Oral History of Danny Cohen

Interviewed by:
Marc Weber

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Weber: I'm Marc Weber of the Computer History Museum and I'm here today on November 18th, 2011 with Danny Cohen who's a pioneer of the ARPANET, of Voice over IP, interactive applications over networks and a number of other areas in computing. So, thank you for doing this.

Cohen: You're most welcome, Marc.

Weber: And I'd like to really just start at the beginning, could you tell us a bit about where you grew up and what were your interests as a child?

Cohen: I was born in co-op in Israel and it was in about, I believe around high school, that age, I read in the newspaper about electronic brains which we called computers today. But the idea of having machine that act like a brain was very fascinating and that got me interested in this area.

Weber: And were your parents in technical fields?

Cohen: My father was electrical technician, but between that work in electronics and computers so it was very big especially since computer didn't exist yet.

Weber: And your mother was interested in?

Cohen: My mother was not technical at all. My mother was very good at people, greeting people and understanding people, taking care of people. My father, on the other hand, was very technical in everything he did in life. I must be somewhat between the two, I hope.

Weber: What sorts of things interested you as a child?

Cohen: Yeah, as a child in Israel, I spent most of my time in a youth movement and we tried as much as possible out of the house and be outside playing with friends. And one thing that we liked probably most was walking and hiking through the desert of Israel but half of Israel was desert and some of them, like near the Dead Sea, was very attractive for hiking. We used to hike a lot and we did lots of things that our parents would never approved if they knew what we did. For example, when we were high school seniors, I with two other friends, at night went from Israel into Lebanon to the Litani River there and back. If we were caught by the Lebanese doing it, we most likely would not get out alive out of that. But it was sort of a challenge that we could not resist and we do it which was one of the least responsible thing that I did in my life for absolutely no reason except knowing that we weren't supposed to do that.

Weber: Would you swim in the river?

Cohen: No, we did not swim in the river, but we took the motor in canteens and put it in the water. It was different than tap water , which was--

Weber: And so --but the youth movement you were in, what was the goal of the movement?

Cohen: The goal of the youth movement was very complicated to explain. The youth movement were aligned with political parties and so the one I was in, [HaShomer HaTzair?] which is the youth movement that belonged to a slightly leftish party. So, most people my age somehow belonged to parties that were on the left of center.

Weber: And were you interested – I mean, you describe the electronic brain article when you were a teenager – but did you like math or science or technical things when you were younger?

Cohen: Yes, I always interested in math and I was delighted to hear that computers in math went together which was easy when the computers hardly existed. In Israel, computers were somehow offshoot of math and electrical engineering, obviously. But what was more mathematical then most places in the States.

Weber: And where did you grow up in Israel?

Cohen: I grew up in Haifa which is a city on the north beaches of the Mediterranean.

Weber: And you grew up in the town?

Cohen: I grew up in town. There was other important thing about Haifa is Technion, the Israeli Institute of Technology also is in Haifa. So, most computers work in Israel started at Haifa which was very convenient.

Weber: And did you have brothers and sisters?

Cohen: No, I didn't, I did not.

Weber: And what did you like to do for fun when you were a kid?

Cohen: The number one element of fun was being away from the parents. Being together with a group of kids doing things, like as I say, hiking or sailing or whatever.

Weber: And what were your best and worst subjects in school?

Cohen: The worst subject was history which is really funny given that my kid, which is very talented in mathematics, graduated with honors from Oxford in history. Yeah, and I'm sure that my history teacher is laughing in their grave.

Weber: Well, it skipped a generation.

Cohen: Yeah, my best subjects were obviously mathematics and physics, chemistry was [INAUDIBLE] and all the rest far, far behind it.

Weber: Describe your -- you had read about them, but describe your first actual exposure to computers.

Cohen: The first exposure to computers when I learned to program and I was programming in language very similar to FORTRAN, I think this is a little bit before FORTRAN.

Weber: And where and when was this?

Cohen: And this was the one in the Weitzman, I'm sorry, the one in the Weitzman Institute was the machine that came from Sweden, was very small machine. I think it had a few thousand transistors, there was also, as memory servied, used rotating drum which was rotating very fast, the machine was called the Vegematic or something similar. It was built in Sweden and this was in about 1961. I was exposed to FORTRAN much later and Fortran was too high of a language compared with Vegematic.

Weber: This was already in college?

Cohen: Say again?

Weber: You graduated in 1963.

Cohen: Yeah. So, this was during my third year in college.

Weber: Right, so that was the first time you actually laid hands on a computer terminal?

Cohen: Yeah, on a computer. I don't remember if this machine even had a keyboard. But we did everything with base using hexadecimal notation.

Weber: Wow. And that was at your university, at Technion?

Cohen: No, the only computer in Israel that I was able to use at this time were in the Weitzman Institute. So, I went to the Weitzman Institute once or twice a week and I got the machine for a few hours which is to say were always the worst hours of the day like midnight. And I programmed those machines and I was very happy to compute the integral of sine X from zero five with the input, when machine didn't have any high level language.

Weber: So you were really spending a lot of time writing the programs and then going in and for just a few hours.

Cohen: And try to.

Weber: But was this for a course?

Cohen: No, it was because I wanted to learn about computers. So, I went to Weitzman and met Professor Pekeris, he was the head of the computer department in Weitzman and he built a computer called Weizac that they used and it replaced an older computer, the Vegematic, that was built somewhere in Sweden.

Weber: So, you were getting access to the older computer?

Cohen: Yes. I was introduced to very old computer.

Weber: You were just informally going and using it.

Cohen: I came to Weitzman and met him and told him I wanted to use the computer and he asked me do you how to use to computer and I said no. So, he said no problem and gave me a manual and say here it is, why don't you compute the integral of sine X. And that was my first exposure to computers. Luckily, I knew someone who also works there and he helped me, this was Emil Purelli [ph?] which was a recipient of several ACA awards that unfortunately died about two years ago.

Weber: He was at the institute?

Cohen: Yes and he guided me through learning about computing.

Weber: And did you have any goal in doing this or just curiosity?

Cohen: Curiosity was more than enough, great motivator.

Weber: What did you study at university?

Cohen: In Israel like most of Europe, unlike the United States, you chose your area of study when you enter the institute, so first year student in math and physics, [INAUDIBLE] chemistry, have practically zero in common except a physical education and foreign language and this kind of stuff. So by the time I finished the four years in Technion, I had more than twice in math that a four year graduate of MIT had.

Weber: What was your actual course of study, what was your degree in?

Cohen: My degree was in applied math.

Weber: And so in your third year you started playing with the computer on your own, did you immediately think this might be something that could become a career?

Cohen: I never thought about career because I did not think that far into the future. But it was fun and it was very inviting community environment, so, since it was fun, I stayed with it.

Weber: And what did you like about it?

Cohen: It is like solving puzzles, the challenge of solving a problem not because you have to but because you want to.

Weber: And do you like puzzles in general?

Cohen: Depends on what kind of puzzles, crossword puzzles no.

Weber: But you like challenges?

Cohen: But I like to be challenged by a good puzzle.

Weber: Do you like mathematical puzzles?

Cohen: I love them.

Weber: More than words?

Cohen: Yes, the less words the better.

Weber: Your next step was the United States.

Cohen: Mm-hmm.

Weber: What made you want to come to the United States?

Cohen: Because the computer technology.

Weber: So, you took the computers quite seriously?

Cohen: Yeah. So, I went to, I think that, yeah, I got my Bachelor in '63. From '63 to '65 I worked on a Master in Israel. Most of my time was devoted to computers.

Weber: Also at the Technion, a Masters?

Cohen: Yeah, which I never finished because I was invited to come to MIT to study applied mathematics, so left the Technion and went to MIT.

Weber: Who invited you, how were you invited?

Cohen: There was some program that was controlled by a few professors from Harvard, yeah, the only name I remember now is Goldstein, I think Sidney or Harvey Goldstein, he was a professor of applied

math at Harvard and what he did mostly was fluid mechanics. So, I thought this would be interesting, it turned out it was not. But so in '67, I moved from Harvard, from MIT to Harvard to work with Ivan Sutherland. Ivan Sutherland is the person who practically invented computer graphics.

Weber: But at the Technion those two years, you were still going straight math direction but doing computers on the side for your Masters?

Cohen: About.

Weber: The fact that you didn't finish suggests that you bored or frustrated somehow?

Cohen: Yeah, because it was not interesting and when the Technion got the first computers, I was probably practically the only person with any experience with computers because the summer between my third year and fourth year, between my junior and senior years in college, I was spending the summer in Israel working on a TVA computer. TVA is the Tennessee Valley Authority and they had a big computer which was an IBM 704.

Weber: And this was in which summer?

Cohen: This was '62 to '63.

Weber: And so that gave you a taste of?

Cohen: Of computing.

Weber: A different possible future.

Cohen: Yes.

Weber: So that made you less satisfied with what you were doing?

Cohen: Yeah, I was convinced I wanted to computer. And for some reason, I got interested in computer graphics

Weber: Why?

Cohen: And once I heard that Ivan Sutherland was at Harvard which was up the street from MIT, I was delighted to jump ship and move from MIT to Harvard.

Weber: But if you're exposed to computers already by '63 with the TVA, why did you stay in math?

Cohen: What did I say?

Weber: When you went to MIT still doing math, right?

Cohen: I went to MIT doing math but at the time, but at that time I discovered that I was very interested in graphics. One of the things that I did for TVA was connecting a Calcomp plotter to the 704 and doing all this required software so other people could draw all kinds of things. One thing we today is start drawing 3D objects, like buildings. And one I do that I generated stereo images, so you could see in stereo.

Weber: How, you had to separate the eyes?

Cohen: You use two pieces of paper and have something of plastic that you buy usually in a souvenir store of a national park and then you generate images that would fit that size and be the right distance.

Weber: But this was for fun during the TVA project?

Cohen: It was absolutely for fun, but it focused me on graphics.

Weber: Were you interested in, not in computer graphics, did you enjoy drawing or were you a graphics person?

Cohen: I was not a graphics person.

Weber: It was more the challenge?

Cohen: I wanted the computer to be graphics computer.

Weber: Why?

Cohen: Not to change me. I once I discover about how to do images on a 704 which was all static, the next challenge was to do motion, to introduce motion. And the challenge in doing all this kind of images was doing a thing like flight simulations where there is not only motion but much of the image is behind you and so there are lines that start in front of you and end behind you and you have to clip them to the right shape and the right place and the right size. And all that is changing and if you did it would be really like flight simulator, if you do it in a certain time frame of say to 15 to 60 frames a second, so all of them together was another challenging, interesting problem.

Weber: And the 704 was not designed as a graphics machine in anyway?

Cohen: No.

Weber: You must have some sort of video terminal at some point?

Cohen: No, the 704 didn't have any video, it's a Calcomp plotter to draw static images.

Weber: So you were hoping to generate frames that could be run as a movie then?

Cohen: Yeah, so we did the frames one at a time and then only later I managed to have a computer that could do it in real time.

Weber: And what were you writing programs in?

Cohen: Huh?

Weber: You were writing programs in what language at this point?

Cohen: On the 704, I believe it was the FORTRAN.

Weber: And you were creating your own programs to a large extent?

Cohen: Yeah, most of them were my own programs. When you go to Calcomp plotter, we didn't have any software, so I had FORTRAN to make software just to draw lines and then to draw more and more complicated objects with different relations. And the challenge was to do it as fast as possible due to time constraints of dynamic machines.

Weber: This was not part of your official work, it was on your own time?

Cohen: Everything is your own time if it's official.

Weber: Yeah. And so you spent the summer in Tennessee then?

Cohen: I spent the summer in Tennessee which was very interesting and when I came back, I was more interested in graphics and luckily I met Ivan Sutherland which was about 46 years ago or something awfully close to that. I think it's 44 year ago. I met Ivan and Ivan convinced me that I want to leave MIT and join him at Harvard.

Weber: How did you meet him?

Cohen: I'm sorry?

Weber: How did you meet Ivan?

Cohen: A friend of mine Barry Wesler told me that Ivan is giving a class and I said, "Who's Ivan?" And then he told me all about Ivan and what Ivan did. The most important was Sketchpad at the time and it was very attractive. So, I went to Harvard and met Ivan and Ivan invite me to his office to discuss problems and it turned out that I knew how to do 3D clipping and he did not. So, he immediately accepted me to his group.

Weber: You knew from experimenting with the TVA?

Cohen: Yeah, I was better mathematician than Ivan and therefore for me it wasn't much of a challenge.

Weber: But also you had been thinking about computer graphics when you did the 704 with the TVA?

Cohen: Yeah.

Weber: What was your first impression of Ivan?

Cohen: I was amazed how fast he was thinking between hardware and software and trading one from the other. I usually used to think about a hardware as a given and cannot be changed and software is

where all the changes are. And Ivan said let's think how we would do it with hardware and from that point, we continued pursuing how to evaluate an algorithm in hardware. Bob Sproull's book on computer graphics describe with much detail the algorithm which he named Cohen-Sutherland 3D clipping and I was surprised how many times people in places have never heard about, they come to me and say I taught your algorithm in class.

Weber: You sat in when I interviewed Barry Wesler and he talked about meeting you, but talk about when did you meet Barry Wesler and what was your impression of him?

Cohen: I met Barry in one of those summers, probably '65, '66 plus minus a year or two and Barry was working for DEC and we just got a DEC machine which was a DEC 338.

Weber: You were at MIT still?

Cohen: No, at that time, I was at MIT but the summer working for Adams Associates which was a software house, I contract and they work for Lincoln Lab and we, meaning Lincoln Lab, got the DEC 338 and I was supposed to program it and there were problems with it. The machine did not do what it was supposed to so we drove to DEC which was about an hour drive from where we were to complain about it and the engineer that was assigned to sort it all out was Barry. And we had something happen, it turned out that Barry was in charge of checking machines and he found out that there was a serious bug in the machine, the bug was that whenever you tried to set some table, the most significant bit always on whether it was supposed to be or not. So, in order to be able to continue the testing, Barry put the table always in a place that would need to be on. Yeah, which was obviously the wrong thing to do because it may cause the machine pass the test. And our table just happened to be in the lower memory with it being zero, so obviously it did not work. And DEC were very embarrassed to find out that that in this case, instead of discovering problem, you just circumvent it but jumping over it which was a good thing to do to accelerate the testing provided that you remember to check for it. Which they didn't.

Weber: That was Barry's idea or not?

Cohen: No, Barry did the right thing. This management did the mistake, so luckily this problem, he say oh, I know what it the problem is and here's the fix for it.

Weber: And what was the fix?

Cohen: Pardon?

Weber: What was the fix?

Cohen: No, he knew that if you put the table in a different place, then it would work, which is not the fix, was the problem, but it makes the problem disappear unless you need to put the table elsewhere.

Weber: And so this is how you met him.

Cohen: This is how I met Barry.

Weber: And formed?

Cohen: Then we were both MIT students and we used to meet each other always on say Wednesday from between two and two fifteen when we changed lecture rooms. And every week it was since we had the same schedule, every week we would pass each other in the corridors and just say hi. And one day, he stopped me and said do you know Ivan gives this class. And I asked who is Ivan? And he told me and he convinced me that I wanted to meet Ivan. He was right.

Weber: Once you met Ivan and you switched to Harvard, right?

Cohen: Yes.

Weber: And officially what were you doing at Harvard?

Cohen: I was a student of applied math which was really was computer science and I worked with Ivan and had so much fun that I would probably stay at Harvard to this very day except that Ivan moved away to Utah. And so I had to move away and I didn't want to move to Utah so I stayed at Harvard.

Weber: But you got a Ph.D. at Harvard?

Cohen: At Harvard.

Weber: In applied math?

Cohen: Applied math meant computer science.

Weber: And you had some very interesting classmates. Who was around at the time?

Cohen: Bruce Faber that stays with Ivan for the rest of his professional life. Harry Louis which is a Dean at Harvard now, I believe in math, not in computer science but I'm not sure. Art Buchwald, I'm sorry, Art [INAUDIBLE] which I forgot what he did later, but for a long time he was interested in drawing data on CRTs and analyze the data, something that I did not appreciate at the time. And several other people who's name I can't remember.

Weber: And where were you living in that period?

Cohen: Very close to Harvard, such that when we needed babysitters, we could always find someone.

Weber: So you were already married?

Cohen: I was already married and we have a little kid.

Weber: When did you get married?

Cohen: I think 1961.

Weber: So very early, when you were still at university.

Cohen: Mm-hmm, yes.

Weber: How did you meet your wife?

Cohen: We were in the same high school together.

Weber: And were you in the same youth group?

Cohen: No, we were in very similar, but not the same.

Weber: And was she interested in computing type things?

Cohen: Absolutely not.

Weber: What was she interested in?

Cohen: She was a music teacher and I really don't remember that much.

Weber: She taught music, she went to university?

Cohen: No, she did not, she was a high school teacher of music and she played the recorder.

Weber: And so she could do that all the places that you moved fairly easily for her?

Cohen: Yeah.

Weber: Then you had a child when?

Cohen: The child was born about 1964. I can't really, I don't remember. I have to compute.

Weber: You were already in Cambridge?

Cohen: Yes, we lived in Cambridge near Radcliffe which was the source of babysitters.

Weber: You didn't want MIT, there were no women or very few at MIT at the time?

Cohen: At MIT no, very few.

Weber: Who was the babysitter?

Cohen: Yeah, because many of the Radcliffe ladies looked more like boys than girls.

Weber: From Radcliffe or from MIT?

Cohen: I'm sorry, at MIT.

Weber: Right.

Cohen: So at Radcliffe they looked like girls.

Weber: So you had babysitters and you could walk to Harvard.

Cohen: Yes.

Weber: Did you like Massachusetts?

Cohen: I absolutely love Cambridge.

Weber: Why?

Cohen: It's hard to tell now because part of it is because of the people around me and which I am sure were replaced by other people which probably was very different. At the time, I liked the environment and the company.

Weber: And did you continue to do outdoor things?

Cohen: Yes, skiing and skating and rowing and forgot what else you do in Boston.

Weber: But the group of people you knew around Harvard, MIT, Lincoln Labs, very interesting group.

Cohen: Yes.

Weber: And when did Ivan go to Utah?

Cohen: Probably about '67 or '68.

Weber: Okay, so that left you.

Cohen: I think '68.

Weber: And that left you at loose ends.

Cohen: Yeah, but even though he went to Utah, he stayed as my advisor, so he was on my committee at Harvard and one day he came to me and said you know, Danny, you better think about finishing and I said oh, what should I do? And he showed me several of work that I did and he said do you see there is a common thread in all of them, you do lots of incremental computers to solve these problems, so why don't you call your dissertation Incremental Methods for Computer Graphics? And have five chapters, each of them would be another piece of work you did before. I thought that was a great idea and by following it, I managed to get out.

Weber: And what were the five chunks?

Cohen: One of them was generating curves, what do you call them, whatever and one of them was about hidden lines using algorithm that was also used by John Rohanack [ph?] later in his dissertation.

Weber: But you came up with the algorithm?

Cohen: Yeah, I came out with the major modification.

Weber: Yeah, but Ivan Sutherland, no, who was it?

Cohen: I'm sorry?

Weber: Sorry, modification to?

Cohen: The Rohanack algorithm to make it hundred of times faster and something with battery nets that would be too complex for me to remember now and I forgot what the other was, one of the things I had a new way of generating curves and in order to show that it's better, I had to compare it with something, so I invented another way of doing it, I found out the second was better than the first. So, we changed the words to say the two methods and this one is better than that because blah, blah, blah.

Weber: And the method for generating arcs you said?

Cohen: Pardon?

Weber: A method for generating?

Cohen: Curves.

Weber: Curves, okay, because you had said arc before, but curves in general.

Weber: The important curves were circles and ellipses and parabola lines and hyperbola better known as conic sections and I also mathematics that was probably foreign to most of the other student around. I have said before about MIT, I had more mathematics in Technion then most students get here.

Weber: And you put that to practical use.

Cohen: Yes.

Weber: So, that took care of your dissertation, then.

Cohen: Mm-hmm.

Weber: And then what did you want to do next?

Cohen: Then I was convinced to join the USCISI in Los Angeles.

Weber: But you knew Larry Roberts and Len Kleinrock before you left the East Coast?

Cohen: Yeah, I knew Larry and I knew Len.

Weber: How did you meet them?

Cohen: Yeah, Larry was using the computer consulting company that I worked for. So, he came with different problems and usually it was my job to solve them and implement the solutions. For example, he wanted, when he moved from MIT, from Lincoln to the Pentagon in Washington, he wanted to have the same computing environment that he had on the TX2 in Lincoln. So, in order to provide the TX2 in Lexington Lincoln Lab over telephone lines to a DEC 338 in the Pentagon and this 338 pretended it was the TX2 and such that it allows the one to see it in Washington and have access to all his programs that were running in Lincoln. For me, that was the first entry into computer communication and it got me interested in it.

Weber: And what year would that have been?

Cohen: This was '68, I believe, around '68.

Weber: Right, when he had been started at ARPA after Lincoln Labs.

Cohen: Yes, then he moved to ARPA and started the ARPANET.

Weber: But when he used to come to the company you were working at, you enjoyed spending time with him I take it? You felt a connection with him when you were working for the consulting company?

Cohen: Yeah.

Weber: Tell me your impressions of him at the time?

Cohen: The first time, I went to the other company called Adams Associates and it was interviews and at the end of the interview, supposed head of the company said to me, “you are a Math major?” Yeah? And he said “here is a paper written by Larry Roberts, why don't you read it and see that you understand it and in two or three days we meet again and we talk about it.” So, I read the paper and found several typos and several mistakes and one mistake was a conjunction that he say I think that blah, blah, blah happened but I did not prove it. Another one was he had a wrong example, it was false to several things. So I came back to Ryder [ph?] & Associates, and said, "I read the paper but there are a lot of mistakes in it." And then they looked at each other and said, "we have a problem because we told Larry Roberts that we'll program it, and if there are mistakes in it, you cannot program it. What shall we do? Are you willing to go to Roberts and tell him this, about the mistakes?" And I say, "Sure." Being a Math major means that if you prove something, it is right, and if you disprove it, it is wrong. It's not a matter of being afraid. So, but, they were afraid of talking with Larry. So they sent me. So I showed those things to Larry. He was aware of most of the things that I had to show. The conjunction, it was wrong. When he saw it, he said, "you're right. No wonder I could not prove it." And there was something else. And then he said to me, "finally someone really read my paper, this paper." It turns out Ivan also read his paper but he don't understand it; he didn't catch any of those problems.

Marc Weber: Which paper was it?

Danny Cohen: It was-- the paper is called "The Homogenous Coordinate for Presenting 3-D Objects"; blah-blah-blah, something like that. That was-- my first meeting with Larry was when I have to show Larry

that he had mistakes; and he was very happy that I caught them before either of them having made a technical report and someone else still not catching them.

Marc Weber: Well and also the error that you found that prevented him proving it would've-- he couldn't have done much with it until someone found the error. Right?

Danny Cohen: Yes. Exactly. I saw- we saw last week or two weeks-- on the 29th, at UCLA, I saw Larry. He didn't change much-- I bet I did though-- in these- for the last years that I know him.

Marc Weber: But you guys, the interaction is probably the same. Right?

Danny Cohen: Probably not very different.

Marc Weber: No.

Danny Cohen: We have different styles we developed with it. Yeah.

Marc Weber: But I think-- who was saying-- I guess it was Len Kleinrock saying that Larry Roberts was quite a practical joker.

Danny Cohen: Yes.

Marc Weber: Was that your experience too?

Danny Cohen: Yeah. As a matter of fact the only time-- not the only time, but the only time I remember now with Larry-- Larry was collecting coins, old coins. And somewhere I found in some store a postcard saying something like: The other day you stopped in our office and you left- and you used to pay a 1907 quarter." Or something like that. I said, "We sold it for $1500.00 to a collector." And Larry saw it, and he immediately said, "Oh probably Danny sent it." And Billy, that was there, asked him, "How can you tell?" And he said, "Because a 1907 quarter doesn't get $1500.00; it'll only get $1200.00." Or something like that. He took it totally serious. But he could see through that it was a joke. But with Larry, you could do it. There were lots of people you could not do it with.

Marc Weber: Yeah. Well they would not see through it. So you became friends or acquaintances?

Danny Cohen: Acquaintances I think would be a better word.

Marc Weber: But Barry Wessler you became friends with in that period.

Danny Cohen: Yeah. Barry and I are good friends.

Marc Weber: So Larry you didn't really socialize much?

Danny Cohen: No. He socialized with other people. I've never been in his house. I don't know if he was ever in mine. But with Larry, I've been in his place many, many times.

Marc Weber: Barry? Yeah.

Danny Cohen: With Barry. And he was in my place.

Marc Weber: And Len Kleinrock you met around there.

Danny Cohen: Yeah, around the time I moved to Lincoln.

Marc Weber: So how did you meet Len Kleinrock though?

Danny Cohen: I don't remember. But it was most likely in Lincoln Lab. And then when we discovered that both of us were going to Los Angeles, the connection got more tight.

Marc Weber: And so ISI-- but ISI was starting around that period.

Danny Cohen: I joined ISI I think in '72; in '73.

Marc Weber: Okay.

Danny Cohen: And they started in '72.

Marc Weber: But so first you just went to USC. Right?

Danny Cohen: ISI and USC are the same.

Marc Weber: Right.

Danny Cohen: Yeah.

Marc Weber: Well I mean USC is the larger university.

Danny Cohen: Exactly.

Marc Weber: ISI is the Institute.

Danny Cohen: Yes. So I think it was Bob Kahn who saw my flight simulation at Harvard.

Marc Weber: Oh true. That was still at Harvard. Talk about it.

Danny Cohen: And Bob noticed-- the difference between my program and all the others-- that mine was running real-time, in real-time. When you run in real-times, there are all kind of remote control issues, that are different than non-real-time. And since he was interested in packet voice, interactive voice, he understood it, and he did real-time.

Marc Weber: But this is later on. Sorry. Please do talk about-- I missed the fact that the flight simulator, you were still at Harvard. So talk about the flight simulator program.

Danny Cohen: When I came to Harvard, the first thing that Ivan asked me to do was to rewrite my flight simulator, to run in the Harvard environment.

Marc Weber: But you had started it at MIT? When did you start your flight simulator?

Danny Cohen: The flight simulator started probably '65.

Marc Weber: At MIT then?

Danny Cohen: No. I'm trying to-- no the flight simulator was done before-- the first time it was done was on an SEL computer; Sierra Echo London. And I did it for the consulting company, Evans & Sutherland, which sold it to SEL to demonstrate how fast the SEL computers are.

Marc Weber: So this was when you were doing side jobs but going to MIT.

Danny Cohen: Yes. And when I moved to Harvard, the first thing that Ivan asked me to do was to rewrite the program for the Harvard environment. And I did it. And that was the only real computer game probably in existence. And lots of people spent nights doing flights, flying the simulator at Harvard. In some meeting someone came to me, someone I'd never met, and he said, "Did you write the flight simulator at Harvard?" And I said, "Yes." And he said, "You have no idea how many nights you cost me. Because I used to come here and play with it, hours and hours, to no end."

Marc Weber: And it was running on--

Danny Cohen: On the Harvard PDP-1.

Marc Weber: And so what were the graphics?

Danny Cohen: The graphics of the PDP-1. Later we go-- and for another consulting company I wrote a PDP-15 version of the same thing. And when the ARPANET came to being, I re-- we rewrite the program such that the graphics happened at Harvard on the PDP-1. But the heavy computer happened at MIT on the PDP-10. And the two of them were connected over the ARPA Internet. So when I came into the room, I would go to the PDP-10 at Harvard, and make him send a message to the PDP-1 at Harvard; download all the programs the PDP-1 needs to run. The PDP-1 will check the input devices; which were the throttle and several switches. There were no pedals. This would cause the computer at MIT to compute where the aerodynamics and send- and compute what you should see from where you are; send it to Harvard, which would display it; change- check the stick and the throttle, and sent it to MIT. It would update the position of the image and send it to Harvard. And so then next morning I called ARPA and told Larry that it was working. Larry could not believe that it was working, and he thought that I was telling what I wanted to write; so asked me when do I think it would work? And I say, "Larry, it already did. Last night it worked." And he said, "No, I want to know when it will work on the computer." It was a very funny conversation until he was convinced that it was already running, and it was awfully exciting to see, because he didn't expect the ARPANET to be this fast.

Marc Weber: When you talked about early games, you probably saw Space War in that period. Right?

Danny Cohen: Yes Space-- I'm sorry-- Space War was the first real game. Space War, you see only the image from the outside.

Marc Weber: Right. The split-flight simulator.

Danny Cohen: And you had to-- the clipping you have to do was of points, not of lines.

Marc Weber: Right.

Danny Cohen: Which is very simple.

Marc Weber: And I know that you're a pilot now. But were you interested in flight? Why did you do a flight simulator?

Danny Cohen: Well the flight simulator I did because it was an interesting graphics problem. But this gave me a taste of flying, and convinced me that I wanted to learn how to fly real airplanes.

Marc Weber: So you did it in reverse.

Danny Cohen: I did it in reverse. And my flight instructor told me that I was the first student who didn't know how to fly an instrument before knowing how to fly visual. Because I taught myself lots of things about the airplanes on my simulator. Unfortunately most of them were wrong. I thought that if you push the stick, the throttle would make the plane go faster. And if you want to go high, to climb, you pull the stick. It turned out that's practically backwards. If you want to really open, if you want to go higher, you push the throttle; not the stick, which is sticky. You can point the airplane open up but it would go down if you don't manage the power correctly.

Marc Weber: So the flight simulator was based on your ideas of how a plane flew.

Danny Cohen: It was based on my non-informed ideas about the way I thought airplanes fly.

Marc Weber: Okay. So you did the flight simulator as a graphics challenge. You moved it to Harvard and then the ARPANET. It's the first flight simulator general one. There was not a specialized sort of custom made--

Danny Cohen: Yeah. The first one was made on the SEL 840-- 018?-- 840 I believe. Yeah. And it was displayed in the Fortune Computer- yeah, Fortune Computer Conference; probably of '66. And it was not far from the IBM booth where they displayed the 360s; it was practically an old computer. So there were always more people looking at my simulator, and standing in line to fly it for a few minutes, than looking at the 360s.

Marc Weber: And how did you control the simulator?

Danny Cohen: The simulator has a stick and a throttle, and several switches. The switches did things like gear up/gear down, or something like that; which is low rate input/output.

Marc Weber: But so you created the stick, or you found an old-- was it from a real airplane or what?

Danny Cohen: No, we did not manage to find a real throttle. But we found out-- but then SEL built one.

Marc Weber: So that's probably the first game controller though.

Danny Cohen: Pardon?

Marc Weber: You could argue the first game controller.

Danny Cohen: Yeah. You could think about it-- and nowadays do you want to count Space Wars? Yeah Space War of course.

Marc Weber: But it didn't have a special controller though.

Danny Cohen: No, you used to do it with the switches.

Marc Weber: Right. Ah true. Okay. And so this you were doing-- your thesis included things you had learned in doing the simulator.

Danny Cohen: Some of them.

Marc Weber: Okay. But the simulator was kind of a separate project; a separate effort of yours?

Danny Cohen: Yes. The simulator was important to learn how to do a [INAUDIBLE]; and how to do it fast.

Marc Weber: But I guess I'm asking what was the relationship between the simulator project and your main work, main academic work?

Danny Cohen: I don't remember.

Marc Weber: Okay.

Danny Cohen: You can probably describe it five different ways, and all of them would be equally true.

Marc Weber: But it was one of the projects you were seriously involved with.

Danny Cohen: It was one of the projects, yeah. And I had lots of fun during those days.

Marc Weber: Were there any other projects that you were doing?

Danny Cohen: Yeah we did a-- for example we did a program that- to draw a bottle; bottles, the kind they're using for perfume. So you could sit near a computer and in a few minutes run tens of different shapes; and do it interactively and computing all the volume of it. It turns out that in the perfume industry the shape of the bottle is more important than the smell. People don't appreciate it but the main variant in perfume are the shape of the bottles.

Marc Weber: And this is in your DVD, right?

Danny Cohen: Yeah, this one is in the DVD. That's how I remembered it.

Marc Weber: And was this-- sorry.

Danny Cohen: There was another program that I wrote to teach my little kid, that was probably four or six at the time, doing simple arithmetics. It would show a face on the computer and say "Seven plus two equal question mark." And if she entered the right answer-- which I believe is 9-- then the face will smile. If you have the wrong answer then it would frown. And then they have tears coming from one eye. If you make one more mistake it would be tears from both eyes. And this is the first computer I did an instruction program I know. *Time Magazine* came and they showed her playing with it. And then it was on national TV. And for awhile I would get some calls from some friends: "Guess what? We opened our TV in Salt Lake City and saw your daughter playing with your computer."

Marc Weber: Do you have that video now?

Danny Cohen: You have this video.

Marc Weber: Oh that's on there? Okay. Yeah, that sounds familiar. And how many children do you have?

Danny Cohen: I have now a boy, which is about 25, and he wants to be a reporter in China.

Marc Weber: But you were also talking about a daughter.

Danny Cohen: And I also had a daughter that was daughter that was killed in a traffic accident about 20 years ago.

Marc Weber: I'm sorry.

Danny Cohen: It's okay.

Marc Weber: But you had two children.

Danny Cohen: I had two children; one at a time. No I'm sorry, there were two or three years that I had both.

Marc Weber: So your daughter was very young when the math program was going.

Danny Cohen: Yes.

Marc Weber: So this was still back East.

Danny Cohen: I'm sorry, say it again.

Marc Weber: Still when you were in Massachusetts.

Danny Cohen: Yes. We did it on the Harvard computer.

Marc Weber: And what other programs did you do up here?

Danny Cohen: One funny thing. Bob Taylor came to visit when he was running ARPA. And we were-- and Ivan was not sure whether we want to show him the program with my kid playing the computer, with arithmetics. Then finally-- because this was obviously not an ARPA military DoD program. And that's why he didn't want to show it to them. On the other hand it was interactive, so he did want to. Then finally he decided to show it. When Bob Taylor saw it, he jumped up and down, and says, "That's absolutely perfect. I want it to run on my computer in the Pentagon." And he says the reason is that Congressmen would not understand the problem with the addressing, but they would understand addition and subtraction. What he did not- what he forgot to mention to us, that he had two kids that were a similar age. So on the weekends he would bring them to the Pentagon and let them play with the computer. But he never mentioned it. Bob, if you ever see this tape, I hope you remember why.

Marc Weber: And any other program?

Danny Cohen: Pardon?

Marc Weber: Any other programs in that period? Any other interesting programs or projects you were doing in that period?

Danny Cohen: Yeah. I think the one that we felt was the most interesting was when we used the flight simulator together with the ARPANET. Because this was exactly what the ARPANET was building for; being able to share computing power in remote places.

Marc Weber: But it was also the first or one of the first real-time applications?

Danny Cohen: I believe it is the first.

Marc Weber: Over any network.

Danny Cohen: Over any network. I believe it was the first network also.

Marc Weber: Yeah. And what you were doing you said with Larry Roberts when he was connecting the TX-- what year was that?

Danny Cohen: I believe in '66.

Marc Weber: Okay.

Danny Cohen: Or '67. That was the first time I did computer communication.

Marc Weber: You said that that excited you, the communication aspect.

Danny Cohen: Yeah. The people who understood, like Bob Kahn and Larry Roberts, were very excited. Most of the rest thought about it as a neat program, and a way to kill a few hours; so you can practice landings and takeoffs.

Marc Weber: No but sorry-- you were already interested in interactive computing.

Danny Cohen: Yes.

Marc Weber: Obviously. With a flight simulator. Then when you saw the beginning of networking, did that strike you as another area you wanted to explore?

Danny Cohen: Yes. So Bob Kahn convinced Keith Sandefur [ph?], which was the director of USC/ISI, that it would be better if I moved to ISI and work on real-time communication. So Keith managed to convince me that this would be a good thing to do. So I left Cambridge and joined them at ISI.

Marc Weber: And you had met Bob Kahn in Cambridge. But he was at BBN in '72.

Danny Cohen: No. Bob Kahn at that time already moved to ARPA

Marc Weber: Oh in the '70s, yeah; definitely. Right. When did you meet Bob Kahn?

Danny Cohen: Say it again?

Marc Weber: So when did you meet Bob Kahn?

Danny Cohen: The real answer-- I'm sorry. The answer is again about '68. No just a second. I moved to-- '67. Around '68 sometime.

Marc Weber: So when he was at BBN, right?

Danny Cohen: No, when he already moved to ARPA.

Marc Weber: Okay.

Danny Cohen: But it turns out that he and I were in the same-- we met two or three years earlier, in the Spring- in the Fall [INAUDIBLE] Conference in San Francisco. But we didn't really meet there. We just were both of us consulting, or whatever. Once Bob moved to ARPA, seeing stuff moving fast, and we were much more interesting than life at Harvard.

Marc Weber: Until you went to ISI, what--

Danny Cohen: I'm sorry, say it again.

Marc Weber: You moved to ISI you said around…

Danny Cohen: '72.

Marc Weber: …'72. So in the very early years of the ARPANET, you were following- you were interested. But what was your actual involvement?

Danny Cohen: When I was at Harvard, we were just using the computer; we learned how to use the computers. I went to ARPA and told Larry Roberts that I needed a bigger disk for my computer. And Larry immediately say, "No problem. You have it." And then he added, "It will be installed at ISI." And I said, "Larry, I requested-- ISI is the furthest west you can go, and we are in the east." "Yeah." And he said, "You are a smart guy. You'll figure out how to use it over the network." Sure enough we did. But it was a very strong motivation, to have as much disk space as we needed, through the network. That was a much better way to motivate than writing a contract that would spell out exactly what we'll do and what they would do and everything. This was the spirit of those days. Another great example is that I came to Larry at ARPA and say, "I'm staying at Harvard. I'll be Assistant Professor, and I need a bigger computer." He asked me, "What do you want?" And I say, "I want a PGP-10." Thirty days later-- not around 30 but exactly 30 days later-- he called and he say, "You'll get it; you'll get it in a month." Another month later I had it delivered to Harvard. It took two months, from the time I asked for it verbally until it was working at Harvard. Yeah. The paperwork took another year or so to catch up with what happened. No proposals, no contracts; just, "You want it. You'll put it to good use. Here it is." There's the business of a hard time handling it. But it wasn't a problem of mine.

Marc Weber: And so then Bob Kahn got you to move to ISI in '72.

Danny Cohen: Yeah. I can tell you. I think I moved in '73; either '72-- probably '73.

Marc Weber: And he was starting to think about packet-voice by then, right?

Danny Cohen: About?

Marc Weber: He was starting-- well the packet radio research had started.

Danny Cohen: No it didn't start yet.

Marc Weber: It's '73 roughly.

Danny Cohen: Whatever it is, the packet radio came after the ARPANET.

Marc Weber: Oh yeah.

Danny Cohen: Yeah.

Marc Weber: Okay. So what did he want you to do at ISI?

Danny Cohen: When I came to ISI they wanted me to participate in the voice, packet-voice project. So first we had to build an environment; the right environment with the right computers that would be able to do all the computings that was necessary. It was several cabinets at the time. Today it is a small fraction of one chip.

Marc Weber: And what was your role in the project?

Danny Cohen: I ran the project, the ISI side of the project. But in addition somehow I became like the project engineer of the entire program. That included like eight or ten different places; like BBNN and Lincoln and Utah and-- oh gosh, where else was there? And NSA. I can't believe my memory's that bad. There should be about eight of them.

Marc Weber: And how was the work divided between them?

Danny Cohen: When the group was put together, Bob Kahn made sure that he has all the tasks covered. And like you needed speech compression. He knows that between Santa Barbara and SRI there are people who can do that. We were assigned to solve the network problems. BBNN was assigned to change the- to improve some algorithms. So and every year we met two or three times; one of them always in the winter in Utah, when the skiing was good. And we were known as-- NSC was the name of our project, for Network Secure Communication. It was secure because it was digital. But most people thought it was called the NS-Ski project. Because we made sure every year that we have one meeting in good ski places.

Marc Weber: So this was your annual meeting.

Danny Cohen: It was one of the three meetings that we ran every year.

Marc Weber: And so you would all get together from the different sides.

Danny Cohen: We would all get together; tell each other what we did. Be totally open because we were not competing. We were all-- we knew that if we do a good job, we'll be- we'll remain all of us. If we do a bad job, we lose all of us. It wasn't a competition between us. It was a competition between us and the problems. And Bob did a great job of dividing the work in a way that makes perfect sense. And the fact is that it's working.

Marc Weber: And how many people total? Like a typical meeting, how many people would there be?

Danny Cohen: How many people would come to a meeting? Like 10 to 20.

Marc Weber: Oh. So it was enough you could really get to know people.

Danny Cohen: Yes.

Marc Weber: And did you have fun at the meetings?

Danny Cohen: Say it again.

Marc Weber: The meetings were fun?

Danny Cohen: Absolutely.

Marc Weber: So what kind of places did you go?

Danny Cohen: I can think immediately about the Utah meetings that we had. At one point Utah lost their contract. But it did not stop us from keep going in the winter to Utah. They were very happy of us coming. We were very happy to go there. And there were people from Berkeley and Stanford-- I'm not sure about Stanford. I'm confusing. But Berkeley for sure; and Santa Barbara, in UC Santa Barbara, and [INAUDIBLE] in Santa Barbara. And we at SRI; ETI/ISI. And SRI; which I probably counted twice. And BBNN. I think that's about it.

Marc Weber: And who are some of the main people that stand out in your memory?

Danny Cohen: Bob Balderson [ph?]. And the reason he stands out in my memory is because he was very active in the voice, see, and also in the VLSI project that came later. And I happened also to run MOSIS, which is a VLSI project, and he was in both of them. And so we were old friends by the time; anyway. And needless to say, Thomas Stockham; that moved from Lincoln Lab to Utah.

Marc Weber: And what was his role?

Danny Cohen: He was one of the gurus in speech processing. What he did for fun, at [INAUDIBLE] Research at the time, was to clean old records of Caruso, singing his operas, and removing the noise that was generated by the old equipment. So he spent hours to no end, working on Caruso old recordings. Which was not part of the project. But many of the techniques, the signal processing techniques that he used were used by us later in slightly different ways.

Marc Weber: And was there much cross-fertilization with people working on audio processing in general; like for music and recording?

Danny Cohen: There was some. But not much.

Marc Weber: Other people?

Danny Cohen: Yeah. I remember some SRI people. But I don't remember why I remember them.

Marc Weber: And so you were sort of the chief engineer, as you said, for the whole effort.

Danny Cohen: Yes, I played this role.

Marc Weber: So what--

Danny Cohen: We discovered in a very early meeting that Bob Kahn was an asset as a participant in a meeting, but it was very hard to handle – as running the meeting, because he would pursue all kinds of things that sounded interesting at the time. So we changed it from him running the meetings to me running the meetings, and he participating like anyone else. And obviously he made the decision about funding and all of that.

Marc Weber: And so he would come out regularly as well, to ISI.

Danny Cohen: Yes, he came out; NSA people came out.

Marc Weber: NSA?

Danny Cohen: Several of them. Pardon? Yeah. The NSA people, yeah, used to say, "We work for the government." And they were the only ones probably with ties on.

Marc Weber: And obviously they were interested in encrypted…

Danny Cohen: Oh yes.

Marc Weber: …communication, right?

Danny Cohen: Uh-hum. I wish now that we spent more time listening to them. We didn't think security was a big problems. Because after all gentlemen don't listen to each other's packets do they? So there was a meeting at SRI that started at nine o'clock one day. That morning I flew in a Cessna 172 from Los Angeles to Palo Alto; got to Palo Alto, got my bike from the back of the plane and pedaled to SRI; and at nine o'clock in the morning, in the California sun. I was all sweaty. I got to SRI, took the elevator to the third floor, and hauled the bike to the meeting room, and started the meeting. The people from Washington, the NSA people, were all with ties, and they could not believe what they saw; not only that I was sweaty, but that I was running the meeting without a tie or whatever. It was a culture shock for them.

Marc Weber: And how were you dressed?

Danny Cohen: How I was dressed? Probably with shorts and a T-shirt. The idea was that I'll arrive earlier and be able to take a shower and change before the meeting. But there was too much headwind, or something else. So it delayed me.

Marc Weber: You flew a lot to different meetings then?

Danny Cohen: Within California; meaning between Los Angeles/San Diego. San Jose and Palo Alto I flew a lot.

Marc Weber: You had your own plane?

Danny Cohen: No but I easily rented, or for awhile I was in a group that together we owned a few planes. One-Four-Romeo; it was the name- it was the number, tail number, of the 182s that I used to fly. One-Four-Romeo.

Marc Weber: And what was SRI like in that period?

Danny Cohen: SRI? SRI was a big place. And big places are usually different. There are more ties in bigger places.

Marc Weber: But SRI also had a big contrast between like the people in the ARC Lab who were real hippies, and then people like Don Neilson who were complete straight arrows and--

Danny Cohen: Uh-hum, yeah. I think that most of the people we worked with were-- on zero to 100, where 100 is the full hippies, we were I think in the 90, around 80 to 90.

Marc Weber: And the NSA was the zero.

Danny Cohen: Oh NSA was probably minus five. But the concept that someone dressed differently can have some technical- any technical understanding was foreign for them.

Marc Weber: Yeah. So they were very skeptical. So what was the interaction like though when you--

Danny Cohen: They many times pointed that if we do it this way rather than this way it would be easier or harder to encrypt. Most of the time they were not right, because things happened later in a different way. But that was what they thought.

Marc Weber: But would that affect really the meetings?

Danny Cohen: No.

Marc Weber: Did you have real disagreements with them about that?

Danny Cohen: No. It was your opinion; fine, you are entitled to have your opinion. And they don't- they would not argue with you. Usually NSA people are not allowed to ask questions. Because this tells you- can tell you about their level of understanding. So many times they're not allowed to ask questions; or to argue.

Marc Weber: Hum.

Danny Cohen: So it's not politeness. It is just to stop the information from flowing both ways.

Marc Weber: So that made it easier to deal with the fact that they didn't necessarily--

Danny Cohen: It's easier to do it when they are in a meeting. When you talk one-on-one with them, they'll start the meeting saying, "Look, I'm not going to ask you any questions. Because if I ask you, you may learn about our level of understanding. So I may lose you in the first minute, or not at all. It may be trivial for me, or awfully complicated; I will not tell you." And you talk for an hour to a person, and he doesn't move his head even. He just sits there and look at you. And we are not used to talk one-way.

Marc Weber: That's weird. Yeah.

Danny Cohen: That's weird. Right. They learn to do it.

Marc Weber: Hum. But so they were funding part of the project.

Danny Cohen: If they funded, they funded it to ARPA.

Marc Weber: Right.

Danny Cohen: So Bob Kahn has his budget; and some of the money came from ARPA, and some came from Navy, and some came from NSA, and some came from other sources. It wasn't my problem, it was his; which he handled beautifully.

Marc Weber: But so NSA was really mostly there to observe. They were not contributing pieces of the project.

Danny Cohen: They were not contributing by any stretch of the imagination.

Marc Weber: Right.

Danny Cohen: TI also used to send people; and they would sit down and take notes, and learn, and ask lots of questions. And one day they surprised us all with integrating on one chip the analyzer. The Speak and Spell technology totally came from us.

Marc Weber: Did you know the people at TI involved with that?

Danny Cohen: Yeah, Higgins; Ricky or Dick Higgins. I forgot. Yeah, they did a great job for that time. The Speak and Spell was one of the biggest milestones in this conversion of voice communication from analog to digital. About the same time that they got their contract, there was a contract from IBM to develop connectors that would connect lots of pins needed for speech processing. Till now, they were not needed if you could do integration on one chip.

Weber: Did you know a Granville Ott?

Cohen: No.

Weber: Okay. T.I.

Cohen: The only name I know at T.I. was Higgins. Which later recruited Randy Cole for my project.

Weber: Recorded what?

Cohen: He recruited.

Weber: Recruited.

Cohen: Recruited Randy Cole.

Weber: From your project.

Cohen: Mm-hmm. A few years later.

Weber: So then what-- tell me, sort of the rough steps of the digital voice project, so you--

Cohen: Sorry.

Weber: Roughly, what were the stages or steps of the digital voice project for ARPA, Voice Over IP.

Cohen: I'm debating from which start I should--

Weber: Well you arrived at ISI, you started--

Cohen: No, it was obvious that we could-- that the communication line on the ARPANET was 50 kilobit per second, not 64, but 50. When you connect-- if it uses ARPANET, if there would be no one on the network. There you could use about-- get about 40 kilobit which was not allowed for audio, because audio required telephony as well, 64 bits per second-- kilobits per second. So the first order of business was to compress-- to compress. So Bob Khan understood it, the he need to compress, so part of the project were people who were worried about speech compression, and they were the BBN people, the Lincoln people, the Utah people, and several others, probably.

Weber: But at that point, speech-- I mean, the telephone companies had done some-- they had used digital lines prior to that. Certainly--

Cohen: They used digital line with 64 kilobit per second, as if 64 was really 56, the 64. When you thought that you get 64, you really got only-- you got, most of the time, 64, but part of the time, 56, and the difference was that you did the eight kilohertz sampling. And you sample eight bits at a time, so this gives you 64 times 8, which is 1544-- I'm sorry, I'm confusing two things. Never mind. Every eight bit which [INAUDIBLE] one bit per byte, could be-- was a control bit that sometimes was used, and most of the time was not, by the phone carrier, for doing things like monitoring the quality of the connection. So if you want to do digital communication, you better not look at this bit, because it is modified and it look like errors. So

eight kilohertz times seven bit is 56, times eight bit is 64. So the phone company said, here is 64. Well for short period of the time, it would only be 56, but it's basically 64. For us it was better to trade this 56. So Bob Khan understood that we don't have enough communication bandwidth, so therefore, with the first thing they worried-- worried about and funded, was the speech compression. Then he understood that he also need the [INAUDIBLE] real time communication, and he funded us and Lincoln, and I forgot-- and part of-- mainly Lincoln and us, to do the real time stuff.

Weber: Who was at Lincoln for that?

Cohen: Jim Forgie, which unfortunately, not with us anymore, and his team.

Weber: And so what was involved in doing that?

Cohen: In doing the networking?

Weber: The real time?

Cohen: The real time. We had to have a format that would carry both serial numbers and time stamps, things that was not part of protocol in those days. Today, real time protocol has it. You need the serial number so you can tell early about loss-- packet losses, and do whatever you should do, if any at all, and the time stamp so you know when to start playing something.

Weber: Right, the sequence to play it in. So you had to create that from whole cloth.

Cohen: So our first protocols, since flight simulator protocols have both time stamps and serial number, which are an obvious part of any real time protocol nowadays.

Weber: And you think the flight simulator is one of the first examples?

Cohen: I think it's the first, yes. I may be wrong, but--

Weber: But you think it is. Okay, so you adapted some of that from your work in the flight simulator.

Cohen: The flight simulator made-- taught us how to think about it.

Weber: So what was different then, because the fact that it was voice--

Cohen: In a voice communication, if you lose a packet, then you just ignore it. In a TCP kind of communication, if you lose a packet, you detect it, report it, resend it, which is three-- two or three round trips around the country, which, in those days, cost 600 millisecond each, so a single bit loss, was like, it could be a second or two of bad data. Yeah, so originally we have the ARPANET protocols, then when we start connecting more networks, Bob Khan and Vint Cerf propose the TCPIP protocol, and we didn't like it, because it cause-- the recovery from errors was too expensive for voice. You know, we didn't want-- so it took us about two or three years of arguments to convince Vint to separate the real time traffic from non-real time traffic, which became separation of TCP and-- between IP and TCP. The way TCPIP was proposed by Bob and Vint, was this one program called TCP, that did both of them. Today we know better, and do them separately.

Weber: But Bob was proposing this even when he knew that real time was a priority. I mean, how did Bob Kahn imagine this, because in the early to mid '70s, he was both pushing real time voice, and pushing TCPIP-- TCP as a unified standard, and how did he think it would work?

Cohen: Yeah, that's true. It was easier to convince Bob, and Bob said, now you have to convince-- convince me, now convince Vint, because he is the program manager, and he should solve it. So first time I went to see Vint about it, was before Vint even moved to Washington. He was still assistant professor at Stanford. And I tried to convince him, and he took about two years until I convinced him, and we separated IP from TCP. —By the way, are you familiar with IPV4? The V4 meaning the fourth version, fourth, do you know?

Weber: I heard you pose the question in your talk at Google.

Cohen: Well, in that case you should--

Weber: But I don't remember the answer.

Cohen: You should remember the answer, it was the version four of TCP. TCP V1, and V2 and V3, were the original TCPIP together. In V4, we separate them, and they stay separated happily to this very day.

Weber: And were other inter-networking standards like C-Crad [ph?] in France, or the PUP work at Xerox, I mean, some of those dealt with this differently as well, right?

Cohen: It took long time for the ISO community to understand this division.

Weber: But did you have any contact with, say Louis Puesan [ph?] in that period?

Cohen: Louis came to several of our meetings, and as a result, they introduced CNNP connectionless, something network protocol that was supposed to send-- you could send the packets one at a time, not as they once noticed a stream, so the TCP opened a connection, virtual connection. CNLP connection-- CLNP connectionless protocol, it don't need not type of connection concept. So there was an error, you skipped it, and you delivered it, rather than the protocol trying to fix it. So voice over IP sounds as if there was an IP and someone, some smart person came and put voice on top of it. No, it was the other way around. We had the voice running, and we insert IP under it, after taking it from the TCP part.

Weber: Right, and did you have contact at all with the PUP people at Xerox?

Cohen: We had some contact from time to time, John Shoch from Xerox came to our meeting and participated and contributed a lot to the general effort.

Weber: What aspects?

Cohen: Pardon?

Weber: What sorts of aspects?

Cohen: He told us how PUP does it for example.

Weber: And how about the people from NPL in England?

Cohen: I don't remember them in our meeting, but the people from Norway.

Weber: Yeah, Paal Spilling, and--

Cohen: Yeah, Paal Spilling, and other people came to many of the meetings, because after we had-- we did the voice over the ARPANET, we did the voice over the satellite.

Weber: Ah, okay.

Cohen: Yeah, and they handled the European side of the satellite connection, and from Norway, they connected to England, which, what we did, we violated probably many laws of the PTTs in Europe, by having connection like that.

Weber: And what year would that have been, that-- by the time you were sending it over the satnet?

Cohen: Probably mid-'70s, but that-- totally a blank about-- I was looking for something else that I could relate to both, that I cannot find right now.

Weber: And Peter Kirstein, you knew--

Cohen: Yes. We-- Peter start coming to our meetings very early.

Weber: When you say, our meetings, you are talking about voice over digital voice?

Cohen: I'm sorry, I was in the voice and then I joined the network NWG. Network Working Group.

Weber: Ah, okay, right, with Alex McKenzie.

Cohen: So all that, when we talk about the TCP and TCPIP and all of that, it was in the NWG.

Weber: Right, that makes more sense.

Cohen: Yeah, which I totally forgot-- pardon?

Weber: With Alex McKenzie?

Cohen: No, Alex was before that. Alex was with ARPANET days.

Weber: Oh, no, he stayed. He did some things further on.

Cohen: And he works, for example, on the original FTP protocol.

Weber: He stayed involved in some of the internet working, but--

Cohen: He was also in charge of the Network Control Center at BBN, that monitored all the communication all the time. But I don't remember he was part of the NWG, but I might be wrong. I have no reason not-- to exclude him, but I really don't remember.

Weber: But in terms of voice, I guess I'm kind of curious, whether, would voice have been easier on some of the other protocols floating around at the time?

Cohen: Yeah, see, the PUP, only kilobit per second. We ran it on lines that were shared a lot, but only 50 kilobit, so it is a factor of 3 times 20, like, 60 times faster than-- so they didn't have to bother about compression the way we did, and without compression, they could run much faster. So PUP was ahead of us. What our project did was not building a system, but demonstrate feasibility. It was totally impractical in the cost of mid '60s and '70s to do these things. And therefore, when we were done, there was a hibernation period of a couple of years, before Voice over IP start-- became practical.

Weber: So when were you done?

Cohen: Say again?

Weber: When were you done, so to speak?

Cohen: There was a very smooth transition from voice only to the network group, and then we have the T1 line across the country that was simulation of the satellite, to come later, and then we changed the focus to be teleconferencing, and once we were teleconferencing we say, why not do video also? There was no vocoder in existence that could do video in the rate that we want, in packets, so it was only one by CLI, but there was not packetized. You needed the entire line. We needed packets that could be shared. So we have to build the hardware, and the one we build it, the ISI is eight parallel TI speech processing chips running in parallel. And-- which was very interesting things. Then, so we starting having video teleconferencing and there were several other offshoots of that, of this effort.

Weber: But that was around the late '70s, early '80s, right?

Cohen: About.

Weber: And the packet voice in the packet radio network, that was what year? When you were saying the SATNET was first.

Cohen: Pardon?

Weber: There was voice first on SATNET before on PR net.

Cohen: IP you mean?

Weber: I mean, there was the packet radio network, which was its own protocol, and they were doing voice.

Cohen: Yeah, and we were interconnected through some gateways before IP existed.

Weber: Right.

Cohen: Because, with IP, you do each of them on IP. At 1961, I believe. That may be wrong.

Weber: Seventy-one.

Cohen: Pardon?

Weber: Seventy-one, you mean.

Cohen: In 1960-- Let's call it 1961 and then fill it in, correct it, yeah. It was my first wedding, first time I got married, and Bob Khan came to town, and it was Friday night, we have a big party, Saturday morning, we took Bob, put him in a car and we drove to the Santa Monica-- to the-- can't believe I forgot the name. I drove him to a local airport, got into a Cessna 182, which I flew, needless to say, and flew on, and we had a radio and we have one ham radio which I had one ham radio with us in the plane, and they connected some different computer, a third computer such that we could do voice over IP from the plane, from the flying plane over Los Angeles to ISI, from ISI using the ARPANET to Washington, from Washington to Vint Cerf's home. And he was home, and Bob Kahn was in the plane, and it could handle the connection. And I forgot if it was voice-- well maybe it was only telnet. It was only Telnet, voice was not running in such a small volume at the time. And the entire exercise cost us 600 dollars to demonstrate it, and the cost of the 600 dollars was not for the plane rental, but was for a running-- for building some PCB that needed for some processing in connections, the two sides of the communication. When we landed at the-- what's the name of the place? Can't believe I forgot it. After we landed, Bob Khan asked, how much did it cost, and we say, 600 dollars, and he say, please don't show it to anyone, because it was few million dollars to get the similar functionality from SRI.

Weber: Yeah, yeah.

Cohen: SRI, of course, had much more functionality, but the basic functionality of connection from a mobile flying platform, it was demonstrated. And for years, we did not tell anyone.

Weber: So this was the competitor to the SRI packet radio van.

Cohen: No, we didn't compete, because we did not participate in the--

Weber: Right, but I mean, you were demonstrating similar functions.

Cohen: Yes. It would be very funny if there was an RFP, and it came with 10 million dollars and we came with 600 dollars. As a matter of fact, in that case, I bet we would not have won, because they would have said, well so much more capacity. I promised not to tell it, and until very recently, I did not.

Weber: So this would have probably been mid-'70s, then.

Cohen: Yes.

Weber: Because the packet radio van started about '73. So, and it took a little while to get going.

Cohen: And I'm trying to say when I got married, the first time.

Weber: For the first time? You said you got married in Israel, right?

Cohen: Yeah. So you're right, it was the second marriage, which is explain a lot. Yeah. Too many marriages.

Weber: How-- So when-- Huh?

Cohen: Too many marriages.

Weber: How many?

Cohen: Two. Two, spelled both with a W, and with a double o, too many. Never mind.

Weber: Probably you and-- you lost me.

Cohen: Two marriages, which were too, T-O-O, too many.

Weber: Right. Yeah.

Cohen: That's what I tried to say.

Weber: Two too many, or--

Cohen: Yeah.

Weber: So your second marriage was in the mid '70s, then.

Cohen: Yeah. Yeah, this is crazy. I'm glad to have this session here.

Weber: Now you have it straight from now on.

Cohen: At least for a while.

Weber: Because in 1961, you were not yet a pilot, you had not yet written a flight simulator, so yeah. But the-- when did Steve Casner come into this?

Cohen: Steve joined ISI in '73, about one month after I did.

Weber: And did he immediately get involved in the packet voice?

Cohen: And he was assigned to my project, and he worked on the operating system support that we needed, and later, he was a focal point in IETF for real time traffic. And guess what, it was-- the traffic, the protocols they develop was called RTP for real time protocol. And he took what I have in NVP, and removed the things that were not general, that were specific to voice, and such that RTP is part of NVP. So today, if I build it, I would know, I would build NVP different now-- differently, if I were using RTP.

Weber: But so his role within your project--

Cohen: It was Mr. networking and computer-- local computer communication.

Weber: Local computer.

Cohen: Pardon?

Weber: Mr. Networking and--

Cohen: And the local operating system, talking to the internet, whatever version it was at the time.

Weber: And so he was involved-- how long was he involved at ISI, then?

Cohen: Until he left, which was probably 20 years later, 10 or 20 years later.

Weber: Okay. And he remained in the-- involved with voice over IP.

Cohen: Yes. He was involved in it after he left ISI. It's a pleasure to work with. He's a great guy. He was nice and smart.

Weber: And I know you did the-- you both did the presentation at Google, right?

Cohen: Yes.

Weber: And so when was the Mickey Mouse phone?

Cohen: Oh, I don't remember.

Weber: And the SRI van, there were the tests of--

Cohen: I don't remember.

Weber: And that would not have been Steve.

Cohen: There's an SRI guy who did it, so we were somehow informed or involvement about it, but not participating in really doing anything.

Weber: So who would have been the people at SRI doing that, then?

Cohen: Earl Craig, [ph?] something like that, or, yeah. I forgot the other name. Was another guy that used-- did most of the radio work, or a big part of it, was really for-- I forgot. But you can, if interested, good reading will be Bob Gray book.

Weber: Which book is that?

Cohen: Bob Gray is a professor at MIT for signal processing. His brother, Augustine Gray, was a part of the team in Santa Barbara. First it's at UCSB, and later in a company called, Signal Technology Incorporated, STI. And he contributed a lot, but he did not like to fly, so in the fact he was scared to fly, so he couldn't come to any meeting, except meetings at Los Angeles, which we had very few of. So his brother, Bob, wanted somehow to memorialize, say, the contribution of his brother, so he wrote a book about a linear prediction in packet networking. And I think the title is something very similar to what I say, linear prediction coding was the coding that we used in-- for speech compression, and most of it was developed in the west coast. So there is a book called, "Linear Prediction Coding in the Packet Networking," or something similar to that, which is very well written, the book, and unlike most scientific books, it has many anecdotes and funny things that happened, or interesting things that happened.

Weber: Okay. And what was ISI like to work at, at the time? Were you in one of those two-- the two buildings, the tall buildings, in Marina Del Rey.

Cohen: Yes. I was in the southern of the two.

Weber: Right. Oh the southern, where ICAN is now?

Cohen: Pardon?

Weber: The one that ICAN is in now?

Cohen: I have no idea where ICAN is. If you are in the ocean side, it will be on your right.

Weber: If your back is to the ocean.

Cohen: If your back is to the ocean.

Weber: Is to the ocean.

Cohen: Mm-hmm. It will be on your right.

Weber: I think that's the ICAN.

Cohen: Most likely.

Weber: I mean, Bob Braden, [ph?] today, is in the building that would be north.

Cohen: I have not been at ISI since they split between the two. I am surprised he's not near ICAN.

Weber: Oh, you know, no, it's in the other building, I believe. I know I visited the north building. But, so you were in-- somewhere up high in the building overlooking the ocean, then?

Cohen: Mm-hmm, and I had a corner office that was looking both west on the marina, where my boat was, and south, where the Hughes Aircraft runway was. It is now all condos, but before that, it was the airport of Hughes Aircraft, and a lot of experimental aircraft would come to get some systems being put on and off, and since I like airplane, I would love-- I was spending a lot of time looking at them, so that's why I had a corner office.

Weber: But you were what, a principle investigator there?

Cohen: Say again?

Weber: What was your title?

Cohen: Division Director.

Weber: What?

Cohen: Division Director.

Weber: Right, and the division was--

Cohen: For a long time, it was Communication. And in addition, I was involved in a lot of other things, and started as a project, like in 1980, I started the MOSIS. In about two or three years later, I started the first exchange. It had a different name, I forgot what it was. It was computerized commerce.

Weber: And what was that about-- actually, let's cover that in order. Let's finish with voice. So I mean, you were-- and you were in the same building from '73 or so, on, and where were you living at the time? You said, Malibu or something.

Cohen: I lived always within a mile-- within half a mile from the beach, so first in the marina, then later in Pacific Palisades.

Weber: But you said you were near where the Getty is.

Cohen: Yeah, this is at Pacific Palisades, near the Getty. The Getty is in Malibu, or was in Malibu.

Weber: Well, there's two of them, yeah. And you were-- where did you fly out of, then?

Cohen: Van Nuys. That's the name I could not remember, Van Nuys.

Weber: But that's pretty far inland, that's the valley.

Cohen: Yeah, but there were better aircraft there, there was an ILS system which means I could always land, and if I flew from Santa Monica, which I did for a while, you can get caught in the fog that would make it impossible to land. And then it is a total pain landing elsewhere, and your car is in the original place, so how do I get from here to there. In the morning, you have to do the inverse, too complicated. In Van Nuys, there is an ILS system, you can land in any weather.

Weber: And did your family fly with you, or--

Cohen: Most of the time, not.

Weber: Colleagues, or did you fly mostly alone?

Cohen: Yeah, mostly colleagues. For most people it's a huge treat to fly and sit in the front, and holding the stick for a while.

Weber: Yeah, yeah.

Cohen: I like to do it before I flew myself, and I know that every boy, not-- regardless of size and age, would love to do that.

Weber: Yeah, my elementary school, we did that with-- the principal had a pilot-- was a pilot.

Cohen: So he took people as a reward for--

Weber: Well he let us take the controls briefly, so-- I don't know if it was a reward. But the people at ISI, I mean, you were-- you had your own group, but was it an exciting place to work? What kind of--

Cohen: I think for most people it was.

Weber: So what was the atmosphere like?

Cohen: First of all, we did not know that there was issue of funding, or not enough funds. When we wanted to do something, we just-- if it was a good idea, it was always funded. Not only that it was funded, it was funded with-- using very fast procedures, that it was not like writing a proposal, and getting it approved, you know, two years later, where all the people that were supposed to work on it and wrote the proposal have gone. When we needed something, it was reasonable, we got it very fast. And so, from time to time, we have some ideas, you know, there was no question, sure.

Weber: And funding was from who? I mean, ARPA, obviously.

Cohen: Basically ARPA.

Weber: Okay, so mostly. And did you have many formal interactions with UCLA and other ARPA contractors?

Cohen: There were some, but we were part of ARPA world, but I don't know whether to call them informal, or not.

Weber: Did you go to UCLA much in that period?

Cohen: Well, UCLA is where I learned to scuba dive, for example. And from time to time, we would visit them to see something interesting that they did, and from time to time, they came to see when we did something interesting.

Weber: And were you much in touch with Len Kleinrock's group?

Cohen: Yes, we did, when the ARPANET started, their group was doing the network measurement.

Weber: Center.

Cohen: Center. NMS? No, it was different.

Weber: NMC.

Cohen: Oh, NMC, was also-- or something like that, I don't remember, but they did lots of the simulation work and planning work, and all of this in support of the theoretical work that Lenny did.

Weber: Right. And how about-- so yeah, so you would go over there and--

Cohen: And we have a lot of meetings, either in our place or their place.

Weber: And Santa Barbara, did you have much to do with--

Cohen: Yeah, for a big I went to Santa Barbara, especially in the early days when we worked on the algorithms, the compression algorithms.

Weber: Ah, because they-- right. So what was a-- describe a typical day?

Cohen: At ISI?

Weber: Yeah.

Cohen: Getting to work at nine-ish, leaving the office at nine-ish. Those are different nines. I talk, either have a project meeting about a new problem, or we are stuck with it, what should we do. So there were meetings. In those days, I used to program a lot. Some of the people who were working on operating systems, issues, some work on the signal processing issues, it was-- I usually worked the signal processing side. And then wondering, at the end of the day, where all the time went. I enjoy every moment.

Weber: And would you eat? You would have lunch there, I assume.

Cohen: It depends. Near the marina there are a lot of places to have lunch.

Weber: And you would have dinner at home, or somewhere there?

Cohen: It depends. People who have working wives or non-working wives, are very different schedules.

Weber: And your wife worked?

Cohen: It depends. If I have to come with a yes or no, I would say yes. But too many caveats. She was always-- not a good way to spend our time right now.

Weber: Okay. And your group was how many people then?

Cohen: I don't know. At the voice, I take it probably like seven people, the voice. But in '80s, as I started MOSIS, which was probably another ten people, five to ten people, it depends. The-- I forgot. There were lots of projects, like, for example, one of them was graphics, remote graphics project, which is another four, five people. I forgot which projects I had. I hope I don't insult anyone.

Weber: And who were you working for?

Cohen: Mostly Bob Kahn.

Weber: But didn't you have a manager at ISI?

Cohen: No. I'm sorry, yes and no. The official answer is yes. Obviously I worked for the Director of ISI. The real answer is no, I worked for Bob. Bob and I decided what I should do.

Weber: And told the director.

Cohen: And told the director, if we remembered.

Weber: And who was the director at the time?

Cohen: Most of the time, Keith Uncapher.

Weber: And did you have a good relationship with him?

Cohen: Most of the time, yes. After he left, his resume, after he left ISI, he worked for NS-- National Center for

Weber: NCSA?

Cohen: Research Initiative, it's NCRI. And when he worked there, with the officially resume, the one that's on the web page of CNRI, say that he's spending like, 20 years at ISI, and mentioned one project only, which was working with me on MOSIS. So Keith sure appreciate what we did, and so, as I say, the jewel of the crown.

Weber: So talk a little bit about MOSIS. That was-- when did that start?

Cohen: Pardon?

Weber: Talk a little bit about MOSIS, when did that start?

Cohen: MOSIS started at 1980. August 1980 was the first day run, so the project started probably four, five months earlier than that. And we did lots of-- I spent the year earlier at Cal Tech because on the computer science faculty, at Cal Tech, working with Ivan. Ivan was at Cal Tech at '80 or so. He recruited me to come join him.

Weber: Okay.

Cohen: Now the number-- Ivan was the number two person in the department. The number one was Carver Mead, and Ivan and Carver did not see eye to eye on many issues, most of them technical, not

personal but technical. And we would have meetings and decide how to do something, and then Carver would do it totally differently. And Ivan would say, but we decided to do it this way, and Carver would say, yeah, but I didn't understand it, so I did it the way I understand better. And he got on Ivan's nerves very often, and I thought, why do I need to be here, when the two of them are fighting all the time. So after really, it came back to ISI.

Weber: But you really relocated to CalTech?

Cohen: No, I didn't relocate the house; I would not leave the beach for Pasadena, that would be crazy.

Weber: But your office moved to CalTech for a year.

Cohen: No, ISI was kind enough to say, what I say that I'm leaving, I'm going to CalTech and he said why don't we call it a leave of absence, like sabbatical, so in the meanwhile we keep your office and we keep your secretary. So the office at ISI was 5 minutes from home, the office at CalTech was 45 minutes so anything practically anything- I kept the office most of the time and get much better secretary I suppose and much better support on anything I needed. So after a year, given that they were fighting all the time I was delighted to go back to ISI. But in this year I I learned about VLSI [ph?] [INAUDIBLE] so I knew enough to be a bit one MOSIS. MOSIS is an idea that came from Dean Conway [ph?] at [Xerox?] Spark and then we were funded to reimplement it for the ARPA. ARPA VLSI community, which was a great community to be part of, by the way.

Weber: But you could send the plans over the ARPANET, send designs.

Cohen: Yes send design of the APRA people can only send design over the ARPANET. People from other company like say Hughes or Honeywell that were given permission to use MOSIS.

Weber: Email?

Cohen: To use other emails which didn't exist and so it was no standard way to send over email so we developed ways so people using other networks could use [INAUDIBLE], other networks, so MOSIS was connected to several networks and you can communicate to MOSIS using any of the network that we supported like MCI network and I forgot all the names of the... you know the difference between tunnel and a bridge; the bridge is high and you can see it from far away. A tunnel is hidden, so unless you know exactly where it is you'll never find it so the people we give permission to use [INAUDIBLE] so people would use the other like tunnel to get to our tunnel and then use it to get to ARPANET and get to MOSIS and then the MOSIS will reply but doing the inverse, using the ARPANET to get to the tunnel to get to the other network.

Weber: And what sort of data could you send?

Cohen: Those were designs.

Weber: Right but you could send large files?

Cohen: Yes and we have to deal with the fact that our files were much bigger than other email could handle so we have to develop procedures that allow you to break files and put them together and there were several other little problems, connection problems that had to be solved and we obviously did.

Weber: But the idea is to be able to send in the design and then it's actually created, right?

Cohen: Mm-hm. Originally the idea came from I believe from Lean [ph?] <inaudible> we sort of got it from them. While she was in Park, supported by Park people so I don't know which of them deserves the credit.

Weber: And it's still operating today.

Cohen: Oh it's still operating today over what is it 1980, so it is 30 plus years later used.

[CREW TALK]**Weber:** So we were talking about MOSIS.

Cohen: MOSIS.

Weber: And the fact I think you could do some testing over it or...

Cohen: Say again?

Weber: That you could send files but couldn't it do some sort of simulation?

Cohen: Oh what I thought we were talking about was that the most of our users could use ARPANET to send us files.

Weber: Right.

Cohen: But some of them could not use the ARPANET because they didn't have ARPA contract and didn't have connection to the ARPANET.

Weber: And you said they could tunnel through to get to it.

Cohen: Yes and solved the problems, we builded tunnel which lately would have called it bridge that is computer that is connected on one side to the ARPANET and the other side say to MCI network.

Weber: You already described that.

Cohen: Yeah.

Weber: But then what would they be sending, just a design ready to be implemented or would there be a back and forth?

Cohen: There would be a design that was to be fabricated.

Weber: Okay.

Cohen: Being fabricated is the first step in a long chain of things that have to happen because what the user wants is not just the VLSI fabricated, but they want it also to be tested, sold into small dies [ph?], and attached the dies to the carrier. So by the time users get back its project, it's all silicone ready to be inserted in a board and tested.

Weber: And so where would it physically be fabricated?

Cohen: When we started it was in any of four or five different fabrication house but now I think that most of them have been in Taiwan.

Weber: And what was the big arguments with what with the Carver Mead [ph?] and..

Cohen: And Ivan.

Weber: Yeah where...

Cohen: Those arguments would happen when I was at CalTech which is before I started MOSIS at ISI so there is no relation.

Weber: Ah, okay. Because you were-- sorry I did get them confused. You were at CalTech for which project?

Cohen: I was at CalTech for a year.

Weber: Just to become a professor there?

Cohen: I was teaching graphics and learning VLSI.

Weber: Okay right and that's what gave you the background to make MOSIS.

Cohen: It gave me the background that I was able to start MOSIS and I did lots of things; we didn't know how to do it so we invented methods doing it which were very different than the methods used in the industry and somehow we were lucky enough to get it right.

Weber: So how were your methods different?

Cohen: For example, we had on wafers with dies of different sizes. The standard in the industry was to have all the dies built the same size.

Weber: Okay so it's fairly radical.

Cohen: Yeah it saves-- it's not a big thing, but a lot of little things together, like they're together made a difference.

Weber: And this was some of your first experience with really hands on with hardware, or not. You were mostly a software guy through your career?

Cohen: Yeah but most of the time I think it was somewhere in between.

Weber: True, compression gets you to the hardware level, that kind of thing.

Cohen: Yes [INAUDIBLE]. One company, I forgot which one, I think it was M-- three or four letters, never mind in the Valley, they looked at what we did and they said that it would never work and we said never mind we pay you to do it the way we ask. And they say but if we do it their way it would be faster, better, or something and I say, never mind, just do it my way; I'm the customer, I'm paying for it and they say okay. A few months later they came to me and say, we notice that you turn around designs in two months; it takes us 11 months to turn around our design with our engineers, can we put some of our design on your wafers and we'll pay for it? And [laughs] I reminded they told me that I don't know what I was doing; which by the way they were right, but we were lucky that I was [INAUDIBLE].

Weber: And what was it, do you remember what the methodology was, the difference?

Cohen: The difference is that I thought about it as a software engineer.

Weber: But I'm saying what were you proposing doing differently?

Cohen: I showed them how to.. for example, having dies of different size required to changing the process and doing it a slightly different way or cutting it different way. And the in ways it was simple, once you think about it, but if you didn't think about it, you are limited to do it one way. There are a lot of cases like that.

Weber: How long were you involved in MOSIS directly?

Cohen: I start MOSIS in the beginning of MOSIS which is the early 1980s and I think I stayed with them until about 1986-87.

Weber: And why did you stop?

Cohen: Because I found more interesting things to do; for example, I did very heavy involvement with the Department of Defense and SDI, Star Wars.

Weber: Ah, right.

Cohen: Yeah so I was delighted that someone else could run MOSIS and I didn't have to because it became routine after a while.

Weber: And who took it over?

Cohen: George Luici [ph?]. And if you ever find him, tell him to call me, he disappeared one day. Not that it was any foul play in his disappearance, but he didn't get along with the Director and the Director didn't get along with it, so separation was the best solution and he decided not to keep in touch with any of us, so let it be.

Weber: And so you moved to SDI type stuff. You're in...

Cohen: I did the SDI stuff from my office at...

Weber: Right but you moved on in terms of projects.

Cohen: Yes then one day I said that the mechanisms that we have to run MOSIS could be used to run any general electronic commerce. The main difference was that in VLSI not only do I need a chip; I'll tell you exactly how to build it. In normal commerce you don't tell how to build it, you say I was item number so and so from your catalog and you say yes it costs so much or no we don't have it in stock or whatever, but they don't ask me how to build it. And so it is easy to adopt our system. So we started a commerce, an electronic commerce project and DOD places could send us over email purchase orders and say we need such and such part and we need so many of them and our computer will get this message and would know where to look, which vendors might have it and connect to those vendors and negotiate price with them and then give me the best price of them all and the best price can be the least dollars or the least time or combination thereof so we started this project and then later it became a fast exchange of I forget what the name was. I called it FAST because it was supposed to be acronym for Fast Acquisition of Standard Part… This would make P then... Or something [INAUDIBLE].

Weber: So this actually was implemented?

Cohen: Mm-hm.

Weber: And you would buy [INAUDIBLE].

Cohen: During the first Bush war, they have the problems that our planes were shooting our tanks, because they were so uncoordinated so someone came with the advice to put IFF devices on the tanks so when a pilot would arrive to attack a tank, he can check whose tank is it but to build it they needed to build it fast; they needed some parts that they could not locate in the states. And our system that was connected to a lot of vendors could automatically look at some of the parts and some of them were found in England and some of them were found in the states, but thanks to us, they got it real fast and they could implement it fast and we got a letter of appreciation from the Department of Defense after the war which wasn't that long.

Weber: But when did you start fast exchange?

Cohen: I assure was it MOSIS it's... probably this was like late '80s. When was the first Gulf War?

Weber: '91, so yeah, sounds right. And you had something on each of the vendors somehow made their catalog visible or query-able, using what?

Cohen: As a matter of fact, the funny thing is that the way we did it then was we ask each vendor what's your format? And we adopted their format.

Weber: Really?

Cohen: Today we do it the other way around; you would say, this is our format, if you want to do business with that, you better use our format.

Weber: But how would they put their data?

Cohen: To use us they didn't have to do any change, they did not know if their connection it comes in the middle of the night and asking for quotations, if there was a person there or not.

Weber: Got it.

Cohen: They could not tell, it's a Turing test.

Weber: Yeah, so it'd come in as what, an email or a fax or something?

Cohen: Yeah over email; everything done by email. Today it's hard to see that the capability was an exception then. Today this is how most things are bought.

Weber: Yeah so they wouldn't necessarily have their catalog in electronic format; they would receive the message and a person would send back what they had?

Cohen: No, so they have the catalog they way they wanted it.

Weber: But online?

Cohen: Yeah it was online.

Weber: It needed to be.

Cohen: But their salesman anyhow needed it online.

Weber: Right.

Cohen: And their salesman have programs to read the online thing and displayed so a person could understand and make a decision or not make a decision.

Weber: So it would send a query as if it were a salesperson and ask, I mean, your system?

Cohen: It sent a query according to their standard operations.

Weber: Got it. And this was run from ISI?

Cohen: Mm-hm.

Weber: And you had what a group of people working on this?

Cohen: Yeah and most of the work was adapting of the interfacing phony [ph?] systems of other people.

Weber: Who funded the system initially?

Cohen: ARPA.

Weber: Okay. And how many people were working on it?

Cohen: Let me tell you how it-- we start one day I was at ARPA in Washington, and I was about to leave to the airport and it was in the 7th floor where Bob Kahn [ph?], and his group and leaving-- I was waiting for the elevator to take me from the 7th floor and the elevator came and Craig Feeds [ph?] was there. I

don't know if you know Craig. Now Craig was the Program Manager and later he was the Director of ARPA and in his common style, he say to me, “Danny, what’s new? What kind of idea are you working on now?” Which was semi-sarcastic a bit and I thought that he would like the idea of the electronic exchange so he asked me, “What you working on?” And I say, “I work on electronic commerce.” And he say, “What’s that?” So I explain to him and he say to me, “You know what, that's the best idea I heard in a few years. Come to my office.” We went to his office and he sat near his Mac- Macintosh, probably Mac II and he type a letter to the Deputy Director Chuck Bufalano [ph?] or something like that and say, “Danny Cohen suggest to do such and such; I think it’s a great idea; how much money do you need, Danny?” I say, “A million dollar.” He wrote it would cost million dollar; send it to Chuck which was the Deputy Director for ARPA. A few days later they say to me, “Danny, go ahead.” And they he say, “Just a second, Danny; I know your very good friend who is Bob Kahn, and if you do it directly with me other than through Bob, he may be insulted, so which way do you want it to go, from me or from Bob?” Being a good friend, I say, “From Bob.” It cost me another year because it took a lot to of-- it took about a year for Bob to approve it; the reason is, he says Bufalano did not send million dollar. He say, I cut a million dollars from your budget and you should fund it from the money that I save. Bob, Kahn say, “you cannot cut a million dollar from my program, because then my entire program would fall apart; I need every penny of it.” And Bufalano could not convince Bob even though he was higher than him on the hierarchy; Bob said if you don’t do that then all of those things, you know, fall apart. You cannot just cut a little uhm… Yeah in retrospect, was it important that we lost two years? No.

Weber: But how did the money come through in the end; did Bob get his budget cuts?

Cohen: Yeah he got it later. Yeah. So at the time it looked to me like a big loss; now, big deal. So what? It was either the easiest or the second easiest million dollar I got from ARPA. Made another call to ARPA, that took me about a half an hour or exactly less, at the end of that talk, I was approved to spend another million dollar on something that was never proposed until then.

Weber: Which was?

Cohen: Pardon? Had to do with the end of the ARPANET. For the ARPANET, those days we paid like, 80-- no ARPA paid DCA, Defense Communication Agency, I think $80,000 dollars a month for each IMP [ph?] port. And in Los Angeles there were like nearly 10 IMP ports, so it meant $800,000 dollars a month to DCA and I said I can put-- get what did not exist yet, so I defined, said this is a functionality I can get to you for much less than that, for less than half a million a month. It was a huge difference and the Mark Pool [ph?] then was a Program Manager, said, “Okay you can do it. You're allowed to spend, you know, like one million dollar to save me all of that things.” It was illegal, I'm sure, but it saved the money-- the government lots of money and there was never anyone suspecting anything bad about it, but that was a very different ARPA than ARPA of today, or the government of today.

Weber: Yeah.

Cohen: And we were lucky that there were people that were willing to risk their necks because they thought something should be done better.

Weber: Yep. And then you were-- there are several other efforts you're involved in Atomic; what was that?

Cohen: Yeah Atomic was a very fast, at that time, maybe it was the fastest communication inside the mutli-computer. The computer has many CPUs and communication between some CPUs and we did this demonstration, Atomic, to demonstrate this technology that was developed at CalTech; it came at CalTech and we used to build Local Area Network. They thought about it only as a network between inside the computer and we extended it to be between computer, provided they were not very far from each other.

Weber: So sort of local distributed computing.

Cohen: Yes.

Weber: Because at that speed they could deal with each other almost as if they were within the same?

Cohen: Yeah they were awfully fast, like 600 megabit per second, which today is a funny number.

Weber: And then there's Miracom and MIRANET.

Cohen: Miracom is the name of the private company that will build to commercialize the atomic technology and the network that we sold, we called MIRANET. The Miracom was the name of the company, and MIRANET was the name of the network.

Weber: And so where did you start at with who, who is we?

Cohen: A group of about 10 people; 8 of them from CalTech, and two from ISI. The ISI was Bob Felderman [ph?] and me and the CalTech side was Chuck Sites [ph?] who really was the leader of this effort and another 6 or 7 people, most of them from CalTech.

Weber: And it was a company in LA or...?

Cohen: A company in Pasadena called Miracom and for an awfully long time, we were profitable, we are profitable, but the amount of money is too small to take it to an IPO and therefore, all of us are not as rich as we expected one day to be.

Weber: But it's still going?

Cohen: It is still going, but I have no idea for how long it will. Right now I believe they are slightly above profitability.

Weber: And then...

Cohen: So they can survive but without making us rich. We are not the only people in the valley that can use those words.

Weber: <Laughs> And then distributed interactive simulation. I've got several DOD but you talked about them.

Cohen: Yeah the DIS, interactive simulation is from…what was it? ISI wasn't in.. probably early '80s and the same Craig Fields that I mentioned before was at ARPA and when he saw computer games coming to life, he said, this is technology that I can use for training real forces. And they did a network, a simulated network that tanks, I don't know, what's the unit of tanks, like 10 tanks, a platoon or some word, so group of tanks can fight another group of tank using the same-- practicing their tactics rather than the actually driving and this was done for the Army by ARPA and the ARPA asked the Army to consult me. So I was consulting to them and I appeared like a day a month, saw what they're doing and making some comments. Like for example, told them to use the ARPANET and not the ISO network. He says, "We're about to be born;" it never did, but...

Weber: What year would that have been?

Cohen: Pardon?

Weber: What year would that have been?

Cohen: It must be around 1980.

Weber: OSI was just getting started then, but yeah.

Cohen: Yeah and they expected-- they wanted to run their programs on the OSI, ISO protocols, and I kept telling them that it would never exist and they were lucky enough to pay some attention.

Weber: And then I did want to-- this is a little bit out of sequence because it was really about the video over the net, and voice over the net, but the movie that you did, was what, or very early '80s, the one <inaudible>.

Cohen: I think or maybe '78.

Weber: But no, no, late '70s, right.

Cohen: It's inside the movie, it says so.

Weber: Yes, but I mean tell me about why you made the movie and the process of making it.

Cohen: We have this teleconferencing system and from time to time we wanted to explain it and demonstrate it to DOD people so they would come to ISI at four o'clock and we'd talk about it and I would say, now as a demo, whoops, it's five o'clock, eight o'clock in Boston; no one is waiting for us. Now it was on the service, it was only the problem that you could not-- is coordinating with other sites was the problem, so one day I said enough of those things; why do you need the other side; let's just do it with a movie; the advantage of a movie that you can get it done until you get it right. And so once we decided to do a movie, I found some young lady in Los Angeles who was very good in preparing it and she came and she prepared the movie for us and she knew what she was doing, luckily. We did not, because we didn't know the difference between, as I told you before, between footage and the movie. We had several times and several projects, people doing movies. BB [INAUDIBLE]did the movie about speech compression; the movie was 20 minutes of someone talking to the camera. Who has the patience to sit and watch for 20 minutes, one person talk? We don't, you know, why do we expect it in a movie. So she came and she did this great movie, for example, for the greatness, we wanted to show that this isn't compatible with normal telephones, you can from the computer to a telephone and vice versa; very much like Skype today. We never said it in the movie but in the movie, I'm supposed to be in the-- I'm running on the deck in the marina between the boats to a telephone booth. It obviously the telephone booth was connected to the standard telephone network, but we didn't have to say it. It's probably the only thing you remember from the movie, that it's connected to the network, because Danny was running into a telephone booth, using payphone and getting the wrong number first. So she knew what to do and how to do. So for $5,000 we got the five minutes footage which is absolutely delight, delight to see.

Weber: And did you-- I mean obviously that does show what your vision of what you thought packet voice would be used for but did it happen-- were there any other ideas that you had that didn't happen?

Cohen: For example, one of the things that we did and we get to it in the movie, is voting, like if you would take a vote and we say if it is-- if you want to use yes, hit 9, this is where the Y is, and if you want to hit no, use 6, or we chose two other numbers, I'm not sure, but today I would have shown those for yes and no and so everyone can punch it and so you immediately know it is 6 to 4. Otherwise you have to say, who is number one, you know, Bob, and they have to poll the people, which take much more time. It is much, much more complicated if you have flow controlled by one person because of several reasons, so we did it in a better way, for example. I did not see this same idea implemented, but I saw many cases where I wish I had it, that you have-- there's a big meeting and you have to scan the people and you don't know who is where and some people join the conference while you are talking, so you don't know what they were yet. So this is just one example of doing things differently and in the movie, we didn't discuss it, but we showed it.

Weber: And did Voice Over IP come more slowly than you thought?

Cohen: Yeah because Voice Over IP is a commercial operation, is to wait until the prices were practical; we as I told you before, we proved visibility, not practicality and I had to wait for [Mr. Murer?] to go several time through the cost curves and performance curves to be in position to [INAUDIBLE] economically. But what we did was to prove that it's technically feasible.

Weber: And talk about if you will the reaction to your "Holy War," paper on endianness?

Cohen: Yes, the "Holy War" paper started about, I can't remember when it was, it must be early '80s, late '70.

Weber: 1980, I think, no?

Cohen: This problem of direction became crucial, and there were a lot of networks were defined [ph?] at the time including the Ethernet, the IEEE Ethernet, 802.3, which is not like the Xerox original Ethernet was a small different. It later was fixed, but there were many committees including the 802.3 that found it very relevant and I would get phone calls and say, "I'm so and so from such and such company and we want to copy off your paper, but we have a copy of a copy of a copy, when we cannot Xerox it anymore; would you be kind enough and send us another copy." And there was a very short period in which people ask for it and it sort of cleared the thinking about it, for many people. So we did not say, do it this way or this way; we say it's your choice, but here are the things that it affects and here's how you think about it. So this paper did not recommend big endian or little endian, it just explained the issue, and the consequences rather than telling you how to do it. Many people today tell me that they should have told-- they should have decided then. Too bad.

Weber: <Laughs> Well maybe it would have been less effective if you'd been making a clear recommendation.

Cohen: If I made the choice.

Weber: Yeah.

Cohen: As we mentioned before when I talked to Paula before, it's easier to bring something new than to change something existing.

Weber: That's true.

Cohen: Because when you do something new, it don't find any ego; when you do something-- when you ask anyone to change anything, you have an ego war with the person that made the previous system.

Weber: Very true. Are there any of your-- you have several patents, do you have any in particular that...

Cohen: No, I think that all of them are too technical.

Weber: Uhm..

Cohen: It's not that you could not understand it but it would be to establish the content would take much more time than we should.

Weber: And do you want to talk about your work out here; I mean you moved to the Bay Area to Sun when?

Cohen: In Sun Labs it was part of the ARPA project, it was high performance computing; you didn't call it high performance, we called it something else, which was also HP, high productivity it was called and it was a three stage program and then we luckily-- we were participating in stage one and two and luckily our proposal for stage three was not accepted and I say luckily because we were all relieved because we probably thing we are really on the cutting edge of technology so we were relieved, not to be called on the carpet to demonstrate what we predicted we can do.

Weber: But when did you move to Sun?

Cohen: To Sun, about 10 years ago.

Weber: And Ivan Sutherland was there as well, right?

Cohen: Yes.

Weber: So...

Cohen: It was one of the things that attracted me.

Weber: And you hadn't worked with him since way back.

Cohen: Since my CalTech days; since '76. Wow, that's a long time.

Weber: Anything you want to say about your years at Sun?

Cohen: Rather not.

Weber: And...

Cohen: But they were great years, it was great bunch of people around.

Weber: So Ivan; who else?

Cohen: Bob [INAUDIBLE].

Weber: And to sort of sum up, did you have different visions for how networking would turn out than it actually did; any surprises to you and...

Cohen: Wouldn't surprised that all the phenomena called social networks that a company like Facebook has 800 million subscribers which I could not believe that something like that could happen. If you came to me with any of the big success stories five years earlier and asked me what I think about this business plan, I'd say you're crazy. Would you believe people will give for free search engine that will crawl all over the internet and charge you nothing for that? Yeah would you believe that Facebook support messages

and bio information for 800 million people and would not charge anything for that? You guys must be crazy, yeah neither Facebook nor Google are things that I could imagine to exist not to mention as a success. All the graphics in the movies and each of their images is like at least seven times more sophisticated than the images that we had. We had line drawings, they have full color, every pixel could be any color, any shade, any time. Today's images you could mistake for photographs; you cannot tell that on many of them that they are synthetic images. I could not have believed this would be possible so fast; when you have a chip, a single chip with tera-ops operation or terabit capacity that's totally crazy.

Weber: So where do you think it will be 10 years from now?

Cohen: Unfortunately I cannot predict because I am too much capture-- because I still have time to adapt to today's technology. And once you started with thinking small, like a fork, fifty years from now, will it be the same way as it is today? Or maybe a laser cutter that will cut the food and a vacuum suction to hold the food and take it to your mouth or maybe you don't eat; you just take pills. No I don't want it; but maybe… I don't know.

Weber: Personally I'm voting for genetic engineering give us tentacles around our mouth that will pick it up for us, but that's just me. <Laughs>

Cohen: People with a beard could need it.

Weber: Anyway, thank you very much.

Cohen: You're most welcome.

Weber: You've been wonderful.

Cohen: And when you hear great ideas about the future; please share them with me, I'd love to hear them.

END OF INTERVIEW

