World War II.

The modern color used by the laboratory was gray hammer tone. It looks so military and blah. So brown and beige just seem like a dramatic change. And that's why we picked this color. And we tried to make it look a little modern. About as modern as we could. The result was when head of the laboratory had visitors he of course brought it to our laboratory because we set the computer back from the door for good pictures and showed it off with a little bit of flair. It was the place they took visitors. Even though we didn't break any rules, we exploited all the things they didn't have rules on yet and made one that was more exciting.

The construction of it is all the things we had learned to put in computers. There's a loudspeaker and amplifier underneath the table for playing music or anything else you want with the computer. The cathode ray tube we automatically built into the computer. At that time there were 4,000, I think 4,000 lines because we focused on one spot at a time instead of a raster like we do today. We use the light pen, which is the equivalent of the mouse [or joy stick] we use today. This is what we use in the aero defense system. With that you could draw, play games and all the things you do for the house today. We used to have a light bulb for every flip-flop. We used Japanese model railroad lamp bulbs. We were joking that we probably confused the industry watchers over there with that order for lamp bulbs. The model railroad business was booming. The machine is made of these little tiny bottles and larger modules. It made it quite easy to make the unit. The transistor was fast but very fragile. The circuits had to be designed around the transistor. It took 12 transistors to make a flip-flop. I believe it is the design that grew into that integrated circuits logic which has become very popular. Because they have exactly the same problem with the power and the transistors as we had there. And so these circuits, I think, were the basis for the modern computer circuits.

The circuitry in this computer was built around the Philco surface barrier transistor, a magnificent piece of design for a style transistor which was just about to become obsolete. It was very expensive but very fast, and very intolerant of power or spark or discharge of any kind. But we designed the transistor circuits around this. And we made them very fast and the circuits, I believe, were the basis for the commonly used T-squared-L [TTL] logic that people build computers out of today. The reason for building the TX-O computer, this was about 1955, was to demonstrate how efficient in power, how fast in speed, and how easy it would be to build a computer for a defense. Now the project wasn't classified. We published everything. We told everybody. Had a lot of interchange with the rest of the world. But the goal was clear that if we had a chance to make defense computers over again, it's obvious that doing it with transistors would just save so much heat and so much space and be so much faster.

This is a very close to being equivalent to the modern personal computer. Someone sits down in front of the oscilloscope, with a light pen and plays games, does things, is creative. Word processing wasn't yet developed. Games weren't yet well developed. But in general it was, you might say, one of the first personal computers.

We designed it as a demonstration but then people did computing on it. When they had a problem that would lend itself to this they used it for computing. They'd bring it [THE PROGRAM] in the form of a paper tape which they generate on a flexowriter. As they typed it, the paper tape would write the information. In the same way we store things on a disk today, the high-speed photoelectric tape reader would read that tape very quickly and then they would go ahead and do programming.

DKA: When you say this is kind of a personal computer and you talk about pictures, [Creating Images On A CRT With A Light Pen] it really confuses me because it so little resembles the PC and I still don't know.

KO: Oh it's exactly the same as a PC. You see what you see in a PC is the keyboard. The cathode ray tube and the light pen. So this is indeed a PC. This [THE TX-0] was designed to be a demonstration of the reliability, the capability of transistor circuitry. And making a fast, inexpensive low-powered computer. The unit itself really could do what a personal computer does today limited only by the fact that the memory was small. You could make pictures on the cathode ray tube, change them, modify them. Read your program in, take your program home, play games, do the things you do today on a much smaller scale because the memory was very small.

DKA: Did you see text on the screen?

KO: Oh yes, the text was very commonly done on the screen. Now as I remember this was an 18-bit machine. All the machines we had up until then were 16-bit. It was 18 because we stored a character in 6 bits. Therefore we could in one word store three very efficiently. So we went to 18 bits just to store characters. When we started Digital we also had 18 bits because we could store 6-bit characters. The world standard later on became 8-bit characters and we all went to 16-bit or 32-bit computers, interestingly, which was the ones we had originally. So this is in a very real sense a personal computer. You could even say that of Whirlwind. It took 2500 square feet. The console was a walk-in room as big as this loft here. But in a real sense it was a personal computer and did personal computer things.

DKA: Do you want to talk, Ken, about how some of the ideas and some of the thoughts and plans that you had when you developed this computer led you to think about your own computer business?

KO: When this [THE TX-0 COMPUTER] demonstrated the usefulness and [the ease of making] computers we started a bigger one called TX-2. People often ask what happened to TX-1. TX-1 was the first one designed and I said, "no way are we going to build that one. It's too complicated for a first one." So we built the simplest possible machine, which was this one and then skipped TX-1 as a name and went to TX-2, which was a very large machine. I was building the hardware. Somebody else was designing the logic and they couldn't settle down.

So after a year or two of that I got impatient and left. That was '57. There [were] a number of reasons for leaving. One was we [had] published what we had done, demonstrated that you could make computers very effectively, much better than anything done with vacuum tubes by far. The commercial world just smiled at us and said we were just academic. Of course, today, we smile at people at MIT and say they're just academic. So just showing them it could be done was one of the reasons for going into business. The things we took from MIT were first of all, the idea of an interactive computer, which was unique. In those days you dropped your problem in the form of a stack of IBM cards in a slot. It went into the IBM machine. The next day you got your answer back, and it usually was [that] you'd made a mistake.

With interactive computing, you put a problem and you'd try something and you [were] instantly told it was a mistake. You could interact, get things done fast, the things we see in personal computers all the time. That concept was strange and the idea that that concept should be introduced in the world. Even more important than that, however, was the demonstration we had at MIT that where you had a group of people who were bright, wanted to work hard, but if you showed trust and openness and confidence and let them work hard, they could turn out amazing work. So the human ideas that came from MIT were probably the most important. These are the ones we tried to maintain at Digital where we hire the best and we can hire the best because we have the ideas. And then trust them, set the general goals so they know where they're supposed to go, but then give them freedom to be creative -- propose, argue, and then show great trust and great confidence and they do wonderful things. Those are the ideas we had at MIT.

There's one other reason, too. I always thought that what I wanted to do was experiment with electronics. I'd gotten to the point where I thought I could talk people into any project I wanted. That probably wasn't true but I had that feeling. There was one thing missing which I never thought of before, and that is nobody cared. It was important to do something they would care about, so we set about to do something in business that people would care about. And that's how we started Digital.

DKA: What was it that people didn't care about? And what was it that made people care about?

KO: We demonstrated all the ideas of high-speed transistor computers, and we thought the world would be waiting in open arms for this. Nobody cared. And it turns out that it takes more than ideas. You've got to sell your idea. So we set about to sell the idea. Now there are some lessons there for people. One of them is it seems like being left alone doing research would be satisfying. Basically it's not -- unless somebody notices it. And secondly, getting an idea, no matter how good it is, isn't enough. You've always got to sell the idea. Putting color into this thing was part of selling the idea. And that's what we set about to do at Digital.

The idea of starting a company was not well developed then. It was strange. A number of companies had started during the Korean War. A number were no longer in existence. In 1957, many of them were in trouble. A recession was starting. The idea was not a popular idea. We were told that the American Research and the Development Corporation were set up just to do this so we went to see them. That's the business they were in. But they were worried because some of their investments hadn't paid off very well. But they were fascinated enough to listen to our proposal. They told us we could go to their board of directors and present it and see what happened. They gave us three bits of advice. One was, don't use the word, "computer." Because *Fortune* magazine said no one was making money in computers and no one was about to. So we took that out of our proposal. We were going to make modules first, anyway. And they said, "don't promise five percent profit." You see we looked in the library. All good companies seemed to make about five percent on sales. The staff said that if you're asking someone to give you money, you've got to promise better results than that. So we promised ten percent. And we made about ten percent most of our history. If we had looked for five, or aimed at five, we probably never would have made much more than five. The third thing they said was, "most of the board is over 80, so promise fast results." So we promised to make a profit in a year.

The other side of the story is that we really did, after 12 months, make a profit. It was so small you couldn't tell if it was plus or minus. But it was like $3000 plus. And we brought it down to General George Doriot. [HEAD OF AMERICAN RESEARCH AND DEVELOPMENT] We dropped the financial statements on his desk. He looked them over and looked up and scowled at us, which kind of set us back. He said, "Sorry to see this. No one has succeeded this soon and ever survived." His lesson of course, was, success is the worst danger in business and in everything else. Maybe because of his warning we're still here. But that's also proved to the rest of Digital that success has done more harm to people than anything else.

DKA: Who is General Doriot?

KO: General Doriot was a Frenchman, came to MIT, but went to Harvard instead. And became a professor at Harvard Business School, for many, many years, in the 20's. [During] World War II he became a general in the American army with a terrible French accent so that when I met him I didn't know which army he was a general in. But he was very popular as a professor. [He] has a strong following still through the business world, his lessons being very practical. Integrity, quality, honesty, doing the right thing. He also then became President of American Research, just to start new companies. His contribution to us was to encourage us, give us support and show patience and encourage the characteristics, which he always taught in his classes.

American Research was unique in a number of ways, probably all based on General Doriot. First of all, they were the granddaddy of all risk capital companies. Since then there have been many risk capital companies. None of them have accomplished what American Research did. Some of them are financially more successful, but they never made the contribution. American Research, the General, had the belief that they made the long-term investment. They wouldn't buy and sell companies at the first opportunity. They would stick with, [and] work with, the company until they were successful, or until they failed.

This sounds obvious, but it's very hard for someone who owns a major part of the stock to be patient. The General really preached this and really practiced it. It was his contribution. We did well for most of the years. Any other company would have attempted to sell when somebody was doing well and clean up on the profit. When things were going poorly, people would be tempted normally to sell to get rid of the problem. The General was patient then, too. He also had a lot of simple rules for running a business, which are always helpful to keep in mind. Most of his ideas he didn't present in a way you had to accept. He presented them in a way, which, after it was done, you thought [you had thought] of them yourself. Or if you didn't accept them, there was no hassle. There are a few exceptions. He said you never want a lawyer on your board, you never want a banker on your board. These are black and white and you'd have to definitely go against the General to pick either one of them. He was always there as a mentor and for help.

When we started Digital there were three of us. I had asked a friend from Lincoln [Laboratory] whom I had worked with to work with me on a proposal. I pretty much had the technology worked out and Harlan Anderson and I studied history of other companies and the financial statements and laid out a pro forma, financial plan for the company. And then proposed it. When we started, my brother [Stan Olsen] joined us the first day. We bought the machinery and started the processes and made the silk screens, and etched the boards and dipped them in solder. We did everything, the three of us. In time we hired secretaries and a few other people. We grew quite slowly. American Research gave us $70,000 and that lasted eight years.

The nice thing about $70,000, you can watch each one of them. We bought things in the hardware store. We were very cautious and very careful, and learned a lot. We learned a lot about accounting. We learned a lot about manufacturing. And we grew consistently. The opportunity to do everything is something exciting in itself and very satisfying, an important part of starting a business. That part I would recommend to anybody [who] had the opportunity to do.

DKA: You said you learned a lot of things. I assume the things you learned helped you succeed.

KO: Well, we learned a lot of things. Some were useless and some were... how to keep pigeons out of the building. Not particularly useful afterward. But just understanding how accounting systems work and personnel problems. How you hire and how you fire. How you purchase. How other companies work. [These] are all things you learn when you're small.

DKA: What did your customers think?

KO: The potential customers were readily easy to define because they were people who wanted high-speed circuits. And so we went to trade shows and we'd call on the people we knew. It was always touch and go. We were profitable every year but you very rarely have so many orders that you feel completely secure. It's just the nature of business.

DKA: What was it you were offering?

KO: To start with, we were offering modules for laboratory use that were faster than anyone else [was making]. So people would buy our modules and experiment with high-speed computer technology or test devices they were building. This was our first offering. Later on we offered modules people would use to build things they were going to sell to others. Then we offered computers made out of these modules; called the first one our PDP-1.

DKA: What else do you want to say about these early days? How did your wife, for example, feel about your going into business? Did she feel worried that you were taking this big step? Or was she supportive?

KO: I can't tell you why, but she was never worried. We probably came from a different world. You never had much in the Depression and you didn't worry about having much. She had come through two wars in Finland, and much of her life, never had enough food to be completely satisfied. You never really worried about failure because you know, it didn't make any difference. So we didn't have anything, we didn't worry about anything. So that was part of it. The pay was what I had gotten at Lincoln Laboratory. So the risk we never really worried about. Now the risk in business is the different risk. And that is, when companies fail, it's a miserable death. They fail and if anyone has an emotional involvement, it really is agony. But it's not the risk you think of normally, the financial risk or something. It's the risk of watching something die. So that risk we didn't worry about. We didn't think of.

DKA: What was your own personal challenge? What was the demand on you that was most acute in those very early years?

KO: The excitement, the fun, the thrill was to do everything. This also, of course, put certain demands on. There are only so many days of the week and so many hours in the day. Balancing that with family was always a challenge. But it never really got out of hand. I never really felt overworked. In general it was very exciting. I came home for supper every night, spent the weekends with my kids. There's always a list of things to do. And you just systematically go through the list. Early in the morning, walking in the woods. Just generating that list of things, keeping on balance. And then click them off one at a time. And as long as it's approached systematically there's no great tension. If they ever jumble up in your head and you get behind there can be quite a bit of tension. But in general it's quite clear what should be done -- not trying to do things that are impossible -- and not worry about the pressures that other people would like to impose on you.

The pressures on someone in business are to take part in every outside activity, go to dinner for something or other every night of the week. Most of them are useless and most of them have nothing to do with the business. Saying no to them is a major operation, a major key to survival.

Another story which I tell when people ask me what they should do to learn to run a business, I say, jump at the chance to run something. If you're working, offer to run the cafeteria, the parking lot, things nobody else wants to run. If you have an opportunity to run something in town or in church, just run something. Manage it. You learn to manage by managing. But don't think management comes from a book and then you're suddenly going to do it. I told the story of how I got started from an MIT point of view.

The other story I tell was that when I was 30 I was drafted to run the Sunday School of a large Boston church which to me looked kind of large and stuffy. Everybody was old. They must all have been fifty -- some of them quite a bit older. I accepted the job. The first thing I did was go to the Lexington library and take out all the books on management. I can remember what I learned then. I can't remember anything I learned since then. But approaching every job because it was a management job, and learning, it's an excuse to learn something. My taking that job was probably a key part in learning and being interested in taking on a management job. The other thing is that getting people to work enthusiastically is always a challenge. You obviously can't do very much yourself. But if you can get others to feel it's their job, their invention, their contribution, they can get an enormous amount done. Making sure they feel that way is a key part of it.

DKA: I wondered if you wanted to talk this morning about the team of people that you brought together to work with you and the principles that you had them follow as you moved towards this first product, the PDP-1.

KO: Developing and managing an organization like Digital is a compromise or a set of paradoxes, or conflicts between leadership and giving responsibility to others. It's obvious that leader, myself in this case, can never be expert in everything. We have to be dependent on those people who are. They obviously have to do the design, set the goals. They have to have the motivation that comes from them, setting the goals. And yet we have to have a common goal and that's obviously the job of the leader.

What I did for good, or for not so good, is probably demonstrated many of our products. Here we have our PDP-1. The background I had, the experience I had was the design of circuits, the design of logic, how you did arithmetic with transistors. But early in the history of Digital we could hire people who were expert in that. The area we couldn't hire people were the making of power supplies, the putting together the packing, the industrial design. So, in that case, I gave the responsibility for the things I had been expert in to those whom we could hire.

DKA: Ken, what would you say was the overall goal in making the PDP-1?

KO: The goal of the PDP-1 was to introduce a new type computer to the world -- in the tradition that was developed at MIT where the computer was very simple, very fast, relatively inexpensive. In this case, [the price was] $110,000 with only 4,000 words of memory. Because it was simple, easy to use, interactive with the cathode ray tube and light pen, it could be used by an individual. Someone could afford to sit there and use the computer like we do [with] a personal computer today. You could also use the same equipment interactively with equipment, that is, with a machine or a telephone system because the price was relatively low.

$110,000 thirty years ago was a lot of money, but computers then cost one, two and three million dollars, so it was relatively inexpensive. And it did open up new applications that people hadn't thought of before.

DKA: Why hadn't anybody done this?

KO: First of all, we had experience with the technology. After years at MIT it was just natural to us. The concept of an interactive computer was strange. Some people thought it was wrong. Almost spoke in ethical terms. Computers are serious, you shouldn't treat them lightly. You shouldn't have fun with them. They shouldn't be exciting. They should be formal and distant with red tape involved. That was the atmosphere at the time. So it was a strange idea. The other motivation we had was that we believed computers should be fun. They were exciting. They could do so many things. The opportunities were just without bounds. This was a great motivation in building a computer. But it was not commonly shared in the industry. Now, the other reason of course, was that using vacuum tubes in the older technology, the machines were big. They were huge. And they were expensive.

DKA: As you look at the history of computers in this period, you see people focusing on operating systems and getting batch processing and more efficient use of computers. Was there a thought that this wouldn't be an efficient use? Was that part of the concern?

KO: The original computing was based on the way people had done computations before. You'd collect all the data, bring it together, process it and send the answers back. The idea of processing it, real time, took a long time to develop. In the world of commercial processing, it's just in the last few years that batch processing has started to disappear. The replacement for it is now called transactional processing, where if you make a transaction with a bank, it is instantly taken care of. Your accounts are updated. And you could have a new transaction almost immediately. So, 30 years later, it has influenced the commercial market. That was dependent on software and large computers that were fast.

DKA: Did this PDP-1 conceptually have any relationship to what you've just described?

KO: The PDP-1, we like to think, along with the circuits we were selling, was a vehicle for introducing the MIT ideas into the rest of the world of computing. The idea of fast simple machines was strange in those early days, and we like to think that we helped change the world. The MIT tradition came about because we were working with physical phenomena. In aero defense we divided the country up into 16 bits and that was close enough for defending it. For most physical phenomena, 16 bits is enough. The rest of the world ridiculed anything [with] that short word length. And, as you well know, 16 bits is the most common of the powerful personal computers today, and up until just lately, most minicomputers. So even the word length probably came out of the MIT tradition, and the PDP-1 tradition.

DKA: Ken, did your whole team have a common feeling about this objective, or was there difference in opinion as to which direction you should go in computers?

KO: When it came to details, we had all kinds of opinions. We spent a lot of time arguing, and openly exposing all the differences. But the firm belief that the world needed fast, inexpensive computers that were interactive was just accepted, without question. We also believed, now maybe this sounds a little naive, that every computer had to have a cathode ray tube. I mean it was inconceivable -- but that you wouldn't have one with a light pen. Also, every one had an audio output. I think somewhere, under this console there's one. Because it goes with interactive computing. If you lost interest in everything else and you were alone with the computer, you could always write music at night.

So that sort of thing was just accepted in the environment. Along with the idea that computers are fun, exciting, and that anybody can learn them -- from a young child on up. When we asked for money we may not have mentioned that computers should be fun. But every time we reported to them, we reported that computers should be fun and exciting and therefore very productive. The demonstrations we put on in the stockholder's meeting of American Research, which owned almost all the stock, demonstrated the fun and the interactivity and the responsiveness and the productivity that came from it. So we openly presented this.

When we were at MIT, we at Lincoln Laboratory gave to the educational part of MIT at the TX-0 computer. Then when we started Digital we gave one of our first PDP-1's to MIT for use by the students. The students could then have opportunity to use that machine anytime, 24 hours a day, and they could sign up for it months ahead and do anything they wanted. They learned more about the computer and how to do things with it than probably anybody had before that because you had dozens of bright people spending all hours of the day studying this. Out of this came what we know of today as video games. We had played fixed games before in an oscilloscope like kalah and the Asian games that you could demonstrate here. But what we know of as video games came out of that group at MIT. These always made great demonstrations -- Spacewar! being the most exciting one. It's still showing in the [Computer Museum] museum. And very close, you can just see that out of that came what we know today as video games. This made a great demonstration for stockholders.

We also played music. I think we had a four-part Bach we could play. We did feel passionately that we had an approach. We were too much scientists to say we invented anything or it belonged to us, or uniquely ours. But we did have this missionary zeal to introduce these technologies to the world. And we got great satisfaction to see it develop, both in the world of human interaction and machine interaction. Interacting with machine tools or laboratory devices or telephone lines. It was the goal we set out to do. It was a goal we formally stated. And this worked out very well.

DKA: Ken, you talked a lot yesterday about the modules that DEC first made as being your initial product. What's the relationship between the modules and this initial computer?

KO: Digital devices are made up basically of just a small number of circuits. You'll put various combinations of signals in and if the right combination is met, the signal gets through.

Then there are amplifiers and things to allow you to run by drive things, or run distances. In making up modules out of these building blocks our original customers could build up computer like devices, or actually computers. We then used them to build the PDP-1. This is the back of the panel but those modules plugged into the back. [POINTING OUT PARTS OF THE MACHINE] These were all wired up and soldered by hand. But the correct modules plugged in the back. If they were defective you could change them easily. If you designed them once and tested them thoroughly and then you used the same ones many places. I think there were probably 20 across, 20 times 20 or 400 modules. Maybe it was 600.

DKA: How did you make it so fast?

KO: The approach to the circuits which evolved at MIT was to set about to make the circuits fast and then the computer simple. It meant very expensive circuits. The transistors cost $12 each. Maybe by the time of the PDP-1 they were down to $6 or $8. That's very expensive. So the circuits in the modules were very expensive, but the result was basically a very simple machine, and one we could readily build and that operated very fast.

DKA: Tell me about the sales of this machine. Who wanted it and what did they think about it when they got it?

KO: We had contracted with some professors at MIT to do the software for us. They didn't come through. We then announced the machine as the machine without much software. So, this was a challenge to a group of customers who wanted to do their own software. The applications normally went to the scientists.

[REFERENCE TO MACHINE ON EXHIBIT - This machine here is not as good looking as the original one. The frame over the cathode ray tube is for hanging a camera on. This ugly bracket was for holding a camera. And it probably was used for high-energy physics experiments. They could take the data, project it on a tube and photograph it. And that was the general application.] The American International Telephone & Telegraph bought a large number of them to collect teletype messages, stored them and then distributed them to the phone lines that were free at an optimum rate rather than storing on paper tape and doing it manually like they did before. So that was an obvious application for it. Our early customers jumped at the chance to [develop their own software] for their special projects.

DKA: One of the things that DEC is well known for is working closely with customers. Was that part of what you had to do then almost as a necessity?

KO: One of the exciting things about this business is that you have such an interesting, diverse set of customers with very interesting problems. Each one is different. Most of them are quite exciting, all the way from physics to telephone controls...education to medicine. Working with them is important. Through our history, many of the ideas came from our customers. We obviously were never limited by my knowledge or my ability to come up with ideas. But we also were not limited by even the people who were responsible [for] various parts of the technology. Customers, when you're close to them, often have ideas. Sometimes [they] actually do the development, and are excited if we take them and produce them. Being close to the customer was very important.

DKA: Is that a sort of philosophical principle that runs through your company?

KO: It's much simpler than that. It's an obvious philosophy. It's very productive. Computer people sometimes think more highly of themselves. So there's a tendency to not be humble enough to take someone else's idea. But the idea itself is so obvious you should just jump at any opportunity to get better use out of your computers.

DKA: You were mentioning several of the uses of the PDP-1 and you mentioned the telephone usage and the scientific usage. What else were people doing with these new machines?

KO: Some of the things we didn't know. Some of the things people wanted to keep to themselves, either because they were government applications or things they wanted to keep private. In the laboratory area you could do things that were so tedious before. One of the first applications for this type of computer that gave dramatic results was to automate the x-ray defractometers. These are devices where people would put a specimen in, take pictures and then take days or weeks analyzing the results. The computer would give them results immediately. If the experiment wasn't done right, they could do it over again. But they could run through many experiments very quickly just because the data was processed automatically.

Another time we put these machines, or one like this, on a Coast Guard ship doing oceanography work in the ocean. It revolutionized their work. They could collect data, process it, [and] if the data wasn't coming out right, they could do the collection over again. The thought that devastated them all throughout a cruise was, if things weren't going well, they wouldn't find out until they were home and it was too late to redo the data. So, it just revolutionized their enthusiasm. There were just an infinite number of applications.

DKA: We hear so much about the Defense Department in the early days of computers, particularly the large computers as being their principle sponsor. Did this new, less expensive device, open up new areas of markets for you or was it still mostly defense and defense-related business that you got into?

KO: When we started, we had the policy that we wouldn't sell to the Defense Department. For reasons dealing with the accounting they demand, not that we were pacifists. And the products they develop are just contrary to commercial activities, the commercial way of doing business. We felt and still feel, still very clearly, that doing business with them hurts one's position in the commercial market. Now we do a lot with them, we sell to them freely because it's our duty to do so. We normally do it on commercial terms, because we still are afraid of changing the nature of a commercial company if you aim your business to satisfy their way of doing business.

DKA: Can you characterize a little bit more the difference between working for a defense market and a commercial market? Is it flexibility and freedom or is it something else?

KO: The government business...the way Congress sets it up and the way that people want to run things...worries about you making profit. They worry less about what they get. That's absolutely contrary to the commercial activity.

Most commercial customers want to do business with you only if you make a profit, and like you more if you make a good profit because it shows you're doing things wisely and you'll be around for a while. The commercial companies always want to buy the best product and they have learned, those that are successful, to trust their suppliers. There's a relationship between the suppliers. The way government business is set up it's always distrust. The supplier is always the enemy. There's always someone who wants to find something. You're treated like a criminal. It's just not a good way to do business. Their accounting is contrary to common sense and contrary to commercial business practice. If you set it up that way you're really not competitive in a commercial market. So we originally made the rule we would sell nothing to them. They, in time of course, insisted because they needed what we had. And we, to this day, limit our business with them to commercial terms.

DKA: In the early days of computing when the business was government, that must have been a risky principle, wasn't it?

KO: No, it was just common sense. It was risky to do anything else. The financial community didn't understand this. We said we wouldn't do business with them. The financial community thought that if you took government money to do your research it was free research and then you had a head start. It doesn't really work that way.

DKA: Why not?

KO: The red tape they put in and their goals are just contrary to commercial goals. Therefore they're always behind.

DKA: As I look at this equipment, I'm curious to know how this differed from what other companies had out. Was this innovative? Was this bringing something to market the market wanted but couldn't have before?

KO: The thing that's unique about the equipment is the fact that it's simple, very fast, and interactive. The market wasn't demanding this. People had never seen it, didn't know about it, and didn't ask for it, with very few exceptions. Some of the students who had used it at MIT when they got to their new company they said, where's the PDP? Our generosity at MIT paid off very well. But in general, the market wasn't asking for it. Market surveys came to the conclusion that people wanted exactly what they had. That's because that's all they'd ever seen. And that's why you get into trouble if you believe market surveys all the time because they never come out with anything useful on new products. So we had to, in general, sell the idea to most of the customers. We are not considered a marketing company because we don't spend money on markets. We don't exaggerate. We try tediously, sometimes boringly, not to mislead or be dishonest. Therefore we're not considered marketers.

We refuse, when we have the opportunity, to sell to someone who doesn't need our equipment. If it won't do the job for them, or won't do it optimally, we don't want to sell it to them. That's considered non-marketing. But on the other hand, the goal we set about was to sell this product to people who needed it. It often didn't look flashy but it worked for 30 years. Now there was a certain other flashy marketing which did help. It turns out that physicists love color and a little bit of spirit.

Now this machine [THE PDP-1] today is a little naive from industrial design. But the color, the consistency did give a little more pizzazz and jazz than most computers; people loved it just for that sake. So that was part of the marketing. The shape of the monitor in that time was unusual. The console really was designed to look good, to have something you like to work with and would attract people. That was part of the marketing.

DKA: Were you involved in the looks of this stuff yourself?

KO: My job was to make sure we had goals and to make sure that people knew them and that we were all running in the same direction, and running with enthusiasm. And then quietly to pick up the pieces that other people left behind, or that we didn't have people to survive. The mechanical design was one of those. So, yes, I was involved in that. It normally is not one of the things people notice, but because I did some of it, I of course will talk about it. It's relatively unimportant. But some of the ideas are interesting.

Early in computers people built a console on the table with all the instruments and lights in front of them, very much like you see in a power plant. Our first PDP-1 was that way. It had all the controls on the table, and big heavy cables going over the computer to connect the tube. Finally it dawned on me. Maybe the first in the industry. Something very simple. In the control, in the power plant, they have a console that way so they can look over at that big array of lights and heaters(?). Sitting at a computer console, the only thing you look over at are dull racks. So the whole thing's stupid. We got the idea of putting it on the end of the computer. After that everybody followed. Now that's a trivial thing, but maybe that was a contribution I made. You never can say for sure because somebody else might have done it first. We got the idea from them. But that's a small contribution. Picking a color, picking the logo type, this sort of thing. There was no one else to do it so those were left for me. I did have a little machine shop practice so I knew how to design. I know how to use a drafting table.

DKA: What's PDP mean? Where did that come from?

KO: When we were almost finished with the computer, before we had picked a name for it, we had a request from the government to build a machine to look for earthquakes, to collect the seismographic information. We didn't quite believe the story that people were that interested in earthquakes but we were willing to let it go at that. The Congress, in their wisdom, said that no more computers will be bought until all the computers in Washington are used 100 percent of the time. Now it seemed unlikely that earthquakes would wait until the accounting machines were unused before they went or the Russians would be so helpful as to not try out a bomb at the time when the machines were available. So they needed a machine but they couldn't buy a computer to run their seismographic machines just because Congress had this rule.

We said you could call it something else. It's really a Programmed Data Processor. So we called our machines, PDP, for Programmed Data Processor. They were able to buy the machine, hook up their seismographic devices, and not [have them] break, and not be challenged on their purchasing of the computer. It was a good name and that's where PDP came from. The job of the leader is to fill in those tasks which no one else is going to do, but never claim credit for them because that's just contrary leadership.

You're supposed to be getting everybody else to work and if you pick up some of the pieces, you should never brag about it. The story I tell people who get confused on this is [a] fable. It used to be in THE FIRST GRADE READER, "The Turtle That Wanted To Fly." He talked the crows into putting a stick between their mouths, and he held on the center of the stick and flew with them. Someone on the ground said, "That's a clever idea, who thought of it?" He couldn't keep his mouth shut. He had to say, "It was me." So my advice to people who want to be leaders is, remember the task as a leader is not to claim credit, but to be the leader and get the job done. The other advice is you've got to make sure everything gets done. And so the logo type, we... I did. I did it myself and I can tell you pretty much where it came from. The first one had a vertical of DEC. It was very clever.

Our first trademark was the vertical DEC. I got the idea for that right from the cover of a magazine. It was a magazine that's probably changed its name two or three times since then. I don't remember which one it was. But having the "D" reverse color at the top of the square I thought was clever. So we simply adapted it to this.

We silk-screened our printed circuit boards. We made up screens with a trademark on it and the name on it, and then we did it everywhere. We put it on our doors. We put it on our used Volkswagen bus. Once the screen was going, you know, we'd put it up everywhere. In time we found that people called us Digital and not DEC. So we made the decision quite formally to change our name to our shortened name, our trademark to Digital instead of DEC. Another magazine, I think it was called machine design at the time, had their name in blocks like that. It looked attractive. Those days lower-case letters were the smart thing to do. So we designed this logotype, and it became the standard. It might also have been that the rest of the machine design magazine used the rest of the word like this. But the ideas came right from the cover of a magazine.

DKA: I've often heard that it had something to do with the storage register of...

KO: No, not at all, not at all. Now one time our experts suggested that lower case letters were passé -- that these were hard to read. There was a newer alphabet. They proposed a variation of this with more modern letters. We brought it to our Board of Directors and I said we want to do it and they said yes. That night we happened to have dinner with the wives and the directors. One of the directors said, "I'd like to call the meeting to order and re-open this question." He was sitting with my wife...my wife doesn't take part in business except a few times and [this] being one of [those times], where they proposed that that may not be the best, but it's Digital, and they proposed we stay with the old one. So we stayed with Digital.

DKA: What did your wife have to do with that?

KO: At dinner, the question of changing it to a more modern typeface came up and she and this director connived together to raise the issue again. When they called for a vote, wives don't have any vote, but we counted 18 together in this informal vote. I said I claim 19 votes and we're going to stick with the original decision. The next day of course we formally went back to the original and never changed it since.

On signs, there was another story. We put signs outside of buildings and after awhile the sign people had very complicated signs. They had Digital Equipment Corporation, and then the name of the location and something else on it. It didn't feel right. So, as I drove with my wife we looked at signs. We concluded that the most effective signs like Mobil or ESSO were just the simple name. So we decided to use that, and that alone, for our signs. It's very presumptuous because not everybody knew who Digital was. But challenging them by being a little presumptuous was also a fascinating idea. It is sure more effective to just [use] that simple word than have a whole lot of other words. So the other story is people still call us both DEC and Digital. There's always the challenge, the question by our people from all over the world, we should go back to DEC because their people use that. I of course answer, no way. We've got so much invested here I'm not going to raise the issue again. If you look carefully, it's about 50/50. And if you listen to me, I may say half the time "Digital" and half the time "DEC." It's not worth changing. The press uses whatever they want to use regardless of what we call ourselves; they're going to use what they want anyway. So, that's it for a long time to come. If people say they propose changing it, I'll say you can bring it to the Directors. You won't win.

DKA: So those little rectangles behind each lowercase letter do not have anything to do with modularity?

KO: No, no they just look good from an artistic point of view.

DKA: Ken, let's go back and talk about the software issue for the PDP-1. You mentioned initially it came out with very little software. As the machine started to sell, what was the company's position on software development? How did you tackle that problem?

KO: In time we invested as much in software as we did with hardware. For a long time we had the same number of people doing both software and hardware. The concentration on the software was never in applications but on the systems to make it easy to write software, also on the discipline to make the software very robust and very reliable. One of the results of this is that almost every year of our history, except the very start, there has been someone who's had a faster computer at a lower price than we have. By concentrating on the discipline, both the hardware and the software, but even more on the software. We exercised extreme discipline, and every year making it better and better. Keeping the hardware architecture roughly the same so that things were compatible -- and just building on more discipline and more security and more robustness.

In time every one of those quick upstarts who offered something faster have disappeared. The belief there is that in computers you really want, above all, reliability. You don't want to lose things in a thunderstorm. If everything goes the power disappears. You want all the things you worked on, all your data tucked away nicely so when power comes on you can get it back again. This has been our approach in software and the thing that's made us unique in the last number of years is this continuation in an organized way of discipline documentation and sticking with standards.

So our approach to software has been quite consistent, but it's been in the area of discipline and documentation. For many years we made the same two computers, the PDP-8 and the PDP-11. We kept that design consistently so that software the customers wrote would continue to work on newer models and the software we wrote would continue to work and get more and more robust. By that we mean, regardless of what happens it will be safe and secure. This was dependent on a high level of discipline and organization and documentation.

Software is something which you can't look at and understand right away because it's a series of numbers, and pages and pages of them. You never know if parts are even used. You might have a million instructions and in no way can someone tell whether parts of it or most of it are just left over and never used at all. When people have trouble transferring software to new machines, they hate to admit that it's often the lack of discipline in the software. So by adding this discipline and the systems to it, we've gotten people to be dependent on our machines and because they have the commitment from us that we will stick with it and continue to maintain it and with discipline.

When the Russians want to steal a computer they want to steal a VAX. The reason they want to steal a VAX is that's where the software is. The reason the software is there is that it's disciplined and easy to use, and built upon for many years. In today's world of software, we have our VAX system. We call the software VMS. We have basically one system. It has about a 12-foot long shelf of books to describe it. Anything you want to do you'll find in there if you look long enough. Every change is tested and retested, and everything is safe and as secure as we can do. The problem with this is that it is a 12-foot long shelf. To take advantage of it all takes some time.

Another system was developed even before we developed VMS called UNIX. It was designed in reaction to complex business systems. It was designed for one person to work alone. It was designed to be without discipline, free flowing, and it became very popular in the academic world because it was easy to learn. It's easy to do simple things in workstations. And we've sold more of that than anyone else has partly because it was designed for our machines.

We've been the biggest player in that market, and encouraged it because there's a place for that casual undisciplined work, and a place for the discipline work. So today, UNIX is very popular for workstations where one man works alone, where if he loses everything because of a thunderstorm, he'll feel bad. He's lost a whole day's work. But it's not the same as a bank who just under no circumstance can ever, inconceivably lose anything. These are the two different realms of discipline and security. Now the promise is we promise that we'll make UNIX secure, and robust, and formal and disciplined, with a lament secretly that when we do, we will lose that free-wheeling, fun, casual, easy-to-use UNIX system that made it so popular.

DKA: I'd like to take you back to the PDP-1. One of the things that you've said is you learned a lot from your customers. What went right with the PDP-1, and what went wrong? What did you want to do different as you moved? Or did you just want to do more of the same? As you saw the company growing, which direction did you want to take it?

KO: We had large orders from ITT, for telephone, telegraph type systems. They decided to go out of that business, which left us with more production than we had orders for. At the same time, NASA was getting ready for their big projects and they wanted to buy 100 computers. And I said, no. The engineer who designed it left us after that because 100 machines would have made it a great success. But growing that fast would have ruined the company. We were making 2 or 3 a month. Getting an order for 100, we couldn't have tolerated. Then if that order disappeared, we'd be in terrible shape. So I said, no, we won't bid on it. It must have taken years before NASA got over that.

DKA: That must have been a hard decision, Ken?

KO: No, it was an easy decision. Suicide is something you don't have to do. My first rule of business [is] you don't have to commit suicide. People think it's a hard decision. [It's] not a hard decision at all. It's like hanging over a cliff on a narrow piece of rope. That's not a hard decision. Some people felt it was hard because the short-term result could have been exciting. But we had to grow slowly and consistently or we would lose everything. Now each step of improvement afterward was quite obvious. The technology got better consistently as time went on and we understood more how to build machines.

DKA: What was getting better? Can you be a little more specific?

KO: The old typewriters which we bought were crude and expensive. As we got better typewriters it just made the computer available to the masses. The transistors got better. Eventually, circuits came into play. We learned how to put more on a printed circuit board. We learned better ways of packaging and as computers developed, more and more of every kind of component with better quality and lower price. That meant we could cut the cost significantly and increase the power. The industrial design was always important because people did buy [computers] for looks. They liked something, it was easy to use, it was very productive, but the looks were important. We always had either a rented industrial designer or part of our own staff. And this [THE PDP-1] we thought was quite good looking. The console had the same general shape as the display, and [the] layout of switches was studied very precisely. We made special knobs for it. It was readily accessible to the tape reader. The tape storage was obviously patched in later on. But it did make a very efficient way of doing it. The punch tape came out here. It made a very efficient and attractive system, we thought.

DKA: Ken, was it all paper tape or did you have magnetic tape at all for the PDP-1?

KO: The software people brought to the machine with them was paper tape. There was magnetic tape for storage but people didn't normally bring the [magnetic] tape with them. They usually brought the paper tape, or they'd bring a tray like this [DEMONSTRATING PAPER TAPE TRAY]

DKA: Now what would it be like for somebody to run a program? How would they set it up?

KO: [DEMONSTRATING USE OF PAPER TAPE READER] They would take the tape out and put it inside here, string it through the tape reader and set it up so it would fold here and the tape would come off and this fanfold. When he left he would have all his tapes put in a tray like this or several trays like this. Any new tape he generated while working on it, he put in trays also.

DKA: What was he doing on the control panel below? What would a programmer do?

KO: As he was debugging his system, he could watch what was happening all through the computer by looking at the lights. He could introduce information through six switches which the computer would sense. If you wanted to play a game, you'd play it by entering information in the switches. The computer would light up lights here, special program lights to tell him various things, or tell him what was going on if he was playing a game. These were just start and stop and continue. [POINTING OUT SWITCHES] If he examined, he'd press this one that would stop the program. He could see from the lights what was going on. He could step the program along one step at a time, and just watch what was happening with his program as he went through. In time, slowly over a period of many years, we got rid of all of this. Now people don't need that at all.

DKA: What was the relationship between what people saw on the control panel and what they saw on the CRT?

KO: The control panel showed exactly what was going on in the computer. The CRT would present pictures that someone worked hard to generate. At that time you couldn't debug from what you saw in the cathode ray tube. Today you don't need this because the cathode ray tube does it so well. We always had very good documentation. [For the] PDP-1, we worked very hard on a manual, and it wasn't very big. People loved it. The competition thought they'd do the same and were dismayed to find out how hard it was to write a simple small manual. Unfortunately, not being a normal user, there's always one thing we left out. We never told which way you put the tape in. I never figured it out. I never remembered it. So there's one weakness in our literature.

There's another literature story: by policy, we would write everything we do in book form for the customer. We formally decided we would print things in a paperback format, and put in everything we knew about a computer. We put a manual out that told absolutely everything. At that time we could have that book printed for twelve cents. Our experts in publishing thought it was a disgrace. Paperback books were inexpensive paper, obviously not glossy and polished photography. But the difference was, a brochure which could say almost nothing would cost a dollar. A paperback would cost twelve cents and we could tell everything in it. One time after meeting on a Friday afternoon, my brother, [STAN OLSEN] to demonstrate something, ripped one of the paperback books apart, and laid it on a table. [Then] he ripped some literature apart and laid it on the table. Come Monday, the janitor had thrown the ripped literature away but carefully put the paperback together.

Everywhere you went in the world -- India, China -- engineers had those paperbacks on their bookcase because they were that popular. We gave them away freely and we got a lot of information out. They were very valuable even to those people who couldn't afford a computer; [they] educated them about every single detail of our machines. So, since then we've been free in literature; we print everything we know [about the system] and [the handbooks] make a real contribution to the customer.

DKA: Is DEC more open with its information about machine design than other companies?

KO: Probably so, because of [our] academic background. But even more important, it takes a lot of discipline to get people to write. After you're finished with a job, it's very hard to write about you've done because you're ready to go on to something new. Getting people to write down all they know about the project they worked on takes discipline and effort. It's one of the things we're never satisfied with but we keep trying to do a better job. As [computer] software became developed, it [software] helped him [the programmer] find the problems and correct them in this interactive way. This is very much more productive than getting your results back once a day. Getting your results immediately allows you to fix it immediately. As you get clever, it allows you to use the computer to help you fix it.

DKA: Ken, did you use card readers at all with the PDP-1?

KO: In general, we used paper tape. The scientific users used paper tape. We always had a card reader available because commercial users or some people whose data came in punched card form did have to have access to punch cards. But the paper tape was much easier to use for the casual user.

DKA: [Was] memory an important consideration of the PDP-1?

KO: Yes. The memory, for many years, was the limiting factor in a computer. We decided to build this PDP-1 a little earlier than we had budgeted because our friends at RCA called us one day and said we have a thousand word memory the customer ordered and doesn't want. We'll sell it to you cheap. So we quickly bought it and said, now we've got to make our computer. The computer was designed around the thousand-word memory. That was the impetus to get going. We sold that 1000 word memory many times. It deserves a place in the museum. We don't know where it is though because people would buy the machine with a 1000 words. Before they got it delivered they needed more. And they needed eight; four, eight or twelve thousand words. And we'd then sell the machine, that 1000 words over again to someone else.

Now those numbers are ridiculously small. But the price and the size of the memory has been growing, the size has been growing, the price has been going down dramatically. It probably is the most serious limitation in the computer at any one period in the history. Every component has to work and be available. The typewriter, transistors, and the memory. Every single piece has to be available. Probably the hardest one, the most serious limitation in any time was the memory. So as we learned to do memories better, as the people that made the cores learned to make the cores better, and to assemble them better, and at lower prices, it just opened up whole new opportunities for computers.

In time we bought RCA's core making facility and the facility in Taiwan for stringing them. And when we were going at our peak, we were making 4 billion cores a month, and stringing them in Taiwan. At that time cores were cheap, memories were bigger than we ever had dreamed, and then we were able to make a large number of computers.

DKA: Did the development of this machine, once you got the idea and had the core and decided to go ahead, did it go smoothly? Or did it have, was it a rocky road? How do you remember the development path?

KO: The first one we built we bought standard cabinets from a supplier. They were rounded and kind of plain and ugly, with a separate console. It became obvious we had to make a better-looking cabinet. One that was more modular, we could increase the size of and that would look unique and more colorful. So, the first one was really plain. But in time we came out with this design and going through that transition frustrated some people because it did take some time. But it probably took less than a year to build the machine. [SETTING IN FRONT OF THE PDP-8 COMPUTER]

One time in the 60's, the Atomic Energy Research group in Chalk River, Canada, asked us to bid on a specially designed digital device to control an atomic pile. They gave us a whole list of equations they wanted built into it. We looked it over and decided we didn't have anybody with enough patience to design a special device to do those, solve those equations. We told them that we would sell them a very simple computer, at a price as if it were a production machine and that they could then program it to do these equations. They liked the idea because they said they didn't really know what the equations were anyway. We then, with that contract, designed our PDP-4 [PDP-5] which at the next go round was called the PDP-8. This machine was just 12 bits long, the shortest we could conceive of. It had the simplest order code and the simplest organization that we could think of. It was not designed to compute, it was designed to control something like... like a pile. Customers bought the machine and started doing programming with it. The great appeal it had was it was inexpensive.

We did a number of bold things. First of all it was bold to make one that simple. The competition laughed at us. It didn't have the characteristics of the computer. We also standardized a teletype printer, which was not designed for continuous use. We very formally made the decision that we would gamble on that teletype and work hard to make it reliable enough for continuous use. That one gamble, and that one small success, probably was a key part in the introduction of minicomputers and personal computers. [REFERRING TO THE ASR-33 TELETYPEWRITER] Printers before that were very expensive. You could not have an inexpensive machine just because of the printer. That machine was quite an expensive, very cleverly designed but made for offices where it was used intermittently.

Computer users are continuously at a very high rate. And so it was a very important development in the history of computers from our point of view. It was a bold thing. Because teletype [manufacturers] said, don't do it. It's not designed for this. In time they appreciated it and together we made it reliable enough for this use. People fell in love with that machine because of the cost. And because of the simplicity, it was easy to teach people.

Out of that came very sophisticated software. It could safely be said that for many years that the PDP-1 was the one machine that introduced computing to much of the world who had any contact with computing. That's because it was readily available and inexpensive.

DKA: Were you surprised at how successful?

KO: Oh, yes. We were brave making a machine at all. We never were brave enough to think that it would become such a popular computer to do computing. The PDP-4 [PDP-5] was built like the old machines. When we were going to redo it and call it the PDP-8, we wanted to introduce new technology. Sylvania had made a new socket that IBM used and it took modules like this. [HOLDING FLIP CHIP MODULE] We went one better than IBM in that we used glass boards with high tolerance on the boards. We had 18 connections instead of 16. We had a clever looking handle that really became our trademark for many years. [HOLDING A PDP-8 FLIP CHIP MODULE] We then had a set of technology that last[ed] us for 15 years or more. Maybe 20 years. It was something we just built on from there.

The modules became quite long and quite high, in time. But for the PDP-8, this was the module. We also set about to use the technology that was developed for home appliances and automobiles. The technology we used before that was basically built upon military technology. So with this machine, we set about to study all the technology used for appliances. I went to several discount stores for hours, studying every single washing machine, dryer, stove, to see how they built things and what we could use. The [idea for the] switch handles came from a Maytag dryer. Using a glass panel without separate lights showing was the technology used in appliances. The silkscreen on the back looks quite attractive. Inside we used the slip-on connectors that were commonly used in automobiles.

We tried every way we could to take the technology that made mass production possible in appliances. The design of this has no screws showing, it is basically held together by these two lock switches. We always had a lock on our computers but only one. We obviously needed two in order to hold this together so we invented a use for the second switch. This one turned the thing off and on and this one disconnected the console so you couldn't mess up things. The fascinating thing is that afterwards every computer had two switches. Even the Japanese computers had two switches. No one ever knew why there were two switches; it was to hold this panel together. But they just followed.

DKA: When they looked at some of the home appliances, what was the driving reason?

KO: The technology we used was expensive. There are very few inventions that come out of the blue completely. Most inventions come from adapting ideas from other people. This goes for ideas of organization, motivating people, how you do things mechanically, how you do things electrically, and just being exposed to all the things that people are learning in the appliance industry. Opened up new sets of technology to make things inexpensive. They mass-produce things at very low price and we had to do the same. They also had more years of industrial design experience. They, every day, sold things on looks. And it was more important to us. So this was part of that.

We had an industrial designer who said we should show off our new plastic handles by covering it with smoked glass, smoked plastic. I didn't like that idea but it turned out to be great. It helped sell. We had rosewood formica on the side which added a richness to it. This machine became the standard for industrial design for computers for some time. It opened up nicely on a hinge so you have access to the inside. It gave people the feeling it was put together with thought and easy to fix and easy to assemble. That machine then made a very important contribution to the company and to the industry. There's another story with respect to this that you could tell many times over. Our first PDP-4 [PDP-5] was laughed at by the competition because it was so simple. But in time, they learned to respect it.

We knew they were coming out with an equivalent. We also knew that they were making the classic mistake that is made over and over again which is to look at someone's old product and think you can do better than that. The thing they've forgot and they should have known better is that we also were working on new products. So one came out with their announcement, two weeks later the other one came out with theirs. And a week after that we announced this one at a much lower price and a much more elegant machine.

That story happens so many times in business where people forget that their competition is not the old machine but the one the competition is working on. The computer is made up of hundreds of modules like this. [HOLDING A FLIP CHIP MODULE] They plug in from the front side into sockets, which are assembled in the rack. And these sockets then are automatically wired by a very large automatic machines. [REFERENCE TO GARDNER-DENVER WIREWRAP MACHINE] So, all that wiring was put on automatically and it was one of the new technologies that were available at this time. So this panel we put into a machine and [could] take it out all wired. Put the appropriate modules in the appropriate slots and assemble two of them and we had a computer. The one gap which maybe you can see is the memory itself and the circuits that drove it are also on these same modules. The modules filled the whole area except this one area, which is core memory.

[POINTING TO BOX WITHIN] It's got a fan on to keep it cool and is driven by circuits also on these modules and together it makes a whole computer. In the MIT tradition, we had the system divided into sections. With these switches we could separate one section and vary the voltage to see if any section was deteriorating and check the margins and replace it if it was in trouble. The power supplies were in the bottom. The whole unit was quite heavy. But as machines went, it was very small and very light. People then had opportunity to have a machine that was all their own and operate it in the same way we operate a personal computer today.

DKA: How is the business changing? Is the computer business a different business at this point?

KO: In one sense the computer business stayed the same. It's just that as things got less expensive, more and more people were able to buy equipment and to use it. With a $110,000 machine you couldn't afford to give one to everybody. At $18,000 [THE PRICE OF THE PDP-8] you were getting close. As this machine got down to $12,000 and $8,000, it became possible to give it to every technical person to use. He could use it to do all sorts of operations.

DKA: Who were your customers?

KO: Schools were one important customer. Because with this you could really give students the opportunity to understand what a computer would really do. It was also very popular in controlling instruments and machine tools and medical devices. Anyplace where you had simple operations, this was just ideal.

DKA: Are people starting to use your equipment by this stage for word processing, or any type of business application?

KO: We believe the first word processor was done on a PDP-1 at MIT by the students. They called it "Expensive Typewriter" because it would tie up a whole machine and an expensive electronic typewriter. It would do many of the wonderful features we take for granted today. In time we offered word processing on every machine that people bought. The technical world had been using word processing long before the commercial market showed any interest in it. The DEC computers were the standard for word processing. We were slow in getting into the commercial area because the technical area kept us busy for a long time.

DKA: As your company was growing, Ken, in delivering more and more products, was the nature of the company changing?

KO: The company changes consistently and regularly. The people we hired initially of course were not trained in computers. They came from all kinds of backgrounds. Musicologists was surprisingly popular. Then in time we could hire very well educated and trained people in computers. This made it change. The initial applications didn't need all the formality and discipline because they were small. The operator kept them in his head and he understood them all. In time, many people had to work on them. The applications had to last longer than individuals stayed on the job. This meant a lot of formality and discipline in the software and the hardware also.

So the business changed over a period, many years from getting the fastest, most exciting thing out to supplying all the discipline necessary to make sure it worked forever. The question's often asked what part the military or the US government play[ed] in the development of computers in developing the advantage the US has to the computer market. In general, I would say they played little part. Obviously, Whirlwind was financed by the military. But during its development, it really didn't have an application, so it wasn't driven by the military. The big drive came because of the high demand in the competitive situation in computers. The advantage the U.S. had was with a few exceptions. Not the fact that the government was involved in the computers or financed things. But the fact that our government never could catch up and try to help us.

Most other countries' government stepped in and tried to help the industry, and once the government did that we knew that that country was not in competition. Every time our government tries to step in, (and they're frustrated often because they can't run things and they can't tell us what to do), they mess up everything. Fortunately the industry has been running so fast they couldn't grab hold of things. When they tried before they did, they were left behind.

I'm sure it's the goal of people to run the whole industry, and if it disappears and goes somewhere else in the world, they'd love to see that, too. But the biggest contribution our government's made is that they never got up with the computer industry in order to help. No one else except the Japanese has been successful. I think a big part of that is that their government's helped and they tried to be dependent on the government and that always sets them back.

DKA: So that relates back to your philosophy of commercial independence.

KO: Yes. The military is always several years behind in computers, and getting farther and farther behind. They're not in a position to lead the computer industry just because of the way they're organized.

DKA: Does that mean that you don't think your relationship with the Japanese government to that industry is a threat to our way?

KO: The Japanese government appears to be the only government that can help industry. It might be because they don't consider industry an enemy like western governments do, particularly our government. But somehow, most of the time they do, they help. But I'm not sure that it's helped them to compete in general. Good commercial competition is what drives industry. We may be losing that now, unfortunately. We may lose it because the government wants to control things. We may lose it because the attitude today is stockholder's rights, they call it, where you take all the resources and give it to the stockholders immediately and invest nothing in the future and get rid of all the assets. [You] don't invest in research at all and that's the fad today. That's considered the ethical, American, moral way and if we continue that way we're sure going to lose it to anybody because there won't be anything left. But if we can avoid that somehow, we should be able to stay ahead.

DKA: What's your view of the right recipe?

KO: One has to believe in capitalism, not the rampant, stealing, robber baron type capitalism, but competition in order to do a good job and continue to grow and develop. When our government tries to resort to protectionism, or thinks they're going to control the world supply of memory chips, they just do no end of mischief. If they continue that way, you don't know they'll stop in creating mischief. If you believe in competition, you will buy from whatever part of the world does the best. And they'll buy from you where you do best. But if you lose one part to somewhere in the world because the cost of capital is less there or because they concentrated, because they worked harder, because they have some natural assets, if you try to change that by laws, you get up into an impossible situation and you'll destroy the advantages of competition. A politician inherently doesn't believe in capitalism because it doesn't make good politics. Our biggest danger I think in technology is not the Japanese, it's our own politicians. Their claim to their constituency is they're going to manipulate everything. They just aren't able to do that in a wise way. All that we've gained we could lose very quickly by just following our trend of protectionism in the technical area, and also our trend in looking out for short term interests.

DKA: As an international company, does your worldwide reach protect Digital from that type of influence?

KO: We do have the advantage of having access to every part of the world. We freely buy from any part of the world. We trust the Japanese. We have operations there. They are part of Digital. We'll trust any company or country that makes good products and is a reliable source, because we buy and sell internationally. This is what we say our country believes in, in theory, and it works well and we follow it.

DKA: Going back to the PDP-8, was this one of the machines that people then began to network together? When did that notion get started?

KO: One idea we took from MIT was the idea of networking. The aero defense system was made up of 23 sites; each one having a very elaborate, very high performance local area network. There was a large number of display terminals. Then each of these 23 [sites] were networked to two arrays of radars across northern Canada. Airborne radars on the coast, human being spotters on top of the tall buildings. It was one very large network.

So networking became a theme in everything we did. We always were able to hook our computers together and for almost all our history we were able to hook to IBM. Networking was always part of it. The big change in networking came 15 years ago or so when we decided that we'd have to network in a very standardized way. Everything we did we used the same networking protocols, and the same networking technologies. That really made networking a major part of our organization. It's these standardized ways that we've been encouraging the world to accept so that we and they can all work together on the same network. We're well under way in that and the new standards will make that possible.

DKA: Ken, were you unique in the industry pushing for that type of discipline?

KO: I think we were quite unique. There's a normal tendency to keep everything you do secret so that others can't come into your area, just like the railroads in Europe used to have different gauge railroad tracks. The reason they did that, was that if someone was invading them, they couldn't drive their trains into your country without stopping to reload. This created an enormous bottleneck for any invader. People tried to maintain their own standards so that anybody coming into their customers would have a terrible time. We had a different idea. It was clear to us that we never could own every computer a company had. It was clear that ideally everybody's computer would be on the same network. So we've been pressing for standards to make this possible for along time. The standards that we've had with great discipline within our own company means that we can tie anything we make together, anywhere in the world quite easy and simply and elegantly. As other people accept the standards, we can accept them in the network. Eventually if all the plans now follow through, the major companies will all accept the same standards.

DKA: How are all the companies reacting to this?

KO: They all have great plans. Some of the standards were basically ours, some of them were IBM's, and some of them were generated independently. There seems to be common agreement that once they're accepted, everybody will follow them, independent of where they came from.

DKA: Thinking about networking on one hand and the type of hardware development that goes along with that, it seems that you followed a pattern in Digital starting with the modules, [and] state of the art memory systems that continued through the PDP-8. How did that hardware pattern continue into your later machines? Or did it?

KO: The hardware continued to evolve as technology evolved. If you look at what we do today, it bears no relationship to the early modules. But step at a time you can see the evolution was quite clear. Today we tend to build things on large boards with large integrated circuits, and the amount of handwork decreases every year. In the last six years I think we doubled our size twice, approximately, and we increased a number of people in production by almost zero. This comes about because our way of building things gets to be more and more efficient, and more and more gets built into the integrated circuits. If you look at it that way, things have changed dramatically. But if you look at each step, each step was a small one.

DKA: What resemblance do integrated circuits bear in terms of logic to the earlier modules?

KO: At first, integrated circuits would have maybe the equivalent of this. Now the integrated circuit has the equivalent of ten of these. I don't know, maybe it's a hundred of these. Because they're so cheap they're used differently. We had to be very economical on how we used these because they're expensive and took a lot of room. The logic is so cheap with integrated circuits that you use it freely and do things that are inexpensive because you use so much of it. So it's a little hard to weigh the differences. But it's created a revolution, a slow revolution because they started off small and now they include so much. But as they get bigger we want to do more. As they get bigger we have the problem of cooling them, connecting them together and the technology puts new demands on how we do things. We even cool some of them with water because they get so much concentrated on one area that takes different ways of cooling them. So things are, over a period of years, quite different. Even though any one year they don't change very fast.

DKA: And as you move from the PDP-8 to the PDP-11 family, was that a major shift in your computer company?

KO: The PDP-11 was a machine we took a long time to design, and worked hard to make it one that would last a long time and have innovation in it that would make it unique for a long period of time. It's still a major product for us, and it must be 15 or more years old. We set about to continuously improve it but still keep it an 11. We had many software systems, each one did unique things. One of them was the predecessor for the common PC software today. Others did other things especially well. The difference in the 11 is that it became the center of the corporate strategy and the resources were all put on it and yet it was maintained with discipline so that the same software played on each machine.

DKA: When you say it became the center for corporate strategy, what does that mean?

KO: Before that, we had several computers going at one time. Almost all our work was concentrated on that one. We also had a very large machine, called the PDP-10. But the small minicomputer area was concentrated on that 11. The next go around with computers, we carry this to a farther degree. The VAX computer was done with a lot of planning before it was started. It was planned so that eventually it would span a range of sizes from very tiny. It was designed so that the same software written ten years ago would play today and ten years from now. It was designed so that any part of it could be taken out, improved, redone and a new one put in and it wouldn't upset the whole system. It was designed with just one software system. It also did UNIX, ten percent of our machines were sold to do UNIX, but the basic software system was only one called VMS. This is obviously very productive, everybody works on it. It gets better and better every year. If the whole company works on one [operating system], it gets to be quite good after a period of ten, fourteen years. But it is contrary to the normal inclination of engineers.

With our PDP-11, and like most other companies, the tendency is to say, with a new software system I can make something special. It does things so much better. Having discipline to avoid that made everything so much better just because we could concentrate on the one thing we were doing. That's what made the VAX very popular.

DKA: And that was a discipline that was hard to maintain in your company?

KO: It was easy for me because someone else did it. Our strategy said we would have one protocol for networking which the idea is somewhat unique to be, have only one. One computer architecture which was the VAX, one software system which is the VMS, and one way of doing local area networking which is Ethernet. The discipline came automatically. Parts of it I really had to take part in because without corporate discipline, people would use different kinds of networking, and you would lose the whole strategy. So it was not my job to develop the strategy. People did that very well without me. Even forcing it through and getting corporate approval wasn't my job. But in time it was clearly my job to make sure we followed it. In general people liked to work with a clear strategy. They like to know where the goals are. The basic decisions on projects are already made. That gives them great freedom to be creative in the areas where we need creativity. Not everybody likes it. When we finally got around to enforcing the strategy we had all along, a large number of the vice presidents quit because they wanted freedom to do what they wanted to do. But the result of the whole company working in one direction was obviously very good.

DKA: Most people think about computers as having fundamentally changed. When the personal computer came, truly to be on their desks at home, at work, how did the advent of the microcomputer effect your business? And how did you see it and how did you respond to it?

KO: The goal we set about when we started the company was to introduce interactive computing. We did that first with the PDP-1. Then with timesharing, where one computer has many terminals and each person thinks he has a computer to himself. With the timesharing end of the terminals, people then were able to do those things which we see with personal computers today. As they did word processing, they did computation.

They eventually did spreadsheets and many, and did games and other things. At one time at my home we used to play Scrabble on a terminal plugged into the telephone with a VAX at Digital. When you had a terminal you had everything that we see now on a personal computer. So that's been around for many years. We saw in the early 70's that it was going to be easy for people to make computers. The type of computers, we had made more powerful than this one, were going to be able to be made by anybody very simply and very cheaply. At that time we set about to do something more difficult which was to integrate or network a whole organization around the world together -- within one room, within the building, within a campus, a city or the world. And that was our thrust. We concentrated on that because the PC, as it was being developed, was so easy there'd be many people making it.

So, we in general avoided it and [instead concentrated] on the problem of networking them but not planning to be the large producer of PC's. We concentrated on the making of networks of small computers and large computers, which is a much more challenging job and devoured all the resources we had. The PC itself was a component to the network. We made some PC's designed to be part of the networking but the general PC market was not for us. There were too many people in it and it turned out to be true. At one time I think there was 500 or 700 people making PC's. Anybody could build them. You could build them in your basement. That was not for us.

DKA: Was there doubt about that decision? Or debate about that decision?

KO: No, because you see our goals were clear and when anybody can do it and there's nothing particularly unique that we can contribute, it's clear it's not for us. Now we had PC's demonstrated here long, probably long before anybody else did. Individually people would make them. But we very formally decided that was not what we were going to do. It would basically be a very good decision. The IBM success in that business was, for a number of reasons, partly happenstance, partly luck, but to a large degree because they had the size, the resources and the experience to set up the infrastructure to deliver millions of these.

It was not a matter of invention, it was a matter of management and resources. They were the ones who could do it. After they had done it, it became easier for others to enter the market. But their contribution was good, competent management. And we were off doing other things. Now the argument we have today is an interesting one. We believe in PC's. We encourage them. We network them. We use them in large numbers. But we still believe that most people in an organization want terminals. Terminals you don't have to worry about data management, you don't have to worry about floppy disks. You just sit down and it does the work for you automatically. So our most experienced, educated computer scientists and my secretary who has access and experience with everything, always want a terminal. It's just so simple to use. There's nothing there. And the secretary doesn't want to take her hand off the keyboard and run a mouse, so the terminals we feel will always be important.

That's a major part of our business. We do supply PC's, we will supply more PC's, we integrate and work with other suppliers, all the suppliers of PC's, to network them. They have a very key part in this system. Now there's the large expensive, very competent PC called a workstation, offering a whole new realm of things. That's a very important market. These cost twice as much as PC's. They have a very beautiful display, sometimes with beautiful colors, always with fine detail, and are used for designing automobiles and airplanes, and for many things for which you want very precise pictures or a lot of material on this display. They get to be powerful when they're hooked up to networks.

Now there's an interesting mistake that people make, the press makes out of innocence. Six years ago they announced that the PC's in an operation have enough computer power to replace the big machine. That turned out to be foolishness. Now they're announcing that PC's, that workstations networked together, have more power than a big computer, and they'll replace the big computers. That's nonsense too. They replaced some of the things big computers were doing because they can do the jobs, but they don't replace the big ones because in any organization you have data that you cannot afford to lose under any circumstances. The last thing you're going to do is have your key data in somebody's workstation where somebody can mess it up. All the protection for precise data has to be separated in a place that can never be lost, never be damaged. And no way are you going to leave it out in the open on a small machine.

So there's a place for everything. The PC's will play part of it, terminals another part of it, workstations another part of it, medium computers and large ones other parts of it. There's a place for all of it.

DKA: You've been in a relatively unique position for the past three decades, four decades maybe, to watch this industry, and to think about where it's going. What really stands out as the key developments in a large social sense in the elevation of the computer and the way it's effecting our society. What do you see as some of it?

KO: I think the interesting thing to observe about computers and computer technology is that the most significant changes people don't notice. Things they worry about never become a problem. For example, the hand calculator really was a revolution. No one predicted it, no one worried about it. It sneaked up on us and suddenly we all have them, we all use them, and we never thought of it as revolution. It just sneaked up on us. All through our life there are computers. Our cars, our homes have computers, and so many things, and we don't notice it. We worried about privacy, worried about computers running our lives, and those didn't happen.

The issue of privacy is that with computers you can specify, society can decide exactly what level of privacy we want. You can have anything you want, which you didn't have before. You're going to run your private finances with [the personal computer]. They're going to run your menu. They're going to run your social affairs...didn't happen. You don't want it and it didn't work. The things we feared usually don't happen. The things of significance sneak up on us and we take them for granted like they always were there.

When I was young in the Boston area, you had one charge card in the big department store in town. They were always in trouble. They never got anything right, and always patching up something. Now you couldn't carry all your credit cards, and very rarely do you have trouble with them. That's a revolution. Now we expect not to have trouble with our credit cards. We don't expect them to make mistakes. That's the computer revolution that we just take for granted. And it goes on and on and on. We have a long way to go. When we ever straighten out medical billing, it will be computers that do it. And after it's straightened out, we'll never remember that it wasn't straightened out.

There are two things I would say to people about computers. One is, don't fear them. Most of the time they're doing good for you. The other thing is, don't ever become lazy. Remember that you only have fun in life and you only can stay ahead if you keep learning. Calculators are not an excuse for learning how to do arithmetic. As for things that computers do, you've always got to be sure that you can do a certain amount of things by hand and know something and learn something. Always learn, and don't ever let computers fool you into thinking you don't have to. I tell our people when I'm asked to lecture, look at the old people you want to be like. I can tell you ahead of time that if people continue to learn, are excited and know about things, and the ones who are boring are those who stop learning and don't think about things. Just don't let computers cause you to get in the trap of not losing things.

DKA: What's coming?

KO: From a technological point of view, I think we can be confident that computers are getting more powerful, and less expensive. This means that we can do things we never thought of doing before. It means that people can use techniques for doing computation which are wasteful, devouring memory and devouring computation and doing things in a way which is so much easier because the computer does all the work. But what it means to the private citizen? It means that your automobile will run better, your house should run better, and it means that we can, little by little, get better service from all the things we struggle with today. And for the people who really have a use for the computers, they'll do things a much more exciting way. It also means that every student should learn to type. Anyone who does any writing at all should have a word processor. It means that people shouldn't be afraid of computers even if they don't have any need to learn. But anyone who has any reason to learn, in all young students, really are in that category. They should have a feeling for computers. It will just continue to be a contribution to society.

DKA: Does anything scare you about what's coming ahead?

KO: I used to think that computers could do no harm. But there are some things which do worry me. Some people study computers and don't learn anything else. Computers are just tools to do something; you better be expert in something and consider the computers the tool. The computers are fun and exciting but they're just tools, and we better make sure that we know something about what the computers are supposed to solve not just the computers. Computers also produce an enormous amount of data and people get confused with that.

Data is not information. That's been pointed out. You put the data in a form which is useful and you have some information. But a large amount of data isn't information. I think in business making graphs is a menace. Very few people know how to make graphs. They don't know why they make graphs. They make graphs because they think you're supposed to make graphs, but they don't know what they're trying to get across. They don't know the reason for it, and if they had the reason, most of the time they wouldn't do it. In that way, computers are a menace to business. We have more graphs that mislead or cause confusion than we ever did before.

But, in general, I think computers do a lot of good. We have too much information, but it's so much better to have free flow of information even though it turns out to be a little too much than limiting information. Computers are going to revolutionize business and society, even maybe in particularly the closed societies because with a free flow of information, it just changes the way we do things. Looking at the big old machines, there's almost no relationship to, or no indication of what a computer will do. Computers will do almost anything you want. If we can't afford to do it now, it can [be done] in the future. The one thing to learn about computers is that they do give us the opportunity to accomplish things we've never been able to do before. This means that our big problem is we've got to decide what we want to do. Most people don't know what they want. Often in society we don't know what we want. But if we decide what we want, most of the time the computer will play a key part in giving it to us.