Oral History of Severo Ornstein

Interviewed by:
Bruce Damer and Marc Weber

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Weber: I'm Marc Weber of the Computer History Museum, and I'm here on November 20th, 2015, with pioneer of almost too many things to mention, Severo Ornstein. But we're going to try. And Bruce Damer of the DigiBarn, who has kindly agreed to do the interview with me. So thank you both for doing this.

Ornstein: Thank you.

Weber: So Bruce, you want to start with a-- or shall I ask about background?

Damer: You can do the background, yeah.

Weber: Okay.

Damer: Yeah.

Weber: So just tell us where and when you were born, and a little bit about your childhood.

Ornstein: Well, I'm told I was there, but I don't remember it. I was born into a family of musicians in Philadelphia, in October 1930. My father was pretty well-known pianist and composer, and that certainly influenced my life. I've also been somewhat interested in music. I don't think there was anything extraordinary about my youth. It was pretty peaceful, and I had a very devoted family. My parents worked together, hard, as musicians. My mother was my father's scribe, basically. So I grew up with the notion that couples worked together. I went to school in the usual ways and was lucky to go to Harvard and…

Weber: What were your interests as a child and in school?

Ornstein: Well, I was always interested in the outdoors, so I became a rock climber. That happened when I was looking around for which college to choose. In those days, you could pick and choose, or at least I could. And when I read in the Harvard booklet that there was a mountaineering club, that settled it for me. So that's actually why I ended up going to Harvard.

Weber: To step back a little bit, what were your favorite subjects in school?

Ornstein: In school, well, I was interested in philosophy. I didn't think that I was going to be an engineer of any kind. I eventually got interested in geology, largely through associations with mountaineering of various kinds. I suppose I would've, remained a geophysicist except for the fact that I encountered a guy who had worked at Whirlwind and--

Weber: Sorry. When I said school, I mean elementary school. Tell us--

Ornstein: Elementary school?

Weber: Tell us. Yeah.

Ornstein: I don't remember. I think I was interested in girls. I don't really remember. I'm not sure at that age, but I don't think I had interests at that time.

Weber: But did you like technical things, did you like literature, did you like reading?

Ornstein: In high school, I really don't remember well enough to be able to say. Yes. I was a reader, but… And a gadgeteer, yes. My father had absolutely zero practical abilities, so I was the one that fixed the electrical outlets and the things that went wrong. But my interest in gadgets I think really materialized only later on, I had, I suppose, the usual young boys' interest in such things.

Weber: And music?

Ornstein: Music? Well, people asked me when I was very little didn't I want to be a musician like my dad? And I said, "No, that's sissy stuff." But when I got into high school I discovered that the girls came around the piano when somebody was playing it… And I knew how to practice, because I'd watched my father practice endless hours. So one summer I just decided I was going to become a pianist. And I did. When I started, I knew virtually nothing, but I spent many, many hours a day-- and by the end of the summer I was playing Beethoven sonatas, Chopin etudes and so forth. I'd heard them all my life, so I didn't have to read very well, because I knew what the music sounded like. And so I was able to pick it out and I did do some reading, but just barely enough to learn things. I had a good memory, so I remembered things immediately, so…

Weber: And your--

Ornstein: And indeed, it worked. The girls did come around.

Weber: <laughs> And your parents didn't push you to go into music.

Ornstein: No. In fact, they pushed me away from it. I came home from college at one point and said I was going to become a musician. I was going to become a pianist. And their eyes bugged out and they said to me, "No, no, no, don't do that." They disapproved of the idea of my becoming a musician. They said, "It's a terrible life. Do something else." Years later we were giving lectures in Amsterdam about the Arpanet Imps, and in the little café where we went for dinner, there was a guy sitting at a piano and he had one of the tape recordings of the Netherlands Philharmonic playing a Schumann piano concerto. And he was sitting at the piano playing against this tape of the orchestra part, and sitting on the piano was a picture of him at the one performance that he had had with the Netherlands Philharmonic in which he had performed this piece. And ever after he was destined to sit in this café night after night playing the same thing over and over and over again. And if I had been a writer, it was the kind of scene that Dostoyevsky would've done well with. I'm not a good enough writer to describe it, but it had, that kind of feel. And I thought to myself at the time, "Thank you. Thank you, my parents, for steering me away from this awful <laughs> thing." No. I felt, when I finally got into the computer field, that that was where I belonged.

Weber: And if you're comfortable saying, your family, were you raised with particular values or religion or politics that were influential?

Ornstein: Well, I wasn't exactly a red diaper baby but my family was certainly politically liberal. Although on my mother's side there was a fairly fancy family that went way back into the 16th Century, actually. But

my father, barely knew who his grandfather was. His family came from out of Russia. And so it was very mixed backgrounds. But my parents were pretty advanced. They were pretty liberal people for their time. So I had a liberal leftist upbringing. Nothing radical, but they leaned in that direction. Strong Democrats, I would say.

Damer: What town were you raised in?

Ornstein: Town? Well, our parents decided that the kids should grow up in the country. And they themselves also liked the country. So they bought a small farm outside of Philadelphia, about 25 miles out of the city. And that's where I spent my earliest years just prior to the Second World War. When the Second World War hit, we actually bought a much larger farm, that ended up with a big herd of cows. I learned to milk cows and do all of the things that farm kids do. And then at some point my parents saw that they were raising a farmer, which was not exactly what they had in mind, and at the same time the music school, which they had founded, started to thrive because a lot of veterans, were coming around with government support, the G.I. Bill, and so their music school prospered. So they decided that we should get a somewhat better education. So we moved closer to the city into a very fancy suburb, Merion, and my sister and I then went to good Quaker schools and we got a really good education there.

Weber: Were there any teachers that were particularly influential on you?

Ornstein: No. I don't think so. I remember some of them vaguely, but I think it was with the usual young kids' attitude about teachers. Not in high school, no. And I had virtually no friends whom I remembered from high school days. I see a lot of my friends who are having reunions of one sort or another and still remember some of their high school friends. I had one kid who was a pianist who was sort of my chum. Years later I went back and saw him when I was 70.. He was the only person that I really remembered from high school. And poor fellow, he had never really been very successful. I think he maybe became an alcoholic. I'm not sure. I think he's dead now. But I didn't have close friends in high school. I had a number of friends, but no really close friends. I developed really close friends only later in college.

Weber: And your sister's younger or older?

Ornstein: My sister is couple of years older than I am. We were reasonably close when we were younger, but our lives drifted apart a fair amount, and my life took a different turn from hers. And we speak now, but we're not close at all.

Weber: And when you were a kid, what did you think you wanted to be when you grew up?

Ornstein: Well, I don't know that I thought in those terms. I think I wanted to be a pilot. You know, I wanted to fly airplanes. I built a lot of model airplanes when I was a kid. I haven't thought about that much, since then. But I don't think I thought in those terms. I wasn't really making a plan. I was just living and getting an education, and I guess I figured that what I was going to do would resolve itself later on. I didn't think ahead very well <laughs> in those days.

Weber: Well, you liked making models. Did you make kits or did you design your own?

Ornstein: I made kits for the most part. You could buy kits and those were the things that I bought and I learned to follow the directions. I learned what happened when you don't follow the directions. <laughs>

Weber: So then you went to Harvard and you said you had your pick.

Ornstein: Yes.

Weber: Then you went for the climbing?

Ornstein: Yes.

Weber: So…

Ornstein: And my college pals were mostly either geologists or mountain climbers. A group of us came together and we roomed together through most of college after the first year. And became life-long friends. I'm still in touch with those who are still alive, so…

Weber: And growing up in the country is when you got interested in the outdoors.

Ornstein: Yes. I guess that was part of it. My dad liked to go hiking, and we, as kids, went along on hikes up in the White Mountains in New Hampshire. We had a summer place in New Hampshire, although we grew up in the winter around Philadelphia. In the summers we went off to New Hampshire and…

Weber: Yeah, it's beautiful.

Damer: From reading your book, "Computing in the Middle Ages," what was very interesting to me was when you went to Gulf Research Lab. And you met Howie. And did you meet your friend Howie hiking or climbing?

Ornstein: No, actually. <laughs> As I recounted in that book,I thought, "Well, I'm a geophysicist, for what that's worth." And it was pretty dull work, as a matter of fact. We were interpreting geophysical records and trying to figure out what the strata under the surface were like, because they were looking for oil, not surprisingly. And one day on the way to work I noticed a climbing rope in the back of a car in the parking lot. I hadn't done any rock climbing for a while because after college I went out to the oil fields in New Mexico to learn about how oil exploration worked. And now I had come back to Pittsburgh, where I was going to put all that to work. I saw this climbing rope, and I thought, "Ah, that's interesting. I haven't seen one of those for a while." So I looked up the guy whose car it was — an old one of those old upside-down bathtub-type Hudsons, and he turned out to be Howie Briscoe. He's dead now, unfortunately, but he was there because MIT had a project called the GAG Project, Geophysical Analysis Group, and it was recognized that maybe computers could somehow help in the exploration — in the correlation between various records, which is what we were doing sort of by eyeball. And there was some thought, that computers would be able to help with that. This was 1950--

Damer: Three, I think. Yeah.

Ornstein: Three. Something like that.

Damer: Yeah, yeah.

Ornstein: Yes. And so that's why he was there. I was there because I was being trained as a geophysicist. But the work that we had to do didn't keep us at all busy, and we became friends. We shared the interest in rock climbing. We went out locally rock climbing. And in the process, he told me about computers. And I thought, "That's pretty interesting." And then he lent me a book on the EDSAC machine which had an extremely introverted bootstrap program. And I looked at that, and I couldn't make anything out of it at all, but I sat down determined that I was going to figure it out. And I did. And I was just totally blown away. I thought that was the cleverest thing I had ever seen, and indeed it was very clever. In those days you had to cram everything in and it was one of those programs that chewed itself over and turned it into something quite different from what it was so that later on when it was--

Damer: So it wrote on top of itself in order to minimize the…

Ornstein: It changed the nature of some of the instructions in the thing. I don't remember in detail how it did it now. I mean, it was enormously complex, but the whole concept, of course, it was a self-masticating program, was new to me. And I couldn't believe I had, you had to, really write down what the program looked like at different phases, because it was changing itself in the process of bringing… Probably today that would seem, it would seem routine to me. But at the time it just blew me away. So I thought, "Gee, this is for me." So Howie taught me programming, and I ended up writing programs for Whirlwind, which was the machine of the hour at the time.

Damer: So you wrote sort of paper programs?

Ornstein: I wrote paper programs. Whirlwind was hundreds of miles away up in Boston. But I had a manual and I had Howie to explain to me what I didn't understand. And so I wrote some simple programs to try to understand what programming was like. When I told my parents that I was doing programming they said, "What's that?" Nobody knew. Nobody had ever heard of programming in those days. But I learned to program the machine, and wrote some test programs. And then Howie announced that you didn't really need all that large set of instructions, that you only needed three or four instructions, all of which could then you could emulate the more complicated instructions. Later I did just exactly that. I built a divide instruction for a LINC later on. But at that time, I found it hard to believe that that was really true, but it obviously was. After rock climbing together with other people, at one point we decided to go up to New Hampshire to go skiing. We were in Pittsburgh, so in the process we went by Boston, of course, and Howie said, "Would you like to see the machine that you've been writing these programs for?" Of course I did. So we went into Whirlwind, and I was again blown away by the mass of the thing, and I remember enormous holes in the wall where tons of cables went through. It was an impressive sight, of course.

The reason Howie knew about Whirlwind, was that he had taught a summer session, course, for teaching people to program Whirlwind. So he was known to the people who were there at Whirlwind, and they said to him, "You know, there's this new Lincoln Laboratory they're setting up out in Lexington, and maybe you would be interested in going to work there. They're looking for people." So on the way back

through Boston, he stopped off, and sure enough, arranged to get a job there. And then later after we were back in Pittsburgh and it was clear he was going to leave, in parting he said to me, "You know, you know enough about programming now that maybe you could get a job there too." And so I applied. I think I wrote letters to some other companies too like, NCR which was one of the companies that was thinking about computers. But Lincoln actually brought me up to Boston for an interview, and by the time I got through, they'd hired me. So I moved to Boston and went to work at Lincoln, and that's how I got to be at MIT. And, course, Lincoln Lab. turned out to be a real source for a lot of things.

Damer: So in a sense, even though you'd only written programs on paper, you were ahead of the game.

Ornstein: I was ahead of the game. Absolutely. Today, I couldn't get a job as a programmer to save my life. But in those days, yes,I was a programmer. It was all, machine level code, of course.

Damer: And you mentioned Belmont Farley and Wes Clark coming to a lecture.

Ornstein: Oh, yeah, right. That was while we were still in Pittsburgh. Howie knew about a lecture by Clark and Farley at the Tower of Learning I think they call it, the University of Pittsburgh. They were talking about the simulation of neuronal activity. I was blown away again. I mean, <laughs> I guess I got blown away a number of times in the early days. But it was really fascinating. They were obviously trying to figure out how the brain worked at the micro level, and they were studying the response patterns of neurons and doing some simulations. I thought that was the most exciting thing I'd ever heard, so later when I got to Lincoln Lab, I always had the idea that I would like to go to work with this guy Clark, and I eventually did.

Damer: Kind of fortuitous meeting for you.

Ornstein: It was. It was. And I didn't meet either him or Belmont at that time, but I got to know them later, obviously.

Weber: And how did you get from Harvard to Pittsburgh?

Ornstein: Oh. Excuse me.

Weber: Entering Harvard and then…

Ornstein: Well, after college, it was time to get a job. Actually, I started graduate school at Berkeley, as a matter of fact, for a year in graduate school. And then went back to Harvard. But in the process of working towards a Ph.D. I realized that my interest in geology had more to do with rock climbing than it did with the substance of the subject. So I thought, "This is wasting my parents' money and my time, putting me through graduate school where I don't really belong." And back at Harvard I encountered people who really *were* interested in the topic. I was trying to be, but it was failing. So I decided to leave school and instead went to work exploring for oil in New Mexico for a while, and then came back to Gulf's main laboratory in Pittsburgh. So it was, that after a little bit of graduate school, I never completed a Ph.D., I went to work as a geophysicist for a while and bumped into Howie and that's how I ended up at Lincoln Lab.

Weber: In Pittsburgh?

Ornstein: Pardon?

Weber: That was in Pittsburgh or that was New Mexico?

Ornstein: It was in Pittsburgh where I met Howie, yeah.

Weber: Yeah. Right. But you're working as a geophysicist then?

Ornstein: Yes. I was working as a geophysicist. Gulf Research and Development Company.

Weber: That's it. Okay. That makes the LINC.

Ornstein: Yeah, sorry.

Damer: So the Lincoln [laboratory] was being powered up because it had this new commission from the military to be involved in the development of all of the missile and aircraft tracking?

Ornstein: Yes. There are a bunch of funny stories I could tell having to do with that. I had been working on the SAGE system initially. In fact, I should probably explain that. I got yanked out of the initial programming course when they discovered that I already knew how to program. And they, they put me in charge, of the cross-telling specs. There were operational specs for the various parts of the SAGE system, the radar, the various functuions, aircraft tracking and so forth. And they put me in charge of the intercommunication between, if you can believe it, between subsectors of the country where you had to hand over aircraft from one place to the next. And they said, "You'll write the specs for that," and I thought, "This is absurd." <laughs> "I know nothing about all this." But neither did any of the others there. We were monitored by Air Force people, but they didn't understand at all what we were doing and we were trying to find out from them how their manual system worked. But probably my view of it was naïve. The people who were in charge at Lincoln certainly understood a good deal better than I did.

I had specs on what was happening within the direction centers which were connected by one kilobit lines. That seemed like an infinite amount of bandwidth, so I thought, "Well, we can do whatever we want with that much bandwidth." So I laid down specs for how aircraft would be tracked from one sub-sector to another — what information had to get passed across boundaries so that the next sub0-sector could take over tracking the aircraft. There were a lot of fine points to it, but I just sat down and wrote what I thought should happen. And next thing I knew, another programmer actually took over the job of writing the code for that. This was all done on a huge IBM computer. Lincoln worked hand-in-glove with IBM at that time. The computer that we were working on was called XD1. It was the preliminary version of what would become the computers that lived in the direction centers. The SAGE system actually got implemented and got built, but I left before that happened. I believe that the XD1 program contained some 100,000 instructions. It was thought to be almost inconceivable that one a program that size could work.

Weber: Oh. Can you describe some of the main personalities that you worked with on the SAGE project?

Ornstein: Personalities. Well, let's see. Well, yeah. There was a-- you want individual names and so forth or do you…

Weber: Yeah, the main people.

Ornstein: Well, Bob Everett was there, of course, and I knew him. I was working directly for a guy by the name of Charlie Zraket who later helped form the MITRE Corporation out of a big part of Lincoln Laboratory. And I was in that part, and I should have gone to MITRE at the point where MITRE was formed. Charlie Zraket tried to persuade me to do just that; I remember him saying "Come along, we'll ride in the general's car." And I thought, "That's just what I don't want." So I , together with one other guy out of the division that was going to go to MITRE, decided we didn't want to do that. We didn't want to become civilian employees of the Air Force. So I decided to stay on at Lincoln and got into a group that was headed by Frank Heart, whom we'll encounter again later.

Frank's group had a number of projects, but the one that I particularly remember, was one in which we were tracking missiles. At that time, a question arose whether a reentering missile coming back into the atmosphere would leave a trail (a wake) behind that could be tracked and by following that track perhaps understand where the missile was going to land. I don't know what good that was going to do, but anyway, that was the question. The question was: does a reentering missile leave a wake that radar can detect? A fairly sizable program was put in place to try to determine the answer. And the way that worked was that they sent a multi-stage rocket up and then turned it around and fired it down back into the atmosphere at high speed. The radar tracked the missile as it went up, and as it turned around and came back down. A computer memorized the trajectory of the returning missile so that the radar could go back and look over the path to see whether there was some signal there or not.

Lots of hysterical things happened as you can imagine. The firings took place in Wallops Island, Virginia. and number of things went wrong initially. The missiles were fired from an island a couple of miles away from the radar site Before they would rise up, if the radar was looking where the missile was as it was sitting on the ground, there was a lot of ground clutter. So the radar couldn't distinguish and track the missile until it got away from the ground so that the radar signal was clear of clutter. These shots took place at night, so you could see the thing visually as it took off. A telescope was mounted with a pair of handlebars so that an operator could, look through the telescope and follow the firing visually by moving the handlebars, These were slaved to the radar antenna so that the radar antenna followed the handlebar motion. And at a certain point as the missile rose above the ground clutter, the radar could lock onto the signal from the missile and take over tracking it in the usual way.

Well, on the first shot the fellow standing there with his hands on the handlebars was expecting something like the big missiles that were taking off lumberingly from Cape Canaveral. And so he was expecting that he would follow it gradually up with his hands and so forth. But these, it turns out, were liquid fueled missiles that took off like a bat. So what happened was that his head jerked back like that and his hands never moved. And, of course, by that time, it was out of sight. On another occasion, I remember someone was standing by with a flash camera and flashed at just the wrong moment blinding the operator so he could see nothing. So it took a while before it worked. And I think it did work eventually. I don't remember the details. I was working on a program that was dealing with the radar

itself and the tracking servomechanism. There was some jitter in the servomechanism that had to be resolved, and the program I wrote detected that fact, so…

Damer: Was that eventually feeding into the Cape Cod system?

Ornstein: Well, Cape Cod, no. This was considerably later. Cape Cod was a forerunner to the SAGE system. It was in existence and was working, when I went to Lincoln in the first place. I remember one of the very early trips was to go down to the Barta building at MIT proper and watch the guys, sitting there at the consoles at the Cape Cod system, which was the forerunner of the SAGE system, which was going to materialize in Lexington. The Cape Cod system was based in the old Barta Building at MIT where Whirlwind was housed. It was a miniature version of what would become a direction center later on for the SAGE system. So the Cape Cod System was very early. This (Wallops Island) was years later, and the SAGE system was starting to work, or at least the experimental one at Lincoln was working. And I had left to join this other group and the rest of the division I'd been in went over to form the MITRE Corporation.

Damer: And you mentioned in the book that you had talked to your father about what you were getting involved with, and you mentioned the name J. Presper Eckert.

Ornstein: Oh, Eckert, yeah.

Damer: And he, turns out that he had met.

Ornstein: Yeah, yeah. Well, one of my parents' sets of friends were named Welch, and Fraser Welch was the son of my parents' friends. He was more of my generation, but in between, and had worked at ENIAC. And so the result of that relationship was that I think it was Eckert. I'm not sure whether it was Eckert or Mauchly. I think it was maybe Eckert, who ended up coming to dinner at my parents' house one night. And so when I got into the computer biz later on, I asked my dad about it. He clearly understood that he had zero in common with Eckert. So, I think nothing was brewing there, but it was clear that he just couldn't comprehend anything about what Eckert was talking about or what he was about. He said he was a queer duck or something like that.

Damer: There're another couple of funny stories from SAGE or from Lincoln, the coffee and broom handle incidents.

Ornstein: In the Experimental Direction Center that was set up at Lincoln there were enormous long racks, of course all vacuum tube stuff and a big drum roaring away on the lower part where the computer lived. Upstairs were the consoles that the Air Force people manned. That was sort of the user part, but downstairs there was this humming machinery and at the end of each of the racks, there was an emergency off button. One night one of the janitors with his broom hit the off button and shutdown the entire Direction Center by accident.

Damer: So, they went through and invented the recessed power button at that point.

Ornstein: Yes.

Damer: And, then also in the book you mentioned the card loader...

Ornstein: Oh yeah, the card reader.

Damer: ...where somebody actually ended up dumping their coffee down there.

Ornstein: A coffee cup went into the card reader and hung up development for days while IBM took it all apart, cleaned it up, and put it back together.

Damer: And, then they had to invent the Plexiglas...

Ornstein: Yes, well the following week the console and the card reader, which was the main input to the machine, was all surrounded by glass or Plexiglas and you could not get in there with a coffee cup.

<laughter>

Damer: And, the name Tom Stockebrand.

Ornstein: Oh, Tom, one of the more colorful people at Lincoln and later at-- he went to DEC later on further downstream in the story. But, yes Tom was there and there was a story he told about himself. You probably remember the pictures at least of the old tape drives, the IBM tape drives with the vacuum columns too.

Damer: Yeah.

Ornstein: You couldn't accelerate the big reels rapidly enough if you wanted to start them up, and so what they did was to provide vacuum columns on either side of the two reels, the take-up reel and the reel that was feeding the tape such that you could accelerate the tape under the read heads rapidly without having to get the reels going as fast. There was enough extra tape in the vacuum columns so that you could accelerate the tape under the read heads and then meanwhile the reels would start to turn, and could catch up. Those were complicated tape units and Tom was in charge of working with them. IBM had developed them and Tom went down to the IBM plant in Poughkeepsie where they were manufactured. By IBM standards Tom was a casual dresser. I don't know what the IBM world is like now, but in those days people made fun of IBM because everybody wore a tie and a white shirt and it was very formal. Lincoln was not at all that way, so when Tom arrived at the IBM plant he was a bit of an anomaly. And, some of the people on the production line where he was learning all about these tape units commented on his casual clothes, and Tom said, "Yes, most days I dress rather casually, but some days I feel so good that I get all spruced up and cleaned up and wear good clothes. Some days I feel so good I put a tuxedo on," and the IBM guy said, "Really." And, there was nothing for it after that, of course, but for Tom to go out and rent a tuxedo and so he arrived at work on the production line where he was working in this tuxedo. And, you might think that obviously the people on the line were chortling about the whole thing, but the interesting thing about it was that he said that in the middle of the day his boss on the line and the bosses boss, sort of the whole string of the managers showed up, took him into the front office, and I guess he thought they were going to chew him out and instead they offered him a job. And, I guess they recognized a really creative guy, which Tom was indeed, maybe not because of the tuxedo, but it

was impressive actually because IBM did not have the reputation of being a particularly progressive company at that time, never did. But, anyway that was Tom's story, one of Tom's stories.

Damer: And, from my notes here I'm seeing when I read the chapter of the Transition XD1 and you wrote a moving toward Wes Clark and the TX-0, TX-2, but in between you're writing a simulator...

Ornstein: No, that actually was after.

Damer: That was after?

Ornstein: Yeah, that was after. Yes, I remember Wes Clark from the lecture he'd given about Neuron Simulation and so when I arrived at Lincoln, I always had my eye on that group. That was the Advanced Computer Group, and I knew they were working on TX2 and I really wanted to get into that group eventually. A lot of people wanted to be in that group, including the guy I was working for, Frank Hart, who was a friend of Wes'.

Damer: What group was Frank part of?

Ornstein: Frank was part of what-- it was Group 21, it was part of Division 2. I don't remember exactly what that meant, all I knew was that I was working on missile tracking at that point. But, I knew that Frank was a friend of Wes Clark's in the Advanced Computer Group, and at one point the possibility, a slot opened up in that group, and I decided I was going to move over there. I applied and it was okay. I was going to be able to move into that group, and so I went to tell Frank about it. And, as I think I said in the book, "I could practically see smoke coming out of his ears," because Frank has always been a person to whom loyalty was really important. His guys were his guys and he didn't like any of them to leave him. And so, when I told him that I was leaving he was clearly upset. On the other hand, he himself would really have liked, I thought, to have moved into the Advanced Computer Group, but he had risen enough in the organization so that he was running his own group. He couldn't just do that. As a peon, I could move over wherever I wanted to wherever there was a slot, and he of course envied me basically that ability, but he had risen to the point where he was not able to do that himself. That may be an exaggerated view, but that's how I saw it at the time anyway. So, I went to work with TX-2.

Damer: Describe Frank Hart and what it was like.

Ornsteirn: Oh Frank, Frank has been described quite accurately as speaking in italics. His voice would shoot up and go way high when he got excited about something, which he frequently did. When I first arrived at Lincoln, I first knew of Frank long before I actually saw him face to face I heard his voice down the hall. He was talking about something excitedly, so Frank was very clear about things when he spoke. And, I was fond of him when I worked for him at Lincoln and later at BB&N. He was a great guy to work for and he was very smart and tolerant.

I guess I should mention another thing. Before I left for the TX-2 group, Oliver Selfridge, another well-known name was at Lincoln, I mean you guys probably know about Oliver. He had a piano in his office at Lincoln and I decided that if Oliver could have a piano, so could I. I wanted to be able to practice during lunch time instead of playing Bridge, which was what the rest of us did most of the time. And so, I asked

Frank and he saw no reason why I shouldn't be able to do that, “but don't make a big issue out of it please.” So, I went and bought a little upright that I could bring into the lab, sent the delivery guy around to the loading dock with instructions to just be cool and call me when he got there. I knew the guards by then. I'd been at the lab for quite a while, and so I got a call from the guards at one point with a rather shaky voice saying, "There's a man here claims he has a piano for you," unbelieving voice, very used to electronic equipment coming in, not pianos. So, I rushed down to the loading dock to find the delivery guy sticking his head in trying to see what was going on in the super secret Lincoln laboratory, and finally calmed him down. I got one of the janitor type guys to load the piano onto one of the wheeled carts and move it into my office. And, after that I was able to practice at lunch time every day. And, it was good.

Damer: There's a lead in here of seeing a pattern develop in your career, which is to take the analog world and throw it at the digital and I remember you recording the piano.

Ornstein: That's right. I had the notion that a computer ought to be able to deal with the sound of music and somehow print out a score for the music. That was pretty naïve, extraordinarily so. Actually, let's see, yes I had access to the TX-2 before I actually joined the TX-2 group somehow and TX-2 had an analog to digital converter built into it. So I played a few simple notes on the thing and recorded it on a tape and fed it into the A to D converter and looked at the results. I was unable to see anything other than just a complete jumble of course because, in fact, a piano's waveforms are extremely complicated. So, I realized that it was not so simple as I had hoped. I thought I would be able to see the individual notes and figure out what was happening, but you could hardly tell anything. I finally backed off and I tried simpler and simpler experiments and I finally got to the point where I could play one note and then another note and I'd look on the result and I couldn't even see where the second note was struck. It was just a jumble. Partly, of course, it was just the nature of the piano that I was dealing with and the recording mechanism and so forth. It was very primitive. But, I decided at that point that that was not going to work. But, that was part of my entrée I guess into the TX-2 group by which I had learned enough to be able to get a foot in the door.

Damer: And, as well here later you actually end up realizing...

Ornstein: Yes.

Damer: ...this vision in 1980.

Ornstein: Yes, yes, yes I ended up pursuing that passion for a number of years and finally doing something with it after many, many years actually.

Damer: So, arriving in the TX-2 group, what does the acronym CDABO mean?

Ornstein: CDABO?

Damer: CDABO.

Ornstein: CDABO, Count Down and Blast Off. There was a long start-up routine for a fairly complicated mechanism to get to turn the machine on, a bootstrap mechanism...

Damer: Complete with alarm sounding.

Ornstein: Oh yeah, well there was that. That was mostly because TX-2 was never really finished. It was in constant flux. It was an experimental machine and it was constantly being added to so people had their hands in the racks. And, I met a guy early on who had had his hands in the racks at Whirlwind and was never the same again when he got a full jolt. And, it really damaged him, and so there was heavy duty power in the racks. That was before the days of transistors, remember those were vacuum tubes. Actually TX-2 was transistorized, but there was enough stuff that was high power that you could get electrocuted. You could get in trouble and a lot of people often had their hands in there and multiple people were working so that when the machine was turned on, when you pushed CODABO there was a terrific horn that went off that warned everybody to get their hands out of the machine before the power actually came up. There were a lot of students who would come to use TX-2 and they were not always warned of the horn. Sometimes in the middle of the night students would arrive to use the machine and would push the button and this fierce sounding horn would go off and scare the wits out of them before they learned that that's what was to be expected.

Damer: So, then you're in Wes' incredible energetic orbit.

Ornstein: Yes, and one of the first things that I did was a simulation. This was the days of core memories and there were people working hard at Lincoln trying to find alternative forms of memory.

Damer: Because core had been invented at MIT right?

Ornstein: Pardon?

Damer: Core was invented at MIT.

Ornstein: Yes. Jay Forrester, had thought it up and the head of the Advanced Computer Group, Bill Papian, was a graduate student working for Forrester at the time, and he was the one that actually built the first core memories for Forrester. Anyway, core memory during those years was the main central memory for all the big machines that we worked on. The 700 series IBM machines all had core memories, immersed in oil and various other things because there were heat problems. But, there was a machine that was designed at Lincoln to test thin film memories. I don't remember how the technology really worked, but it fell to me to do a simulation of the FX1 machine. That was the first time I was not only a programmer, but was actually learning how the logic of the machine worked. And, I was introduced to that by a guy by the name of John Frankovich who had been an early programmer. I mentioned him to you guys earlier. I think you should interview him because he's extremely knowledgeable and articulate. He experienced all of that history. He also has a good memory. So, John taught me about how the FX-1 machine was going to work and I wrote an emulation program for it using TX-2. It’s very easy to simulate a simpler machine inside a more complicated machine. It was the first program I wrote for TX-2 and, I got it working around 11 o'clock at night. I called Wes to tell him that it was working, and to my amazement he said I'll be right in.

Damer: And he asked what kind of coffee you drank.

Ornstein: Yeah, that's right. And, he appeared with a great thermos of coffee at midnight and we sat there together just playing with this emulated machine on TX-2 and I thought now that's a great boss.

Damer: And, you were surprised at the rapidity of his mind...

Ornstein: Oh, yeah.

Damer: ...so quickly.

Ornstein: Maybe he had been planning it ahead of time I don't know, but he came in and started flipping the switches as though he'd been using this emulated machine forever, and immediately patterns started appearing on the TX-2 display screen I'd used to represent the FX1 screen. Yes, I was amazed at the rapidity with which he took over and sat down and started writing programs for the emulated FX-1 in the switches.

Damer: What's interesting for me is around that time, around 1959, `58, `59...

Ornstein: Probably about then.

Damer: ...Richard Feynman made a very famous talk about there's room at the bottom about nano, the nano level, the atomic level field to do computing and all those sorts of things, but Wes, you mentioned, gave a talk where he said, "Well, computing will be free one day, pretty much free, and one day we will paint computers onto the walls."

Ornstein: Yes, I still can see him with his painting motion going.

Damer: Yesterday, we went to a show here in Santa Clara where they have printers painting circuitry on everything and so...

Ornstein: So, it actually came to pass.

Damer: ...Wes' vision came to pass so describe him talking about that.

Ornstein: Well, it was a couple of years later that Wes started talking about how computer electronics were going to shrink and how we needed to focus on how computers were going to be used, what the user interface was going to be like, how we were going to use these machines interactively because when the electronics shrank and became cheap enough we would all have computers. At the time, that was thought to be a preposterous idea because most of the computers at the time, like TX-2, filled a room the size of this one. So it seemed really very unlikely, but he apparently had foreseen what was going to happen before anybody else.

Damer: In fact, when I think of Wes I think of Ted Nelson also having this vision. But, in truth, Wes was actually building the machines that would be the personal machines...

Ornstein: Yes.

Damer: ...that would have interactive displays like TX-2.

Ornstein: Yeah, there were a lot of people with visions, but they were really painting in the air as it were whereas Wes was grounded. He really knew how to design machines. He had designed TX-0, TX-2, and a couple of other small machines as a matter of fact so that he knew whereof he spoke, and it was just a question of predicting how the components were going to shrink. And, he'd seen the Flip-Flops go from the size of something you carried in like...

Damer: Like a SAGE Flip-Flop, not 50 pounds.

Ornstein: ...well not 50, but heavy single Flip-Flop. So, he had seen that shrink down with the advent of transistors. TX-0 was the first machine to utilize transistors to test them as switching elements. And, then, when that worked, Wes began pushing for a much larger machine. In fact, there was a TX1 that he had proposed but it never got approved and so it never got built and a slightly cut down version turned out to be TX-2, which was approved and, of course, was built.

Damer: And, TX-2 was built before TX-0?

Ornstein: No, no TX-0 came before TX-2.

Damer: And, then, one day he asked you to go around the lab...

Ornstein: Oh yeah, well again, yes. That was like in 1960 maybe, something like that. He said, "Yeah, why don't you go around the lab. and see what kinds of things, a smallish computer might be good for. I didn't come up with much, but he really knew what he was doing independent of that and he was bent on that track.

Damer: He had disappeared for three weeks.

Ornstein: He started working at home for an extended period, and he brought back with him at the end of that the design for at least the CPU of a new machine. At the same time a woman named Mary Allen Wilkes joined the lab and she and I were jointly assigned the job of figuring out what it would be like to program a machine of this design. Wes described the machine well enough so that we could see what it was like to write programs for the machine, what it felt like. And, that was really the forerunner of what turned out to be the LINC. We didn't realize at the time what was starting to happen, you know there were so many things going on at Lincoln that were novel, especially involving TX-2; there was so much creative work going on there.

Damer: And, Sutherland was doing...

Ornstein: Yeah, Ivan was doing Sketchpad. Larry Roberts was doing communication experiments trying to use a regular phone line to see if you could use it for high speed work. And, there were just any number of things that were happening so it was a time when it was not surprising that a brand new machine was going to spring into existence. Lincoln felt like that, so there didn't seem to be anything terribly unusual about the fact that we found ourselves getting immersed in the building of the new, small

computer. It was the kind of thing that happened at Lincoln. Only in retrospect did I start to realize how revolutionary it was. I had also, even then, worried about the fact that I was part of the growing military industrial complex and I didn't like that. One day I overheard Wes talking to one of the other members of the group there about how he really would prefer if we could focus more on other kinds of applications, not just the Air Force requirements. And, so, the machine that he designed, the LINC, was directed at neurophysiological research from the outset. And, there was more cross-pollination going on between various labs at MIT and Lincoln than I wasn't aware of at the time. All I knew was that there was this new machine coming into existence and that it was going to be applied to medical research somehow. So, that was just very pleasing.

Over a period of not too many months the design got more or less congealed and we actually decided how we were going to build the machine. Charlie Molnar appeared on my radar at about the same time. He was in the Air Force, but he was clearly interested in neurophysiology and also had real electrical engineering capability. Wes never pretended to be a circuit designer. He was a logic designer and he understood machine architecture and was innovative in the machine architecture, but not in the circuit design. Charlie was, on the other hand, a real down-to-earth guy who could, in fact, build circuits, the necessary circuits.

Damer: And, the physical aspects of the tape units.

Ornstein: Yeah, and the tape units. Wes had designed a large tape for TX-2, which was quite novel. It had pre-marked tracks on it for timing and a complex shift register code that would allow you to identify where you were on the tape so that you could actually have locations. IBM tapes before that did not have fixed slots on the tape. The tape that Wes built for TX-2 and later modified to produce a much smaller form for the LINC, did have that feature. I got involved in the part of the logic that controlled the tape units and pre-marked timing and mark channels (basically formatted the tapes) and also all of the control to run them to do the reading and writing. But, Charlie designed the mechanical units, actually Charlie and Tom Stockebrand together. Stockey was a very, very creative guy, but he was a little casual about details, but nonetheless very creative. He and Charlie put together the first actual physical tape units and they were the forerunner of DEC-tapes. If you've seen DEC-tapes, you've seen LINC tapes basically. The DEC-tapes followed them because eventually Stockebrand left our group and went to work at DEC carrying the design of the tapes with him. They appeared as DECTape on all of the DEC machines for years afterwards. They were the forerunner of today's CDs.

Damer: The concept of an efficient, portable, reliable...

Ornstein: Yeah, where you could take your stuff away with you and...

Damer: You could send it in the mail. I mean you think programs-- it was really quite a revolution.

Ornstein: It was, it was.

Damer: You could do a paper tape, but not much capacity.

Ornstein: Yes, that's right, but this was the first time that they were what Wes called snapshot tapes that could-- yes, that was revolutionary. There were a number of things that were revolutionary. Wes had all along, on TX-0, TX-2, been particularly concerned about the user, the way the machine felt to the user. He wanted it to feel accessible, to be something that you could play with. That was the antithesis of what had existed up to then with card readers as the main contact between user and machine.

Damer: And, you were fighting the now major stream of the big dealers of the...

Ornstein: Well, yes.

Damer: ...timesharing world.

Ornstein: That's what happened, of course. Yes, in that era, the high priests of computerology at MIT were somehow convinced that machines were always going to be big and and expensive, so they were busy seeking ways to share machines. That had been the rule before that, batch processing of various kinds had gone on. Machines as they became accessible to more than one user, more than a handful of users, people were seeking better ways to cram a bunch of users onto one big machine to share it.

Damer: Through telephone lines at low baud rates.

Ornstein: Well, initially it was just you had a shot at the card reader and the printer at Lincoln; that's how I did a lot of programming in the early days on the 700 series machines, 704, 709, 7090 and so forth. You simply stood in line or signed up one way or another and you handed your batch of cards to the operator, you were never allowed to touch those machines with your own hands...

Damer: Or your coffee.

Ornstein: And, yeah well so when Wes built all of the machines that he designed, he insisted that they be treated the way we treat personal machines now, it's your own machine at least for some chunk of time. For a large chunk of time it was very expensive, but he foresaw that eventually it was going to be cheaper, so even though it was expensive he managed to arrange that TX-2 was given over to one user at a time for extended periods, and that was the rule when I got there. You could sign up for a four hour stretch to have the machine to yourself. You had the complete machine, you had complete control over the whole thing. There was no intervening operator and you sat down at the console. So I think, Wes' major contribution was to make computers more accessible for people to use interactively.

Damer: And, all of them would interact.

Ornstein: All of them were like that. Well, one could argue that Whirlwind was not, since there was only a handful of people, and I don't really know how that worked. I saw the machine but I never was a programmer for the machine.

Damer: To this day, our restored LINC in the DigiBarn, and I can sit down, load LAP6, and within a few minutes on a 256 by 256 CRT, and a keyboard, be doing stuff that's interactive, plugged into a regular...

Ornstein: Well, and TX-2 was certainly that way, too, but it was a much bigger machine. Ivan has said that he was able to do Sketchpad only because he was presented with a machine that had this kind of capability. And it was unique. When I was working earlier for Frank Heart, for example, I was working, at one point, on a simulation studying undersea sound transmission having to do with looking for submarines. As part of that, we had on the IBM--I think it was the 7090, I don't remember--a large screen that could, in fact, display picture, and we did use that in our simulation work. But it was not interactive at all. It was just a place where you could put up pictures, and that in itself was not like the TX-2, where you could interact with the picture under program control, and therefore shape what was happening by your input. There was no input for that on the IBM system.

Weber: And the TX-0 was interactive?

Ornstein: The TX-0 was. I never actually, personally, saw the TX-0. I read about it and I know about it. But yes, I believe that that was also-- as far as I know, all of those machines, really, TX-0 and TX-2 and the LINC and then some of the other machines, in all of them interactivity with the user was of the essence. That was really the important feature of those machines.

Damer: And for Wes, that was one of the key features...

Ornstein: And for Wes, I think that was key. He'd done that with the big machines, and I think, with the LINC, he was betting that it would be possible to have those same kinds of facilities-- in primitive form, but those same kinds of facilities for individual users, for individual machines that were the property of individuals.

Damer: And, of course, another huge revolution of the LINC was that it was made to be a kit, and many of them, to be distributed...

Ornstein: Yes. I think of that as an orthogonal feature. It's true that we didn't have a factory, and those machines were going to go out into the world without any maintenance organization to back them up. I mean, they were unique in the world, and so the people who were getting them-- well, we haven't discussed how that happened.

When the LINC first started working, we carried it down to NIH headquarters in Bethesda, to show them what it was about, and they fairly quickly connected it to signals coming from a cat's brain, and they were able to see things that they had never been able to see before. Because they were able to do averaging and get a signal to appear out of the noise, something that they'd been struggling to do for a long time. So NIH got very interested. Meanwhile, the Air Force was not interested so Lincoln Laboratory was not interested in pursuing the LINC in the medical arena. But the National Institutes of Health took one look at it and said, "Man, this is what we need." And so they were, willing to fund it, but still Lincoln was not interested in NIH money because their overhead was much lower than that of Air Force money.

Weber: When you moved to Kendall Square?

Ornstein: So yes, a group of us moved down near MIT proper. We lived up over a health food store in Kendall Square, and that's where we put more LINCs together. NIH funded a program to give LINCs to a

variety of medical researchers around the country. There were competitive submissions for that and a bunch-- I don't remember how many, 20 maybe -- that were awarded LINCs funded by NIH to take to their laboratories to use in their individual disciplines. There were neurologists; there were cardiovascular people; there were psychologists — all sorts of disciplines were represented. And we worked furiously one summer to make those machines available. They were provided in kit form, largely I think, because we needed to have the people who were going to take them away understand them well enough so they could fix them because we couldn't possibly provide maintenance on those machines remotely. So all the people who came-- the doctors, either brought along a technician or were interested enough themselves to learn. We ran courses to teach them how the machine worked and how to program and all of that other stuff. It was one of the most intense periods in my life and it was probably true for all the rest of the crew, as well, and we were a tiny crew.

Weber: So you had these...

Damer: Talk about the group.

Ornstein: Oh, well, that was the closest-knit group I've ever worked with. We were working around the clock because we had to make these kits for the people and then we had to teach them how to use them. As the deadline approached one of the fellows had a dream that-- let's see, how did that go? It was a dream about Wes driving a bulldozer, and it was headed towards a cliff. And Charlie, in the dream, was hurriedly trying to attach wings to this bulldozer <laughs> as it was approaching the cliff. And that is sort of a symbol of how we all felt at the time. We were faced with a deadline when the doctors were going to come and we had a machine, the design of which had only just recently been completed. We were supposed to make multiple copies of it. It was a really frantic time, and the fact that we were able to make it is a testament to a lot of stomach lining and a lot of blood that was laid out in the process. We all worked our butts off for...

Weber: How many of you? And what year?

Ornstein: Well, in the actual machine production, there were maybe four technicians and-- because the rest of us should not be wielding those soldering irons making the patches that were necessary, and it feels like about half a dozen. I mean, it was just a tiny, tiny crew. I can name most of them and they all appear in the...

Weber: Oh, okay. They're in your book?

Ornstein: Well, Wes, of course, was the leader of the group, and Charlie. Mary Allen Wilkes, who had been the original programmer, ended up writing the software for the operating system. At that time an assembly program is all that we had. And then, a couple of other people, especially Mishell Stucki, worked closely with me. I could probably find some other names. There were other people who were in the group but they were more interested in the applications and the relationship to the medical community. For the actual hardware, putting the hardware together, t hat's about it.

Damer: And then, one night, you mentioned that because all these kits had to be assembled and they had to travel in station wagons and aircraft, went to Chile and things like that. That one night, you had gotten one of the units to work and we were all happy about it and, of course, then, Wes picks it up and does the Forester test...

Ornstein: Well, that was the console <laughs> unit, which had a lot of lights and switches and moving parts, and yes, one of Wes' feature actss, recently reenacted at a show in Germany as a matter of fact,. He learned what he called the Forester parity check, which was to subject any piece of hardware to a certain amount of abuse, and if it didn't survive that then it wasn't good enough. I remember we got the first console working and Wes came in and said, "Let's give it the Forester parity check," and lifted it up about six inches and dropped it on the table. Of course, everything went to hell in a basket, but we learned a lot from that. And he was recently at Paderborn...

Damer: In Paderborn, yeah.

Ornstein: And there's a picture of him. There was a LINC that went to this show in Germany, and there's a picture of him beating <laughs> on it, symbolically. iI's not a working machine. But he was just...

Damer: Not anymore; right?

Ornstein: Well, <laughs> no. It was hard enough to make a working machine for the Vintage Computer Festival a few years ago. To get one machine working after 50 years that was long ago obsolete.

Weber: And talk a little bit about Wes and what it was like working for him.

Ornstein: Wes was extraordinary. Still is. He's just a little quirky — whimsical, I guess, is the word. He has a wonderful sense of humor. You had to-- I love the guy. I mean, there's no question. He's one of my favorite people on the planet. But you had to tolerate a certain amount of quirkiness in him, and had to understand his humor. He was also a terrific instructor, a terrific mentor. I learned an enormous amount-- not even only about computers, but about how to live. I mean, he was really a guy who understood humanity pretty deeply, and of course, understood computers a lot, and loved to teach. I mean, there was no question. I remember him explaining to me how a flip flop worked, the early days, and how-- and he would lead you on rather than just tell you. He would let you discover it yourself, you know, and sort of point you a little bit in the direction. So he was a terrific instructor. He's an extraordinary human being, aside from being a brilliant engineer. So as I say, I learned a lot of-- all sorts of things from Wesley.

Weber: And his leadership style in a group?

Ornstein: I think other people that stuck around felt the same way I did about him. After we left Lincoln-- you know, during the days at Lincoln, I didn't know him so well. We became friends, gradually, over the time as we-- certainly, when we moved on to the LINC, when it was decided we were going to leave Lincoln, because Lincoln was not going to fund the LINC and Wes decided he was going to leave. I remember the meeting in which he announced that and he said, "By the way, LINC stands for Laboratory Instrument Computer." Because up to that point, we had assumed it stood for Lincoln, of course. And I remember going up on the roof at Lincoln with him and saying, you know, "Wherever you're going,

<laughs> I'm going there, too." And I think the other people that joined him felt very much that way, that he knew what he was doing and we wanted to go along.

Damer: Wes described to me -- whimsically, how he was fired for insurrection by Lincoln.

Ornstein: <laughs> Well, yes, it's hard to think of him as being anything other than very respectful of people. But yeah, Lincoln really did not want to accept NIH funding. I think it-- first of all, NIH overhead was lower than the Air Force overhead. Whether that had something to do with it or not, I don't know, or whether it just complicated their bookkeeping too much. They knew how to deal with the Air Force. They didn't know how to deal with NIH. It was a whole other thing. For whatever reason, they really did not want to do that and that was where the future of the LINC, obviously, lay. So it was perfectly understandable that we were going to have to leave Lincoln.

Weber: So how did the group...

Damer: I was-- a question of how you guys ended up at Washington University, but go ahead Marc.

Ornstein: Oh, well...

Weber: Is that after the LINC?

Ornstein: What happened was that we left with this prototype LINC and went down to Kendall Square, down to MIT proper, and we were there for, what, a year and a half, two years, something like that, during which time we perfected the LINC, redesigned it quite a bit. Built a prototype of the new version, and then produced multiple kits for doctors. A program was set up, the LINC evaluation program, whose purpose was to understand whether and how a diverse group of medical researchers might use a computer like the LINC. They were to come back in a year or two years-- (both, actually) to see how it's worked and what they say and whether it was successful?"

Our office at MIT was called the Center Development Office for Computing in the Biomedical Sciences because the hope was to build an inter-university center at MIT for developing computers for use in medical research. This was a proposal for a whole new center, and somewhere I have tucked away a newspaper that said, "MIT receives 37 million dollar grant," or something like that, for establishing this new center. It was to be an inter-university center involving people from Dartmouth, from Princeton, from Harvard, Yale. All of the Ivy League schools were going to be involved. There was to be a new building at MIT and so forth. It was a major, major thing that was supposed to take place.

Sadly things went bad at MIT. One never knows the actual cause, but on the surface of it, we were an insurgent group from-- you know, none of us had faculty positions at MIT we were staff people. And when there was real money and a real thing was going to happen, the powers that be at MIT wanted to run the show. But by then we really wanted to run it ourselves. We wanted to be in charge, and I guess, that's-- Wes is the "we" because, you know, I was just still a peon. There was apparently, a very dramatic meeting in Charlie Townes' office--he was Provost of MIT at the time--in which it was clear that the group was not going to remain at MIT any longer.

So the next question was where were we going to be instead. We traveled around the country, visited various possible universities, to see where we could work most fruitfully. We wanted to be connected to a medical school somewhere because we wanted to be in the medical arena, but we wanted to do computer research. And the two possibilities that I remember most distinctly were the University of Pennsylvania, where there was a lot of work that would have fitted in and there were people there, who were interested, and Washington University in St. Louis. In the long run, George Pake, who was the Provost at Washington University who later would found PARC,, decided that he was going to back Wes to the hilt. I remember a site visit where the NIH people were interviewing us and the powers that be, at Washington University. They asked George Pake point blank, "If we don't fund this, are you going to hire all these guys, anyway?" And George Pake said, "Yes." So I think that probably decided the issue.

It was clear that we had the kind of support there that we had not had elsewhere, and so that's how we ended up in St. Louis. I hated St. Louis with a passion. It was not my kind of place. It was out in the middle of the country. The nearest mountains were miles away, and the climate was abominable, as far as I was concerned. We loved working with one another there. It was fun. It was great. We had had the experience of working together really closely at MIT. But when we moved there, I had said to Wes, "I'm good for three years here, and after that I don't know where I'm going to be. But I don't think I can stand to be here longer than that." And that turned out to be almost precisely how long I was there.

Damer: During the Washington University period, was that when Sutherland and Bob Taylor came by for a visit?

Ornstein: Yes. When we went there the question was what we were going to do. It was clear that we were going to pursue the rest of the LINC program. The evaluation program was continuing, and there were other questions about what was going to be a follow on. We had used the standard DEC modules in building the LINC. Had to design a small amount of stuff ourselves but, basically, most of the central machine was built out of standard DEC modules. But you had to know a lot. You couldn't just plug those things together ad infinitum. There were loading rules that you had to know. There were a bunch of rules that you had to worry about, and Wes had the notion that it ought to be possible to design building blocks that could be plugged together without ever thinking about electrical issues. There should be a very simple set of rules for how they worked, and you shouldn't ever have to worry about electrical issues, loading issues, etc. All those would be pre-solved. That was the extent of what he had in mind. How to do such a thing, nobody knew.

Weber: They weren't even to be clocked; right?

Ornstein: No-- well, that came later...

Weber: Came later.

Ornstein: Wes had just declared that that's what he was going to do, but he was in tough shape. Wesley, like many geniuses, had ups and downs, and he had just been through this burst of activity with the LINC,

and he was worn down, worn out. And so I remember sitting the room where the NIH people asked him, well, how was he going to do that and just to say a little bit more and so forth, and he just sat there glum. He didn't really know, at that point. He just-- he was worn out, I think, is what happened. So when we moved to St. Louis, it was with the promise that we would figure out how to make such building blocks.

I had worked hard previously, on the LINC and TX-2, but that was probably the most productive and creative period of my life — working on the initial design of macromodules. Mishell Stucki, who had been a central member of the LINC team, and I arrived in St. Louis at about the same time, and we went to work together. As I said, Wes was really in tough shape at that point, so Mish and I were left pretty much to ourselves, and...

Weber: So Wes was...

Ornstein: Pardon?

Weber: When you say, "tough shape," I mean, was he coming in every day? Was he...

Ornstein: He came in every day, but he wasn't being his usual productive self, charging ahead and leading. In that case, he was sort of waiting, so Mish and I went off with a blank sheet and a vague set of rules to try and figure out how one might do that sort of thing. Wes was there, but he wasn't really working directly on the problem, initially. I'm speaking of when we first arrived in St. Louis. Misha and I sat down and fought through it together and we gradually started to make some progress. We realized that a system which could extend arbitrarily couldn't use a clock because there would eventually be timing problems that you wouldn't be able to resolve. So it had to be an asynchronous system. Mish worked out the signaling system that that would be used, and together, we sketched on the white boards (they were green boards at that time) and with the Polaroid camera every day we took pictures of what we had devised. I remember at one point, we went to Wes and told him exactly what we were thinking, and he said, "Good show, fellows. You've reinvented ILLIAC III." <laughs> And "Go back into the pit and do more." And we did. And eventually, as it started to come together, we defined a set of proposed basic units, at which point Wes' interest picked up again. He was sort of in recovery mode, I think. And he then, got really interested and, of course, took over the project. But I think that Mish and I actually did the key initial work that got the engine going, so to speak.

Damer: And was that when Sutherland arrived and looked at the design...

Ornstein: Yes. We had defined a set of building blocks, registers and control units -- a very general set of building blocks from which one could build a simple computer. We had devised a scheme with data paths and control paths. And so at that point, Bob Taylor and Ivan, paid us a site visit.

Weber: Together, yeah.

Ornstein: They were working conjunctively at the ARPA Information Processes Techniques Office which was funding a good bit of our work, along with NIH. They showed up one day and wanted to know what we were up to. We described these units to them, and Ivan, in his usual way, said, "Let's see, now," and sat down with a blank piece of paper and started to sketch. And in minutes, he had drawn up a small

but complete computer out of the units that we had defined. And I remember very clearly-- he doesn't remember this. I've talked to him but he doesn't remember -- he looked up at one point, and said, "By golly, fellas, I think you've done it." And that was a real accolade coming from Ivan, of course, at that point. But we knew we'd done it. We weren't surprised, but we were pleased. And I think that was, in fact, Ivan's first introduction to thinking hard about asynchronous machines, which came to be his forte, and years later, he pursued that in great depth. And it may yet be-- as Chuck Thacker has said, may yet be that asynchronous machines lie in our future, as the clock systems come up against some very fundamental limits, speed of light and things that will make it impossible to make machines faster with clocked systems.

Damer: A few years ago, when you brought Bob Taylor to the DigiBarn and we powered up the LINC, you mentioned that at some point, Taylor was introduced to the LINC. And because it was such a transparent machine, where you could see the register state, had a screen and what not, that this was the way that Bob Taylor learned about how computers actually worked.

Ornstein: Yes. There were some features, which today may seem silly but were very, very key to the understanding. Wes built into all of his machines the ability to vary the speed under manual control, essentially. He just put a manually controlled delay into the clock so that you could control the speed of the machine. You could not only slow it down but you could actually step it, instruction-by-instruction and, in fact, even cycle-by-cycle so that in the lights, you could see absolutely everything that was happening.

Weber: So for troubleshooting, it's wonderful.

Ornstein: Yeah. Well-- and then, also, another thing that existed on all those early machines-- I don't know about TX-0, but TX-2 and the LINC certainly had a speaker. And the speaker could be attached to pretty much any bit in the machine, or at least, a number of different possible bits. And so if you attached it, for example, to the low order bit of the memory address register in the machine, and then you listened to what happened when the tape was moved forward, you could hear it go, "Rrrrppp." You could hear the actual address register speeding up, of course, because the tapes speeded up over a short interval. And while data was flowing in, the tape was speeding up, and so the memory address register was going faster and faster, as the data came into the machine. So you could actually listen to your program running, and that turned out to be useful-- especially, in conjunction with the ability to slow the machine down and to step it . Very useful in debugging, it turns out, at least, in those machines. I used that on the TX-2, certainly.

Damer: Scott and Jerry sent me a video when they were storing the machines in St. Louis, playing Bach, like polyphonic music...

Ornstein: Oh, yeah. That had been done long before. As a matter fact, that was done on the Memory Test Computer, which had been built for testing the first core memory...

Weber: And the PDP-1 was done...

Ornstein: Well, yeah, the PDP-1 came later. But when I first went to Lincoln, they were playing "Stars and Stripes Forever" on MTC, the Memory Test Computer. So that was not-- that was...

Weber: Yeah, that's been done.

Ornstein: ...nice but not new...

Weber: But perhaps, the concept that the LINC was small and complete-- with the console design, it was completely transparent, and you could really understand...

Ornstein: I think the ability to control it and slow it down and step it and see it inch its way through the program was just terrific for program debugging. And in terms of understanding how things-- how your program worked, it was very, very helpful.

Damer: So Taylor did learn...

Ornstein: A lot of people learned a tremendous amount from those features on the LINC, yeah, by being able to play with it yourself.

Damer: And what sort of-- you mentioned an operating system was done...

Ornstein: By the way, excuse me for interrupting. But Licklider also learned that way, at the console of TX-2. Lick was a visionary, of course, but unlike Wes, he couldn't build anything. He couldn't write programs, actually. He just had this vision, which he expressed very well. The same with Taylor also-- I mean, a lot of the visionaries had no ability whatsoever to realize their vision. Wes was unique in his ability, not only to have forward looking visions, but also to be able to implement them and therefore, influence what happened downstream.

Weber: Where would you put-- I'm curious. I mean, Doug Engelbart was an engineer but not a computer builder. He was somewhere in the middle in terms of...

Ornstein: True. He was somewhere in the middle and was involved directly in the construction of his system. I don't think Lick was ever involved directly in anything. He was just a visionary, you know, and wrote about it very clearly, but he never built stuff, and Taylor certainly never could build stuff himself. But he had...

Damer: I think you whispered in my ear when we were showing Bob the LINC again, "Bob still doesn't understand how computers work."

Ornstein: <laughs> Well, at the very bottom level, that's true. But, you know, he didn't need to. He understood what he wanted and, of course,was a superb manager and recognized talent. I've worked with three really extraordinary people; Bob, Wes, and Frank Heart — those are basically the bosses I've had. Well, an earlier one at Lincoln, maybe. But yeah, Bob had a super skill in collecting good people and he had super good intuition about which people to listen to -- Butler and Chuck and Alan Kay and Ed McCreight and Bob Sproull, a handful of really smart people. He recognized that their vision was really

where to go. And then, he was able to persuade the rest of the lab. I mean, when the Dorado was built, the people who were building LISP, really desperately needed a more powerful machine than the Alto, and there Bob did a masterful-- I was a victim. Bob did a masterful job of persuading us to put in the effort necessary to build what amounted to-- what ended up being the Dorado. Because we didn't want to do it, initially. We fought hard against it because we all wanted to do our own thing, and it was clear that building the Dorado, which is a faster version of the Alto really, faster and more capacious version of the Alto, was not what we wanted to do. But it was clear that the lab needed it and Bob managed, very cleverly, to cajole us into doing it, and once sort of key people got persuaded that that was what was going to happen, then it went forward...

Damer: And around the time of-- so when Bob was doing the site tours for all the ARPA funded centers, they were-- and we know the story of Bob having three desks and three chairs and three manuals and three timesharing systems and coming up with the ARPANET concept. Or maybe Lick had that belief in network systems, but...

Ornstein: Oh, yeah, Lick, I think, had a much bigger...

Damer: Lick had a bigger...

Ornstein: ...vision, yes.

Damer: Through your mission in St. Louis and then deciding to-- you had at that point sort of a branch point.

Ornstein: Yes. I had had enough of St. Louis. We pulled away and headed for Boston. I had two possible things to do-- two job offers. Ivan was head of, I guess, they didn't call it computer science at that point, but that's what it was at Harvard and Ivan knew that I was interested in music and so he offered me to come to Harvard and work with graduate students there on whatever I wanted to with respect to music. And Frank wanted me to come to BBN. He didn't know what exactly I'd do, but he wanted me to come to work there and I finally decided that I would do that. I'm not sure why. I guess I felt I didn't really know what I wanted to do about music. I didn't have a program in mind and I guess I should say that I don't think of myself as a real innovator. I'm very clever at helping somebody who has a good idea, helping them to push it forward, roll the rock up the hill. The idea that I would myself have initiated the rock, and started pushing it, and saying, "This is what we need to do," I don't do that well. But what I do do is recognize somebody else's rock as the right one to push and then help push it. And so I didn't feel that I understood well enough what I wanted to do with music and computers at Harvard. I knew there were a lot of things I didn't want to do and so I decided to go to work with Frank. I knew him and the situation at Harvard looked complicated and then it ended up that I was able to not only work at BBN, but I also taught at Harvard as a BBN employee. Harvard hired me and BBN, of course, scraped off the excess into their coffers. So that worked well and in fact I loved the teaching. It was a lot of work, I found. It took a tremendous amount of preparation, but I taught a first graduate seminar, relatively small dozen people or so. And then the next year a big major introductory course to programming and hardware design, sort of a combined thing. And that was fun but a lot of work, but when I first went to BBN I thought that I might

work with Wally Feurzeig and Seymour Papert at MIT on the Logo Project looked as though it was something.

Damer: Seymour Papert.

Ornstein: Seymour, of course. Looked as though it was interesting, but somehow I couldn't get a foothold in that. And so then I moved over temporarily into the group that was working on the Tenex System because they were doing more direct hardware work, which I supposedly knew how to do. But I never got connected there either and I was beginning to think, "Maybe I should have gone to work with Ivan at Harvard after all." And then one day Frank handed me the RFP for what turned out to be the ARPANET, and he said, "Why don't you take this home and see what you make of it." And I did and I guess by now I have become famous for saying what I said the next day when I handed it back to him. I said, "Oh, it's straightforward engineering. I'm sure we could build it. I can't imagine why anybody would want such a thing." So much for my vision. But we did in fact work very hard on that proposal and spent more money on it than any previous proposal-- BBN was not used to spending that kind of money on a proposal and they were upset. The management was upset that we spent so much time and money writing this proposal, which they thought there's no way in the world it's going to happen that BBN is going to get it because all the big guys were bidding on it, Raytheon, Westinghouse. I mean I don't even remember who but you know the big companies were bidding on it. The idea that BBN could possibly win that kind of contract seemed just ludicrous at the time, but we thought we had a really good proposal and we did. We did a lot of design before we ever submitted the proposal. By the time we were awarded the contract to build the IMPs, we knew just what we were going to do -- there was no thinking time required. We just turned the switch and the system ran.

Damer: When you were still competing it you had to go and present your design to them as well in the competition process?

Ornstein: Oh, absolutely. But Larry Roberts was the guy who Taylor had conned into heading the project. And we knew Larry and I thought that was a downside because I thought, "Well, Larry will be afraid that if he gives it to his old friends that it would look bad because it would look like it was nepotism going on," or whatever you call it?

Damer: You knew Larry from Lincoln?

Ornstein: Yeah, Larry Roberts.

Damer: Right.

Ornstein: Yeah, of course we knew him. He was working at Lincoln at the time along with Ivan at the same time that I was working on TX-2. We all knew one another and so Frank and I and others felt that we had to be better than anybody else or we were not going to even be considered. But Larry quizzed hell out of us and we had answers ready for him and he finally decided I guess that he could-- it got gradually narrower and narrower and we were still in the running, you know, the way these things work. It got narrowed down and finally he decided to give it to us to do. And I think there was a lot of shock in

some of the bigger companies because they assumed they had it nailed, you know. And they hadn't done their homework nearly at the level that we had. I mean, we really should have gotten it. It was the right thing. Larry was smart enough to realize that despite the potential threat of, you know, favoritism and so forth.

Damer: 3C?

Ornstein: Pardon?

Damer: Some of the ones that tried and failed with the bid?

Ornstein: I vague-- I think I remember Westinghouse, Raytheon.

Damer: Not IBM?

Ornstein: I'm not sure. IBM may have bid on it. I don't remember. I don't remember, but there were a number of big companies and there were a bunch of companies that I didn't know about at all. I don't know whether AT&T bid on it.

Damer: Had you proposed the Honeywell 516?

Ornstein: Yeah, that was really Frank's choice. He understood very well how important reliability was so he insisted we use a hardened version of the 516, which you could drop from an airplane and it would continue to run.

Damer: The Forester test.

Ornstein: Yeah, the Forester test in spades. The year that we started this there was the joint computer conference and Honeywell had a hardened 516 that they had suspended from the ceiling of the place and the had a sledgehammer there and they were offering people, "Go hit the thing as hard as you can and it will keep running." And indeed it did. I mean, they were so intent on that that they actually had suspended one from a hook and had a sledgehammer there for the passing tourist to take a whack and see if he could stop it.

Damer: And Frank had seen this?

Ornstein: Pardon?

Damer: Frank had seen this?

Ornstein: No. I think that actually was after we had already chosen that machine-- that hardened machine. And the classic picture of Frank in front is on a hardened machine. That's what we used because he was very concerned about reliability -- in fact, we all were. I mean we--

Damer: As you pointed out in the book this machine had to have 100 percent up time and it's IO system was going to be driven really hard and it was kind of new.

Ornstein: Yes. They had never run the IO so hard as we were going to run it with a bunch of high speed lines coming into the memory. And, in fact, that uncovered a problem in the machine design Years before when we were working on the macromodules we had come upon a problem with synchronizers that had apparently not been recognized previously. Wes says that I was the one who said, “But what if?” And kept insisting there was a potential problem while everybody said, “No. No. No, a synchronizer will solve that.” But what if? And the problem is very fundamental. It’s when you have two conflicting signals hitting a circuit, the question is which way is it going to go? When you connect an external device such as a printer to a computer the device's request for service, isn't synchronized with the computer's clock. Sampling an unsynchronized signal can give rise to ambiguous results which can cause chaos in a computer. The way a synchronizer works is that on one tick of the computer's clock the device's request line is sampled. This may or may not set a request flip-flop. The presumption is that on an ensuing clock tick the flip flop will have either been set or not and will have settled down so that sampling *it* will produce an unambiguous result. That was supposed to solve the problem because it allows the flip flop a settling time of at least one clock tick. Well, it turns out that flip flops, if hit marginally enough, will actually still be undecided, and not resolved by the time that next clock tick comes along

We knew that that problem existed. As I said, we'd run into it in the macromodule project and I taught my students about the problem in the design class I taught at Harvard. And one of those students, a guy by the name of Ben Barker, was working with me on the hardware design for the interfaces for the IMP and suddenly the IMP started failing once every day or two. It would run just fine and then suddenly it would be off in no man’s land, halted for no reason trying to run program in the middle of some data. Some crazy-- and no consistent symptom, totally different every time and there it would be stranded. And it was Ben who said, “Maybe there’s a synchronizer problem.” And we looked and sure enough there was a case where the service request flip flop needed an additional clock tick settling time, but only very rarely.

And so we called the designer of the machine. It took a long while to get through at Honeywell to the guy who had actually designed that part of the 516. And he finally came around and was smart. To see the problem on an oscilloscope, Ben built an aggravator, which caused the potential problem much more frequently even than was being caused by even the high-speed lines. If you did that and you looked at the turnover of the flip flop on a screen in a darkened the room, you could see suddenly a ghost of the occasional place where the supposedly synchronized flip flop would still be undecided a full clock tick later. Most of the time, of course, the bright trace showed where it either turned over sharply or did nothing which was fine and dandy, but what was that little ghostly trace doing there? And when the Honeywell guy saw that he then realized that there was indeed a problem and we knew what it was. There was a simple solution, which was just to delay sampling the flip flop one more clock time because flip flop will eventually settle down. Although in theory-- I mean, cosmic rays will cause it to settle down eventually. It won’t just hang forever. The pencil will not stand on its point forever. Something will knock it over, but it was occasionally taking a long while and causing an otherwise working computer to suddenly go berserk.

Damer: Your term, I think, become known as the “synchronizer glitch”.

Ornstein: Glitch, yeah. Well, a glitch is of course a general term that we just adopted -- it was apropos for this kind of behavior. So and, yes, and it took years before digital designers understood and allowed

for it. Digital designers had left electronics behind and they had come to believe that they were operating with devices, which were really digital. But inside a digital device is an analog something at the next level down. So that's what was happening. And I think that what had happened is that logic designers had just believed that everything was fine. Took a long time before people started to say, "Oh, yeah, we've got to be careful about this." Now, I think it's fully understood. As things have speeded up you tend to get this problem increasingly so you've got to deal with it properly. Although there's no absolute solution, the solution of simply allowing more settling time works — unless you're going to live for 100,000 years with the same machine.

Damer: One of the things I appreciated in your telling in the book, this focus on reliability is when you guys ship the first IMP to UCLA. Got it there right side up, but that it worked out of the box and it surprised the UCLA crew.

Ornstein: Yeah, they were not-- well, first I think the thing that surprised them more than anything else was that we actually met the schedule. Very few projects of that kind actually meet schedules and I think they were counting on the fact that, "Of course, the machine is going to be late by at least a month." But it was right on time and it had never happened before. It took a lot of hard work and determination. We had a terrible time getting Honeywell to take over the building of the interfaces. We designed the interfaces using their packages but they never understood them. And so what we would get when a machine got delivered was an interface that was all screwed up and we had to straighten it out ourselves and finally I got fed up with doing that and I said to them, "Don't send another machine that you have not fully checked out." And I knew that the next one that was coming had not been checked out. So when it arrived at the loading dock, I simply said to the truck driver, "Take it back." And that was not the kind of thing that happened. I remember-- Frank looking out the window and wondering is this the right thing to do? But it was and they took it back and after that they fixed things because they had a fixed schedule and they had been shipping us garbage. But I'm hardnosed so it got straightened out eventually, but it took a lot of battles.

Damer: Talk about the IMP team and the different people and their roles.

Ornstein: On the IMP-- on the IMP team? Well, it was, again, a crew of people that really had a lot of respect for one another and that turns out to be important because otherwise you can get sidetracked onto irrelevant arguments of one sort or another and that never happened. We all knew one another pretty well at that time and we worked very smoothly together. The hardware guys, I was in charge of the hardware for the special interfaces that had to be designed and all the non-standard stuff that went into the IMP. There were the interfaces to the host computers as well as to the phone lines and there was some other special stuff having to do with reliability. We had a watchdog timer, for example. It's a thing that's I guess standard now so that no matter what happens if the program stops-- if the program is not kicking this timer periodically, the timer will go off and will reset the machine and start it up again from scratch.

Damer: Like a dead man switch?

Ornstein: Yeah. And so, you know, we had to design all that-- so there was a certain amount of special hardware in addition to the interfaces that we had designed and I was in charge of that.

Damer: And who was working for you?

Ornstein: Pardon.

Damer: And who was working for you?

Ornstein: Mostly Ben Barker and who else? There were some other hardware guys-- Mike Kraley, Martin Thrope, Tony Michel. People whose names you probably wouldn't know now. Very good guys. Ben, for example, had been one of my students. In fact, BBN hired over half a dozen of the students from my class at Harvard that I had met that way and could say, "That's a good one." I don't remember the other names of people but they formed a team that worked very well together.

I met Bob Kahn at that time for the first time and he best understood the error control and how that was going to work because that was his specialty. But he also wanted to learn about actual hardware design and so he asked if he could work with me on the design of the interfaces and I thought, "That's terrific. Of course it will be wonderful because teaching somebody is the best way to get something right. So he would ask all sorts of questions and I explained to him how the interfaces would work and that was fine and we became friends. In addition he and I worked together at my house late at night a number of times trying to understand some of the system problems such as how to do flow control — all of the things that you have to do in a network, and he was very much into that kind of thing. On the other hand, I-- my memory is that he did not understand simulation and when he wanted to do simulation his notion of simulation wasn't that you build a model internal to the computer. He wanted to see-- he actually wanted to *see* what-- wanted to build a simulation so that he could watch messages flowing and the rest of us thought that was crazy. Probably he may have been right, but the schedule was not to allow for that kind of exploration. Had we followed his suggestions, we were never going to make the schedule and so one can debate today whether that was a wise decision or not, but Frank was adamant about holding to the schedule if we possibly could. And so that did not allow for a lot of time for that sort of thing and our guys were pretty good. Guys like Will Crowther and Dave Walden were pretty good at gedanken experiments in which they could intuit how things would behave. And so the IMP program was constructed pretty much by the seat of the pants and it was okay. It did have flaws that later had to be corrected but it worked well enough to get the project off the ground and it worked on time well enough to get the things off the ground. Lenny Kleinrock's claim that this was the first message that was sent was nonsense. We had sent messages between IMPs at BBN. The only difference was the length of the wire and that really does not make any difference. I mean, it could but it doesn't if you do it properly.

Damer: But you were then from IMPs to host, and from host to IMP, IMP to host?

Ornstein: We had done all of that stuff. You can actually do that. You can make a phone call from one room to the next or even to somebody in the same room and it verifies that your phone is working.. If you then cannot make a call from coast to coast, it's the fault of the phone company, not the phone itself.

Damer: And your IMPs didn't crash like?

Ornstein: None of us was surprised at all that it just worked when they set it up. I would have bet my entire fortune that it was going to work. We were that confident of the work that we'd done and we had tested it up the wazoo.

Damer: So you were building the NCC, the Network Control Center, before you shipped the IMPs? The Network Operation Center?

Ornstein: Yeah, well, that grew along with the IMPs. I couldn't say that it-- no, but we certainly had tested the IMPS. You could just feed the output back into the input so you could do a certain amount of self testing. We'd done an enormous amount of testing and so we were absolutely convinced. And we also had the phone company modems so that we were actually feeding it into the phone system and back out. So we knew that--

Damer: But you had not necessarily connected them to a host computer but that wasn't particularly the point?

Ornstein: No, we did. We had a mini-host inside the IMP for testing that so, as I say, I would have bet my bottom dollar that it was all going to work fine and it did once the network started to grow beyond just having a single site, which is really odd. It's between two machines. Then we started to get flow problems that hadn't been anticipated properly and needed to be fixed.

Damer: And how many people were in?

Ornstein: In the IMP group?

Damer: I mean there's the classic photo of you guys, but is that pretty much the full group?

Ornstein: That was it.

Damer: So about a dozen?

Ornstein: That was it. And in fact there were a couple of ringers in there from Honeywell that didn't really belong. In fact, there was an interesting thing. You know, Crick, the crick of DNA. His son was working at-- with Wally Feurzeig at BBN when I came there so I got to know him. And just recently he apparently pointed at a picture-- I think that classic picture and he said, "That's me," in the picture and it wasn't. It wasn't. It turns out it wasn't he at all but there was a bit of a brew ha-ha recently in which he thought it was but it wasn't. I think in fact he thought the Honeywell guy was he. It wasn't but it got settled and, I think,he finally decided, yes, that's right. I never knew him to have anything to do with the ARPANET at all or the IMPs. He worked-- he was working in a part of the company that was overseen by somebody else, Paul Castleman. Didn't have anything to do with the ARPANET.

Damer: There's been some dispute over how important Frank-- Bob Kahn's contribution was?

Ornstein: You know, I probably shouldn't comment on that. There have been a number of people who felt they needed and have gotten, in my mind, more credit than they deserve. I've felt-- and I said so in the book — that I thought Frank's contribution has been under-rated. 25 years later when there was a celebration and BBN was pounding its chest hard about how heroic everyone had been and Frank, of course, was featured because he actually was in charge of the project. And he stood up and said how fortunate we had all been to ride the crest of the wave of this interest and concern, but it was not in anyway pounding his chest. He was just saying he was fortunate to have been on hand at the time. Not a word of bragging did he have and I don't do well with people who feel they need to brag about their achievements. I worked with-- fortunately with people who for the most part haven't had to do that and so it turns me off when people do. And I think that people, Lenny, Larry Roberts, Kahn, and even Vint Cerf to some extent have exploited and exaggerated their roles. In fact, I've had a brew ha-ha with Vint recently because I probably overstated my concern in his case.

Damer: I should have asked this somewhat differently. Taking that aside, what do you think Bob's real contribution was?

Ornstein: Bob Kahn? At the time I think what he wanted to do was going to put sand in the gears and we were just a steam engine rushing towards a schedule, a deadline. So at the time that felt like he was a problem. But actually I think that in the long-run that he was perhaps correct. After the project was over, I had connections with Bob for quite a while. You know, he just showed up at our place a couple of years-- or five years later. We were friends but I think he was more interested in the future of the network. I, at least, was just doing it as a job, as an engineering job and, as evidenced by my crack at the time, I didn't foresee what was going to happen. I think Bob was much more aware of what might become of the network. He foresaw better than I did and of course others foresaw, even more. I think that, given what's happened, it's been possible for people to look back and say, "Oh, well, I knew that was going to happen." But it was certainly not stated in the early documents. I mean the kind of thing that the ARPANET was spoken of as doing, was to let a lot of these PDP-10 systems share programs and data. None of this email. I mean that came-- you know, all of the things that the network has later proved useful for are the ones-- the things that have dominated were not-- were not mentioned at the time and I think it's easy to look back and say, "Oh, yeah, I knew that was going to happen," but I'm skeptical of some of that.

Damer: But you worked on SAGE as well as ARPANET. Could you talk a little bit about the difference between the kind of very special purpose networking if you would call it that SAGE versus the ARPANET.

Ornstein: Well, you could think of SAGE as a network but I don't think of it that way. I think of it as a bunch of isolated computers, which occasionally had to communicate about some event that was going to be passed along. I didn't follow SAGE in later years. Maybe it turned into something different but I rather doubt it. I think that the networking in SAGE was only very specialized. There were particular kinds of messages that went between the sites as an event or a thing had to get passed along but most of the SAGE system was dedicated to doing its work within its own purview. And so it's only when something crossed over into another area that communication was required between centers. But the program in all the direction centers was essentially the same. I mean they were parameterized for where the various radars were and so forth that they had to deal with, but the basic program was the same in all of them.

And that's totally different from either the ARPANET or the Internet where all the machines that are talking to one another are unique and different from one another and there needed to be some way to make them communicate. That's why Wes' suggestion of a separate little machine that would handle the network traffic was important.

Damer: How did that happen? What's the timing of Wes' suggestion to Larry Roberts and the taxi ride?

Ornstein: I was just talking to Taylor about this. I wish I had brought my notes because he knew which year and I can't do that without my notes from that. But roughly the notion of for the ARPANET was brewed within ARPA. ARPA, as Bob explained it, operated the information processing techniques office anyway, operated mostly by having people who wanted to do something write a proposal and then they would decide whether to fund it or not, which ones to fund and so forth. But most were proposals that were generated outside. The ARPANET was unique apparently in that it was a thing that was suggested from within ARPA itself, within the Information Processing Techniques Office (IPTO) itself. So it went in the other direction -- outward from IPTO.. The RFP went out asking for proposals for how to do this and then they would decide which proposal to fund. The way that developed was partly based on some of the work Larry Roberts had done at TX-2 on trying to understand how phone lines worked and could be used. There had been discussions within ARPA -- I don't know who instigated it. Probably Lick [Licklider] maybe, even early on. I don't know, but ARPA called together the principal investigators of all of the contractors that it had. The main programs that it funded and oversaw. They had a meeting once a year just to talk about what each one was doing so there would be cross fertilization and because it was a limited number of major subcontractors. Our project, for example, at--

Damer: Washington University.

Ornstein: Washington University was one of them, but there were many. And so there was a principal investigators meeting once every year and one apparently was held in Ann Harbor, Michigan where ARPA itself presented the notion of the ARPANET and they discussed how to structure such a thing. It was not at all well defined — they just wanted to tie these computers together somehow. Well, I mean, there are lots of ways you can do that and these bright people all had different ideas about how to do it. So there had been a lot of discussion at this Ann Harbor meeting. And after the meeting Taylor, Al Blue, Larry Roberts, Wes, and one other guy maybe, were driving to the airport in a rented car and they were talking about what had been discussed in the meeting and Wes made a suggestion how to do it. Bob tells me at one time they had talked about putting a central node in the middle of the country at SAC headquarters to control the network, and all of the traffic would flow through that one node. Well, that's a crazy idea. So that it had evolved to the point where the host computers in the various sites were going to all talk to one another directly and there was going to be a network, but because it was a network, messages going by a site weren't necessarily for that site. They were to be passed on somewhere else and that was a heavy load on the sites. The various sites did not like this idea at all because it was going to add to their work and they were mostly timesharing systems that were already overloaded and they didn't want somebody else from another site to come and take cycles away from them and they certainly didn't want to pass messages along that weren't for them.

Damer: It was a real-time computing job.

Ornstein: Yeah.

Damer: Or timesharing.

Ornstein: It was-- well, everything is in some sense is real-time. I was taught and learned that time-sharing was a pretty bad idea from the outset. In any case the sites didn't want to do this so Wes' suggestion simply offloaded all of the network traffic that was going by. The only process-- the only stuff that that site then would have to deal with was at least stuff that was directed to or from that site. The rest of the stuff that was going by was going to be offloaded onto these small computers. That turns out to have been a really good idea and the router that sits in my basement is this big and it's the size-- it was the size of a coffin back then but that was really what the IMPs were was just really routers.

Damer: So in a sense this is where Wes Clark took his passion for small interactive responsive computing and got it injected into the network?

Ornstein: Well, he believed in small computers. He had dealt in small computers. We haven't talked about the L-1, the ARC, and so forth, which were also small computers. Those were more specialized but, yeah, he believed in small computers and knew that the timesharing systems would have a struggle because not all the computers were identical in this case, unlike the SAGE system. These host computers, were all different from one another and they'd have to learn. They ended up actually anyway having to learn a good deal at the next level up. Not at the hardware level. At the hardware level at least there was some uniformity, but at the next level up where you had protocols built on top of protocols they really had to learn. They had to all come to an agreement about certain things and they really had to deal with one another.

Damer: The flexibility of the network not only because part of the network could go down and things would be routed around but when you came to build these mini-hosts inside the IMPs and you got the ability to have more remote console-type connections so they could get to a host but it was in an IMP and that was the flexibility of having the small computer to support more users.

Ornstein: Yeah. Yeah, Wes I think always thought that the terminal IMPs were maybe a bad idea because that was sort of like time-sharing again. Yeah, the terminal IMPs led to a very amusing incident that I should probably report here. It's in the book also. The terminal IMPs allowed people with terminals just relatively dumb terminals, to access the network through this mini host which was built into the IMP. But the terminal lines came to be viewed then, as part of the network, which had not been in the original deal at all, nonetheless were viewed that way by people. They, the guy sitting at the terminal who was trying to use somebody's computer somewhere through this terminal IMP, didn't care that this was not part of the network. He wanted the damn thing to just work. So we at BB&N became responsible for the maintenance of these lines from the terminal to the terminal IMP. And so since we had that kind of responsibility, we developed a means for testing these lines. And the testing of the lines was done just routinely by dialing up the terminals. One day the table of terminal phone numbers that were to be used, turned out to be, have a flaw in it. <laughs> And some guy's personal phone number was in the table. So when the computer dialed thinking that it was <laughs> testing a terminal line, it, of course, did the same thing you'd get with a fax machine. When the call is picked up, it says, "beep." One line seemed not to be

working and the guys listened in to see what was going on. And what they heard was the dialing and when the line answered they heard a voice on the other end say, “Hello?” And then they heard <laughs> the “beep,” and then they heard the guy at the other end say, “Oh, it’s you again, is it?” “Klunk.”

Damer: <laughs>

Ornstein: And so they realized that the computer had been repeatedly dialing some poor bugger’s private phone line, not a terminal.

<laughter>

Ornstein: Well, flaws of all sorts show up. Fortunately that one was only painful to that one guy. It didn’t down an airplane or something.

Damer: So after rollout and after the network was up and running, what was your work at BB&N?

Ornstein: Well, we, made a proposal. I think it was Frank's idea initially. You know, the 8000 series of microprocessors were just coming out at that time, and I remember Frank calling us together and saying, “Can’t we build a computer out of a bunch of these things? Can’t we make a really fast computer?” And, of course, IMPs were the thing that we had funding to do, so we would use that as the application for such a machine. And so we started looking at what other machines to use to make a multiprocessor, out of. And we ended up with a machine that was built by Lockheed. It was probably a mistake, but they had a thing called the SUE, the Lockheed SUE, which had a number of features that presumably made it particularly suitable, for this kind of use whereby you could connect a bunch of them together on a common bus. And so we decided to go for that, and we did build a multiprocessor. Carnegie Mellon was also building a multiprocessor. And they viewed that what we were doing was a specialized machine, because it was going to be dedicated to the job of being an IMP, albeit presumably a high speed one.

We also were again focused on reliability, and the fact that we had multiple computers not only made it possible potentially to have a higher bandwidth, but it also made it possible if one died that another one could pick up the slack so that it was more reliable with multiple machines. And so we explored that with what came to be called the Pluribus. I left BBN when that project was more or less iwas working. We had built machines that were working. I don’t know what happened to it eventually. There’s a problem connecting a bunch of machines to shared memories. And a lot more was done with that after I left, but we had it working in such a way that we had a British visitor one day who said, “Ah, you think this thing can’t be knocked down.” Because we said, “You can take out any single element. You can do any single thing to it, but just one at a time.” This was a multiple rack thing, a monster machine, actually. But it was a bunch of computers, I mean. Each rack had several machines in it, so it was-- and memories and so forth, and he went down to the bottom of the power supply for each of these racks and he went, switched this one, and then he went to the next rack and switched that one, on and off and on and off and on and off and on and off and went down the row. And, of course, the machine did pause and he said, “See, I told you.” And then about a minute later suddenly it was up and running again, because we had really focused hard on dealing with any single error. And it surprised hell out of him that it actually came back

up and was working. We were keen on reliability -- the machines were watching one another. Somebody said that should be called the Association of Computing Machines.

<laughter>

Ornstein: Because it was, it really was, a remarkable thing. And it worked quite well. It worked really well, so… But, you know, a lot of multiprocessors have followed that and become commonplace now, but that was one of the first ones.

Weber: Did Tony Michel overlap with you or…

Ornstein: Oh, absolutely. Became lifelong--

Weber: Because I've interviewed him. Talk a bit about it.

Ornstein: Oh, yeah. Tony was working at BB&N. I met him first when I was at, working over, in the PDP-10 group, the TENEX group.

Damer: Which was with Ray Tomlinson.

Ornstein: Pardon?

Damer: Wasn't Ray on that, Ray Tomlinson?

Ornstein: Yes, Ray Tomlinson. Yes. <laughs> Ray, I met Ray, at the meeting of the 25th anniversary or whatever it was.

Damer: Is he the man behind the "@"?

Ornstein: Yeah.

Damer: Yeah, yeah.

Ornstein: And he said, "It's a hell of a thing to be famous for," because he was a very bright guy. And here he had gone down in the history books as <laugh> having invented the @ sign. And so that was something important. I mean, you know, he just felt the irony was enormous.

Weber: Yeah. When we interviewed him he was hilarious.

Ornstein: But yes, I-- pardon?

Weber: Yeah, we interviewed him too. And it's clear that he's not completely keen on his role.

<laughter>

Ornstein: No. Of course, he would prefer-- he did remarkable stuff. He was a very, very bright guy. In fact, my wife's playing, a lot of Jotto these days, and there was a Jotto program on PDP-10 that I believe

he wrote that was stunning. It was absolutely stunning. You could not beat that thing. And, you know, I don't know whether you know about Jotto. It's a word game a little bit like a game called Master Mind, which you play with colored items. But Jotto is one in which you play with words, with real words. And you're supposed to, by matching, by making guesses, you match up and you eventually are able to figure out what the hidden word is. And in the version that Ray had written for the PDP-10, you were playing against the machine. It had a hidden word; you had a hidden word. And it could always guess your word a lot faster than you could guess its. Of course, it had enormous database. But it was a very clever program. It was a very clever. And it would provide you, with test words and then you tell it, "How many letters are matching your word and how many are in the right place?" and so forth. And it would ask questions that appeared to have no relevance whatsoever. "Why'd he ask that?" And then, "boom," your answer is… <laughs> And you could never understand how it--

Damer: Sounds like Eliza.

Ornstein: I could never understand how it worked. It would always just suddenly nail you to the wall. So yeah.

Damer: Sounds like the Eliza program almost.

Ornstein: Well, no. The Eliza program was something else. That was a bit of a fraud. Oh, that also had a BB&N story. The Eliza program was the program that pretended to be a psychiatrist and would ask you questions about, you know, well, that's well-known. Weizenbaum did that at MIT. He actually did it as a sort of, I think, as a-- he did not think he was doing something. He was making fun of such things actually when he did it. And the fact that people took it seriously, and some people said that, well, there was a story about somebody saying that they wanted other people to leave the room while they were having this discussion with Eliza because it was too personal and so forth. Well, one of the guys at BB&N, one of the the members of the IMP crew, Bernie Cossell was building a version of Eliza on a time-sharing system at BB&N, just for the heck of it. This is the story that is posted under the heading, "Machine Passes Touring Test." Because one day, what's his name? Newman, the architecture guy, came in and Bernie had been working on a terminal in his office and had left the program running for anybody who wanted to come in and try it out and test it. Bernie left a not saying, "Enter all your comments here, and end them with a period," or something. And so Newman came in looking for Bernie, and when he saw the sign on Bernie's machine, he simply typed in, "I need to use the computer tomorrow. Will that be okay?" "Why do you need to use the computer?" came back the question. Now, Newman thought he was talking to Bernie at home, but he was actually talking to the computer. Or no. He thought he was talking to Bobrow. Because I guess Bernie had been using Danny Bobrow's machine. Anyway, he was talking to the machine. He didn't realize it and typed in something about having some customers coming in <laughs> And the computer responded, "Tell me about your customers." And you can just imagine this, the thing. I've got the full dialogue at home. It is absolutely priceless. It is unbelievable. Poor Bob Newman --Bobrow appeared to be being insubordinate, you know and Newman was understandably furious. And he finally in fury types in "Call me right now." but forgets the period, so nothing happened. So finally he picked up the phone and got Danny Bobrow at home. Danny wakened from a sound sleep, and here's this guy screaming at him over the phone, "Why are you being so snotty to me." And what does Bobrow say? "What do you mean, why am I being so snotty to you?"

<laughter>

Ornstein: Absolutely perfect. So that got recorded, <laughs> to Bob, poor Bob Newman's shame, <laughs> as machine passes touring test. Because he didn't know he was talking to a machine. I told that to my class and they just loved it.

Weber: That's good.

Ornstein: I have the actual transcript of the conversation, which Danny still has, I'm sure. Yeah.

Weber: <laughs> That's excellent. And Tony Michel? You want to start…

Ornstein: Tony, back to Tony. Tony, became part of the IMP crew after having worked with the Tenex group. He worked with me later on on a multiline controller for the IMP. I don't remember him as actually being part of the crew initially though, so I don't know exactly at what point he came to work for Frank, but he lasted longer than any of the rest of us at BB&N. I think he's now given it up finally, but he was slow to give it up. He was working there a year ago, so he lasted there beyond anybody else. And we became friends. Tony bought a house in the deepest, darkest south end in a very, what was then, a very tough part of Boston. At one point, I decided to leave BB&N but then I changed my mind and didn't. When I decided to leave I had an offer both from Xerox PARC and also from Bob Barton, who was working down in La Jolla at the time with a group of really bright people. I didn't know which of these things I wanted to do. Barton was a character very much like Wes, equally bright. You know who Bob Barton was? He was the guy that designed the Burroughs machines. And he was running just a small little research group, a maverick group in La Jolla at the time.

Weber: Connected with anybody or was he completely independent?

Ornstein: Oh, yeah. He was working for Burroughs.

Weber: Okay.

Ornstein: He was working for Burroughs and he wanted me to work with his little group. And that looked more like the kind of group that the LINC group had been, a bit of a maverick bunch, a small number of people. I liked the people a lot. But I never could make up my mind between that and Xerox PARC, which looked also pretty interesting, of course. Frank had been beating on me to stay at BB&N. He tried pulling out all the stops but in those days good people were unmanageable (I was certainly unmanageable) and could do what they wanted. And so Frank had given up after a whole year of trying to persuade me to stick around. Laura and I took a trip up into the Magdalen Islands, which are up in the middle of nowhere, trying to figure out what to do. I finally figured out that I should just stay at BB&N. So I went back and I walked into Frank's office and told him, and he practically collapsed. <laughs> He was so surprised. But then after another year, the reason that I had wanted to leave, came back again. And so I-- but I--

Weber: And what was that?

Ornstein: The work there was getting more and more military. The Milnet was getting started and ARPANET was taken over. It was no longer under IPTO control. You know, it was taken over by the Defense Department, DARPA, it became, and…

Damer: And things were heating up on the West Coast and…

Ornstein: Yeah, yeah.

Damer: Yeah.

Ornstein: Yeah, right. A lot of my friends had, by then, migrated to PARC. PARC was a big draw and--

Damer: Bob Taylor.

Ornstein: Well, all the people that I knew were… Jerry Elkind, who had headed the PDP-10 group, was at PARC. And Danny Bobrow. I mean, there were a number of people who had come out there.

Weber: [George] Pake.

Ornstein: And Pake, of course, was there. So when we came back from China, we stopped at PARC. I looked around and I saw all these familiar faces and I thought, "What am I doing on the East Coast?" And so--

Weber: You went to China?

Ornstein: Yeah. That's another story. Barton had organized a series of meetings about computers and education, educational kits, he called it. I somehow got invited to a meeting in Aspen, and Wes was there and a whole bunch of fairly well-known people were there, Tolly Holt and so forth. And Ron Resch, and I don't remember who else was there, but it was Alan. Maybe Alan Kay wasn't at that one. He was at the next one. Anyway, in Aspen, I got to thinking that I wanted to go to China. I liked to travel, and I decided I wanted to go to China. And so I floated the idea at that Aspen meeting, and Barton was there. And I don't remember. Oh, Chuck Seitz was there from USC. Or from Caltech, I'm sorry. And a lot of the people that I knew. And so I said, "Why don't we organize a group and try to go to China?" And eventually, I did that. I finally got together a bunch of people, I knew and by then I had met some pretty well-known figures. For example, Al Perlis. Al had been a member of a visiting committee coming from NIH to evaluate the work that we were doing in St. Louis. And so I'd been in that meeting and I thought, "Well, if I can get Al Perlis interested in going to China, then other people will come along." So I called him up fearlessly and said, "Al, you probably don't remember me, but we were in a meeting together and I'm organizing a trip to go to China." And, "Who did you say you were?" <laughs> He said. And I repeated my story, and he said, "Who else is going?" Well, I'd made a list of people that I wanted to go with, so I read him my list. I hadn't talked to one of them. I just read the list, and he said, "Ah, it sounds like a blue ribbon group. Sure, I'd like to go." So I crossed his name off and then I called the next person on the list and I said, "Well, you know, Al Perlis is going." "Well, okay." So shortly I had about 15 people. It was a complete con job. I had about 15 people, as I recall, on the list. And it was just at the time when Nixon went to China, and there was a little guy who was a dwarf. This is starting to sound like a made-up

tale, but he was actually a dwarf. He was a China specialist. His name was in all the papers at the time, because he was connected somehow to the new, new interest in China. And he spoke Chinese. I didn't know he was a dwarf when I first contacted him. I just saw his name in the paper, looked him up in the phone book and called him. And he was very interested in the idea of a group of computer scientists going to China. We had no Embassy in the U.S. at the time, but he knew the people at the Embassy up in Ottawa. So Tom Cheatham at Harvard and I got together with this guy Dan Tretiac and we went up to a meeting, Dan had arranged in Ottawa. I had gotten resumes from all these 15 people, and they made an impressive stack. I mean, you could practically not lift it, because these were well-known people including Perlis and Herb Simon. Dan had arranged for a meeting up at the Embassy in Ottawa. So we went up there, took these resumes with us, and said we'd like to come to China. And we had sort of a plan of what we wanted to do. We wanted to go and talk to the Chinese computer people about computers. And we left all the resumes and I went home and I thought, "Well, that's the end of it." And months went by, we didn't hear anything. And then suddenly one day on my desk appears this letter from the Embassy saying, "We'd like to invite you and five of your colleagues and wives to come to China," and so forth. Holy shit. By this time, people had dispersed. Tolly Holt, who had been on the list, was in Israel. And they only wanted a half a dozen. I was going, because I'd thought of it. And so we went through a sort of a self-election process to narrow it down from the 15 down to 6. And then we accepted the invitation and told them who were coming. And, of course, at about that point the State Department got really interested and called us up and wanted to know what was up, because they had been trying to get other people to go to China, and the Chinese had turned them down because the academy, the National Academy, which was sort of a governmental branch, had relations with Taiwan and the Chinese, when they came to visit later, went all the way around the world to avoid flying over Taiwan. I mean, it's a symbolic thing. So they were not going to have anybody from the academy. Actually, Herb was a member of the academy, but that came later. And so they invited us to go. So we packed up and went and…

Damer: And that was in the middle of the Cultural Revolution. You were at a university, the professors were all--

Ornstein: It was post the worst of the Cultural Revolution.

Ornstein: But yeah, it was very, very close. And, of course, we went as Americans with sort of American attitudes and me in particular with no respect for anything. And so the Chinese, I found that the Chinese managed to find a way to shy away from any sort of political talk. We were treated really like VIPs. I mean, we each had a car and an interpreter and so forth and we'd go blasting through some town with the horns blaring and six cars in a row and, you know, I thought, "This is terrible." And, you know, running over chickens and maybe people and flushing them out of the way. It was bad news. But they thought they were treating us royally, and they certainly fed us well. Anyway, it was a big adventure, and it worked out very well. And we had a good time. But that--

Weber: So you'd just come back from--

Ornstein: Pardon?

Weber: Oh, sorry. I think you had just-- I interrupted you. You had just come back from China.

Ornstein: Ah, yes. I was still at BB&N at that time, but we stopped at PARC. And as I say, I looked around and I saw a bunch of familiar faces and I thought, "This is where we should be." I think I'm the only person who had to give two interview talks, because I had already given a previous talk at PARC and they had offered to hire me and then I said, "No, I'm not coming." So I'd gone back to BB&N. So now I'm applying again. So they said, "Okay. You got to give another talk." So I'm practically the only one, as far as I know, that had to give two talks at PARC to get hired, but they didn't then, did they? <laughs> Don't turn us down again. <laughs>

Damer: You arrived and fell in love with your Alto?

Ornstein: Oh, yeah. Indeed. Of course. That was… Well, the Alto, in my way of thinking, there are two really significant break points in the development of the personal computer. One was the LINC and the other was the Alto. And the Alto took, did just exactly, what Wes would've anticipated. It got smaller and faster and better in every way. But also the user interface changed dramatically. Chuck made a decision, which was a bit of a daring decision, Chuck Thacker, who really was responsible, made a decision to commit a big chunk of the main memory to the display. And that just cracked open the user interface that we know today. And it had been impossible to do that before because of the cost of memory. The kind of thing that LINC had for display was a little CRT this big around. You could do a lot on it but you couldn't do a lot of stuff like you could do on a TV screen.

Damer: As you point out in the book, because of PRAMs the console went away.

Ornstein: Yeah.

Damer: Yeah. And so suddenly you had this clean machine that the whole interface was just--

Ornstein: Yeah. Nothing but the screen, yeah. All the bootstrap stuff that you'd had before disappeared. So I think of the LINC and the Alto as the two main stepping stones to the-- each contributing something very important, but the LINC was certainly first. And sort of philosophically pointed the way. And, of course, the stuff that Doug did then also was…

Damer: As we heard in 2007 from Alan Kay, who, course, worked on Dynabook, interim Dynabook, was Alto.

Ornstein: Yeah.

Damer: Describing to us that the LINC was the first--

Ornstein: Thing that he--

Damer: --machine that you could have the experience of personal computing.

Ornstein: Yeah, yeah. Alan understood the importance of the LINC and has been a booster for Wes for a long time, because he's understood that. I don't know why Wes has not been better recognized in the world. I mean, considering the importance and the enormously-- I mean, it was such a heretical thing to do at the time that he did it. It was… But he's not a self-booster. He's absolutely the epitome of a very quiet retiring person. And that may be partly responsible. Maybe you've got to boost yourself better. I--

Damer: Perhaps in the recording of this history, right sizing it, really saying right here, who else but Wes Clark is really the father of personal interactive--

Ornstein: Yeah, well, I think--

Damer: --the experience of personal interactive computing.

Ornstein: Well, he was the first. Of course, now, a lot of people have seen it, but he was the first. And at a time when it was very much not de rigueur. It was a--

Damer: And others had this idea that they would do hand waving, but Wes Clark actually built the machine.

Ornstein: Yeah, actually built the thing. Yeah. I think he had been, he's a figure, who has been far too little recognized. I feel as though I've been playing Huxley to his Darwin, if you know that story. I feel very much as though I have, and others, have had to do the sort of boosting of his name because he's very retiring. He's not the kind of guy who stands up and promotes his own thing. But as far as the work he, the sort of the philosophy, of how computers should and could be used, he just saw the future much more clearly than anybody around him. And so that was, that's really important.

Damer: Even before Thacker's memo where he's argued the case that the price per bit or the price per pixel was going to drop--

Ornstein: Yeah.

Damer: --here you have Wes 10, 12 years before, saying computing will become low cost.

Ornstein: Yeah, yeah.

Damer: And…

Ornstein: Yeah. Well, Thacker gets, in my book, Thacker gets high marks for understanding that and having the wit to then put his money where his mouth was in the Alto and later machines. That was the next big, big thing. Those two things are the two major steps as far as I can see. And that weren't obvious, at all obvious. I mean, Chuck's contribution was not obvious at all. It was an act of daring just as the LINC was. So, you know, that's what makes it…

Weber: Well, they were building, I mean, at SRI, they were also building interactive systems fairly early.

Ornstein: Yeah, yeah. Doug. But Doug was doing it, of course, on a time-sharing system, on a 940.

Weber: Sure. But the interactive personal part.

Ornstein: But the interactive thing, yes. Doug gets enormous credit-- and he, of course, also, I mean, in terms of output, Chuck did the display part and Doug was the one who--

Weber: Doug and Bill English.

Ornstein: --saw that he had to have some means of dealing with a screen like that.

Damer: Bill English and--

Ornstein: Yeah. Well, Bill, of course--

Damer: --<inaudible>.

Ornstein: --built, I guess, the first mouse

Weber: Yeah. And was there much, I mean, how well did Wes know--

Ornstein: Doug?

Weber: --Doug and that group?

Ornstein: Pardon?

Weber: Was there any real interaction between the NLS group and Wes?

Ornstein: I don't think so. Wes knew Doug and had enormous respect for. They were very fond of one another, I think, and… But I don't think that Wes had any impact on what Doug did in NLS and--

Weber: Or vice versa, that you're aware of.

Ornstein: I knew Doug first through the internet connection that we sought. Somebody, <laughs> I think it was my wife who told me, that somebody described dealing with Doug, who was certainly a visionary. Said that when he was with Doug, it was as though he held a-- and Doug was explaining something. It was as though he held a hard, round egg in his hand and he could understand exactly what Doug was saying. And that when he left the room after he'd gone away it was as though the shell had gone and the egg was just <laughs> falling through his head.

<laughter>

Ornstein: I know how that feels. When I first arrived at PARC, they gave me a job to do so that I would sort of learn the systems and get into the thing. And that was to, there had been, an interface between an Alto and a printer.

Damer: And that was--

Ornstein: And the thing was called--

Damer: That was EARS.

Ornstein: EARS, which is--

Damer: EARS, yeah.

Ornstein: --Ethernet Alto… R. I forget what the R was.

Damer: Rotating thing.

Ornstein: Yeah, maybe that was what it was. Anyway, Gary Starkweather had built the first laser-driven printer there at PARC. And the guys had already built this roomful of equipment, which was EARS, to allow people to print via the Ethernet When I arrived there already, you could send documents into the Ethernet, to the printer via the EARS hardware But EARS was a roomful of equipment and it was realized that that could be much simplified. And that was what they gave to me to do to build a much smaller interface to the printer that would just fit right into an Alto actually.

Damer: And that was for Dover?

Ornstein: Yes. That was what made Dover. And Bob Sproull, another figure-- is he a Fellow here? He should be. For God's sake. I don't--

Weber: I don't think he is.

Ornstein: I just look at the pictures and I--

Weber: Yeah. He's certainly someone that should--

Damer: I think he has been.

Ornstein: I don't think he is.

Weber: Nominate him if he's not.

Ornstein: But Sproull is one of the brightest people I've ever come across.

Weber: Yeah. He's certainly well-known.

Ornstein: And he was leaving to go teach a course in India, and he did a core dump to me in my new office at PARC, and was describing stuff that I didn't, I didn't know anything. And he was filling the board with little sketches and drawings and I was only half following, and I thought, "Okay. Well, he'll go away and I will then be able to study this over and I'll figure it all out and I'll understand what it is I'm supposed to do and how it's supposed to work." And I came in the next day and I found the guy who was the buildings person. I had asked him to move the whiteboard over because I had a slightly different layout

for the office. And the guy was just maneuvering the whiteboard and he had a great big belly and his suit was rubbing on the <laughs> whiteboard. And he'd erased half of it. So for the next week I stared at the whiteboard and tried to figure out and remember what had been written there. It was totally, it was a total mess. I finally figured it out. But that was unnerving. <laughs>

Damer: So that was Dover, which became…

Ornstein: The Dover became, yeah, the first real--

Damer: And where my career came in as I worked on software for the Xerox 9700, which was the commercial application of Dover.

Ornstein: Yeah.

Damer: And one of the things I did as a connection to PARC, because I did presentations at PARC. Not a dealer, but I did presentations at PARC, was I wrote a converter to take all the Alto fonts that were driving Dover, out of that format so they could be driving the 9700 and it was kind of the end of the line for the Alto.

Ornstein: Uh-huh. Uh-huh, yes.

Damer: And that whole thing that you helped enable.

Ornstein: Right. Right. You know, the TX-2 actually had xerographic printer.

Damer: Printer.

Ornstein: It was the first such thing, I think, connected to a computer. But it was very different. It used a--

Damer: Looked like a drum.

Ornstein: Yeah. But it had a… To make the characters, it had a little device that had-- the beam was focused through a thing that had silhouettes of the characters. So it was splaying the characters onto the drum. But yeah, that was the standard, that was the printer on TX-2.

Damer: Yeah.

Ornstein: And it was the only one. And then, in fact, John Frankovich, whom I recommended to you, who was sort of my mentor in the first, at first, in the group when I was doing the FX-1 simulation, and the first night that I was going to be left alone <laughs> with TX-2, and I was going to-- you had to use a printer. It was the only way you could see your program then. I remember his <laughs> turning to one of the other guys and saying, “Is that fire extinguisher still in there?” “Okay.” Because the xerographic printer was, would, overheat sometimes. It was program control of everything and if you didn’t run the paper through, if you had a program bug so that didn’t run the paper through at a reasonable time, the

damn thing would catch fire. So it was-- or it was a fire hazard. So there actually was a fire extinguisher right underneath <laughs> the thing too, in case.

Damer: At PARC, after Dover, then was it Bob's idea for Dorado to create a new powerful workstation?

Ornstein: Well, no. No. I think everybody understood that you could do better than the Alto by then, because better integrated circuits came along. And I suspect it was some combination of Chuck and Butler that… Taylor certainly pushed it and persuaded the guys, the hardware guys, including me, to actually go ahead and work on it. And we all resisted pretty hard, and when I finally agreed to work on it, then they wanted me to sort of manage the thing, which I guess I did. I only did that in agreement-- I only agreed to do it in conjunction with Ed McCreight, because I knew Ed was very smart and he would be very helpful. And I demanded also that we would-- they really had, we had resisted hard, so they needed to persuade us. And so I said, "Okay. Well, it's going to take this guy and that guy and that guy." We ate up a whole bunch of people. We had a really large group of people working on it, and it was necessary. And I furthermore said it was going to take two years to do it. And Butler took me aside at one point and said, "Don't tell people that. You're right, but don't say that. They'll never have the courage to embark if they think it's going to take that long." But, it did and...

Damer: So, it was like in a sense a book end because the preparing of the LINC for the kits and the people training was a massively strenuous process and here you find yourself with Dorado which was a really major challenge in the timeframe.

Ornstein: Yes, it was and Butler-- but Butler and Chuck had largely designed the machine. They'd understood quite a lot about it. They had a lot of the architecture already laid out. So, it was really more a matter of implementing. There was some...

Damer: The idea of three 10s was like 10 megabit connection, 10 megabyte hard drive and 10 mps processing. That was the general idea of the spaciousness of it.

Ornstein: If you say so. I don't frankly remember it well enough now.

Damer: But, how were they. You said they had to persuade you. What was the goal they were trying to get you interested?

Ornstein: Oh, I think it was the people who were running LISP just simply were running aground with nothing but the Alto . It just didn't have the horse power to do what they needed to do.

Damer: They tried to use the dolphin, I think, for it.

Ornstein: Well, the dolphin came along at about the same time as the Dorado.

Damer: Oh, okay.

Ornstein: Yeah, but the Dorado was viewed as the machine that would run LISP at a reasonable speed. And, what can I say, we all worked very hard on it and about half-way through at the end of a year I took

the whole gang up to Yosemite for a long weekend of carousing and relaxing after because it was a really brutal effort. And, Ken Peter...

Damer: Ken Pier.

Ornstein: Yeah, you knew Ken.

Damer: I know Ken.

Ornstein: He died recently unfortunately, but he after we made the machine, it's sort of a measure of the kind of thing that can happen to people working so hard, so intensively for such an extended period. After we got the first machine, finally, up and going, he basically collapsed. He went into decline because it had been so much of a struggle that he believed that we would never be able to reproduce the machine. It was supposed to be a machine that everybody in the lab would have one. You know, through the lab and he thought we'd never be able to produce it in quantity. We made this one work, but that was such an effort that he thought-- he went into decline. He had almost a nervous breakdown and I ended up being sort of his therapist for awhile and as it became apparent that, in fact, it was going to be okay. It was going to work. But, he had worked just unbelievably hard on it and thrown himself into the work on the machine and it was just mostly a matter of exhaustion, a long drawn out exhaustion.

Damer: As you pointed out, it was noisy enough and hot enough that it actually had to be rack-mounted and you had to have basically your terminal...

Ornstein: Yes, it...

Damer: ...and certainly for music composition it wouldn't have been good to have the Dorado in the room.

Ornstein: No, it was hopeless. Now, it had been thought initially that the Dorados would be in your office, but it just wasn't going to happen. It turned out too big and too hot and too noisy. And, so it actually ended up back in the machine room. Jim Morris, who was one of the researchers at PARC, said that he learned that-- what did he make a crack about, living in the machine room. When the computer moved into his office, he realized that he was now living in the machine room, which had previously been off somewhere else. But, with the Dorados it returned to that, the Doroado terminals were in the offices and the Dorados themselves ended up down in an air conditioned room down in the basement. But, just a stack of them basically, very noisy.

Damer: But, when you came what was your first project at PARC?

Ornstein: At PARC?

Damer: Yeah.

Ornstein: Yeah, that was what got to be called the Orbit. That was basically the board that turned an Alto into a printer controller.

Damer: Right.

Ornstein: Yeah, that was the first thing I did there.

Damer: And, then straight to the Dorado.

Ornstein: Yes, I think there was some other things that I was pushing. I was trying to push more on the development of the Ethernet and use of machines across the Ethernet. That happened, but I didn't have anything to do with it because I did get drawn into the Dorado project. And, then, after the Dorado was finished Taylor-- I had wanted to do the music thing and the music thing being I wanted to pursue the idea of something that would allow you to put up a score on the screen.

Damer: Back to your original attempt at Lincoln.

Ornstein: Yeah, I had, in fact, it had been a long-term interest and, in fact, at one point I decided that you needed to sense under the keys of the piano, that listening to the sound you were never going to be able to analyze the sound to figure out which notes had been hit. So, I started figuring that maybe you would...

Damer: With gauges you could...

Ornstein: ...feel the actual pushing down of the keys on the piano, measure that. Eventually, I did find a graduate student from MIT that we had a program at PARC that welcomed in a small number of graduate students from MIT to apprentice for learning and they would then get to use the work there as helping to satisfy the Master's degree typically. And, one year we hired a guy who said he was interested in music and I thought ah-ha I know what to do with that, and so...

Damer: John.

Ornstein: ...John Maxwell.

Damer: Maxwell, yeah.

Ornstein: He turned out to be an extremely bright guy, a little eccentric, deeply religious, which I am not, but he did a masterful job with the program that he dubbed Mockingbird. That was really the first...

Damer: That was like over just the summer of 1980 right, because you had, and it was the first program that really showed off the Dorado.

Ornstein: Yes, it was, it was. And, they loved it. Well, you've got on your site, you've got the video of the demo...

Damer: Yeah, we digitized.

Ornstein: ...that we did.

Damer: Yeah, it was the major demo and I know it was a dealer and a demo.

Ornstein: No, PARC had funds. The dealers were just within the computer science lab.

Damer: That's before all the rough questioning.

Ornstein: Yes, absolutely, brutal, very brutal. I mean I was in a meeting in which-- a lot of different meetings, but there was a big no smoking sign at one meeting and one of the people would come in and give talks there and it was known to be an obstacle course. I mean whatever it is where you hit people over the...

Damer: Oh yeah.

Ornstein: And, the guy looked up at the sign and said, "What'll happen to me if I smoke in here?" And...

Damer: No, he said, "Will I get stoned if I smoke in here?"

Ornstein: Well, yes someone said, "It depends on what you're smoking." But, another guy who was clearly floundering in giving his talk, I think it was Thacker that suddenly in the middle of it, he made some sort of claim and Thacker just shouted, "Bullshit!" And, the guy was as though he'd been struck and it was, I mean he was right, Thacker was right of course because he was floundering, but it was not a place not to know what you were doing to stand up in front of.

Damer: Well, with the beanbag chairs and the bicycles in the hallways, it looked relaxing, but...

Ornstein: Yeah, it looked relaxing, but it was anything but. And, that's where the new people who were coming that you had to give a talk that's where you gave the talk, but the larger forum across all of PARC and there were other labs besides the computer science lab. There were a number of labs, and that's where we did the Mockingbird demonstration. And, yes it was probably the first really good public demonstration of the Dorado because it had everything. It was a sexy, what can you say, it was a sexy demo and people loved it.

Damer: And, that was of the music.

Ornstein: Yeah, that was the music program.

Damer: That was a beautiful demo with the keyboard and...

Ornstein: Yeah, it was absolute raw, naked fun. It was just absolutely delightful, delightful.

Damer: At one point on the screen, you show, because this is real staff notation on the screen. It's not like the earlier alto experiments where it was just dashes.

Ornstein: No, it was a full score on the screen.

Damer: Full score on the screen. You showed a score where all the letters sort of crashed down, were all clung together.

Ornstein: Oh yeah, yeah. Well, I stole that. There was a guy by the name of Peter something. Yeah, okay well he had a book that he put out and he had some hilarious drawings.

Damer: Peter Schickele.

Ornstein: Peter Schickele, yeah. And, he had a book in which he had a bunch of hysterical drawings of music scores that had been-- and I used those and I just copied them and used those in the opening slides of the thing and everybody was in hysterics before we even got to the substance of the talk. So, it was a fun talk to give.

Damer: So, to Mockingbird, you describe it as a composer's amanuensis.

Ornstein: Yes, I learned the word amanuensis, which is an important word you know, it's a scribe, somebody that takes down your ideas. Yeah, well yes that was groundbreaking at the time. When I knew we were going to do it, I had gone around to a bunch of famous composers, classical composers and I had an entrée because of my father who knew a lot of them and so I went around and I remember Lenny Bernstein [ph?] whom I managed to talk to, interview in New York, and I don't think he understood what was happening. You know, the computers had not gotten of the alto type had not gotten out into the world, nobody had seen a mouse so we had one. When we did the demo, we had to explain what a mouse was doing. See that thing on the screen, you notice it's following this. I mean, you know, people had never encountered those things before, a computer with a screen. So, I don't think that any of the people that I talked to, and I talked to Aaron Copland and Samuel Barber, people who were well-known, and I don't think they understood what I was trying to get at, you know trying to understand how they wrote music, how does it happen, what do you do. it was interesting. The most interesting I thought was Samuel Barber, who I don't know if you know, but he's a well-known American composer, he said, "I just keep a notepad by my bed and if I wake up in the night thinking of something I just scratch a note and you can sketch enough down so that you can..." but they all worked differently. The interesting thing with it-- what I wanted to do was to capture playing on an instrument and then find a way to turn that into a score. And, then we succeeded in doing that, but when I asked them individually, "Do you actually try things out on the piano?" and they said, "Well, I do, but nobody else does." I knew what to make of that. I am a good pianist so I do, because it was sort of thought to be frowned on because your hands maybe were going to be writing the music rather than you, and so it was a notion that you would be improvising and that that would not be somehow as legitimate as somebody who would just write away from the piano. I was used to both things in watching my father writing, but he did use the piano. He was a fine pianist and so I thought why not use that as in input tool, and we did and that was long before midi, midi didn't exist at that time. So, we basically had to design the equivalent of MIDI to be able to use it and we doctored up a synthesizer to use for that.

Damer: So, then came the time, fortuitous retirement from PARC.

Ornstein: Yeah, yes. Yeah, PARC didn't mean for me to go, but it was fortuitous because, in fact, I had decided to retire myself and Taylor said, "What're you going to do?"

Damer: This was at 51 years old.

Ornstein: Pardon?

Damer: You were at 51.

Ornstein: No, I was 54.

Damer: Four, mm-hmm.

Ornstein: Yeah.

Damer: So, this was `84?

Ornstein: Pardon?

Damer: You were born in `30.

Ornstein: Thirty, yeah.

Damer: So, `84.

Ornstein: Yeah.

Damer: When did you join PARC?

Ornstein: Seventy-six, `76. Well, I don't remember exactly how it was because I negotiated with them. I stayed on an extra year beyond what I had originally thought to quit. They offered me a golden handcuff deal. Well, not a gold handcuff, they offered me a deal that I couldn't turn down hardly, and so I accepted it and then they decided that it wasn't for real, that it was a mistake on their part and they tried to renege. So, we negotiated. I mean I stayed on an extra year and then left. So, I don't remember whether it was `83 or `84, it was somewhere in there. I'd have to look back to get the exact date. But, anyway it's many years ago now and I have never earned a penny since. Nobody has ever paid me to do any work since then.

Damer: So, you and Laura could go helicopter skiing.

Ornstein: Yeah, we've had a marvelous 30 some years now living out in the wilderness.

Damer: Had you already moved into the Santa Cruz Mountains when you joined PARC or after?

Ornstein: No, no, we built that place after we retired from PARC.

Damer: So, you lived where in Palo Alto?

Ornstein: No, we had been living in Portola Valley and we sold the house in Portola Valley, and for a while then we rented a place up on the ridge. We had intended to go live in Europe, but we had started a Computer Professionals for Social Responsibility and we couldn't let go of it because there was nobody

else to run it, to really keep it going and so we ended up not being able to really leave and at one point Laura said we own a lot of paper right, no roof, but a lot of paper. And, so that's when we started looking for a house and we couldn't find one we liked so we decided to build one.

Damer: You had met her around the time you went to China?

Ornstein: About the time, 1972 when we went to China. Yeah, in fact, we met on the platform in Hong Kong after our group came out from China and been together ever since.

Damer: So, by chance.

Ornstein: Well, no, no we had met at the second workshop about educational kits. The first one was in Aspen, the next one was in Saratoga, and we had met there. This was just months before we went to China as it turned out. So, we hardly knew one another when we got together in Hong Kong, but turned out that was the right thing to do.

Damer: And, she ended up working at PARC.

Ornstein: Yes, she ended up working at BBN too. She came to the East Coast while I was still at BB&N at that time and she came to the East Coast and worked at BB&N, and then when we moved-- so we always worked together at the same place in sister labs. At BB&N there were two different labs, too. She was working with the language people and I was working with the ARPANET gang. And, then when we moved to California, she went to work in Alan Kay's group and I went to work with what became Bob Taylor's group.

Damer: Because she was in education, computing and education?

Ornstein: Yes, yes.

Damer: And, another through line your misgivings about the military came in constantly sort of out of the way as the military work came in at the various organizations, and then came CPSR [Computer Professionals for Social Responsibility].

Ornstein: Yes.

Damer: Talk about how that started.

Ornstein: Well, yeah you know...

Damer: The election of Reagan and Alexander Haig.

Ornstein: Well, I had noticed even before, you know I knew Jerry Letvin in Boston, who was a very sort of leftist kind of person, and I knew Terry Winograd back then too, also. And, I had been strongly against the Vietnam War. I thought that was just a catastrophic mistake, so I had a long history of concern about military things, and even back from during the Cold War, during the days at Lincoln Lab I was also very-- I was very happy to leave there and go to work on medical things, so I had a long history. But, I noticed

that most of my colleagues there was never a political discussion, not at work. You never talked to your colleagues about that. And, when I got to PARC and at the time that Reagan got elected and it was time where there was a lot of saber rattling going on on both sides with the Russians and it really became quite a scary time for me, and I finally realized that I finally figured that I was going to speak out about it, and I did, and I sent a message. At that time, there was no network outside, but there was within PARC, there was a network and you could send messages. There was a message system and I sent a message around within PARC, pretty broadly circulated saying that, "I don't know about you, but I'm worried about this, and what do you guys think about this?" I was worried about the threat of nuclear war because it looked for a while as though the idiots in Washington could cause a lot of us a lot of grief. And, that took some nerve because it was into an environment where such discussions just didn't happen, and almost immediately I got positive response and negative response. A lot of people said, "This has no business, you have no business talking about such things at work." It's not that, you know or I believe that you have to be strong so, all sorts of political opinions...

Damer: Such, through strength.

Ornstein: ...suddenly got voiced and a group of us who felt similarly started talking together and eventually out of that grew CPSR, yeah.

Damer: And, how much did you look to physicians for such...

Ornstein: Quite a lot, quite a lot, and that may've been a mistake because we organized ourselves. We used their structure. We thought of their structure, but it didn't-- doctors are more ubiquitous. They're more widely scattered. The computer people were sort of focused in here and in Boston and then a couple of other places maybe, but they were so localized that the idea of a national organization, I mean who in Montana was going to-- what computer outfits do you know of in Montana or Idaho or pick your favorite place. It's pretty concentrated.

Damer: Because it's most of research, not just someone running a computer center.

Ornstein: Yeah, no, no that's right. We were talking about computer professionals that would be. Well, it served its purpose I think for a while and, of course, then when the Wall came down in Germany, the Berlin Wall came down, it didn't go away, but the immediacy of the threat seemed to disappear so I think that was really what undid. And, then people got all sorts of-- diverse interests got picked up. Actually, the guy we eventually hired as the Executive Director, Gary Chapman, he died in a kayaking accident a couple of years ago, very tragic, but he really wanted to try-- he had the right idea. He really wanted to try to shift. You know, the funding of computer research that the government did throughout the years of the `60s and `70s where if it hadn't poured money into it, the field would've developed much more slowly. It put a lot of money into a bunch of universities. It was through the Defense Department and Gary said, correctly as far as I was concerned, "It should come through the National Science Foundation, why does it have to..." Well, the answer is it had to be through the military because that's where the money was and that's where you could persuade Congress to put money. For a general thing that the average senator or representative, what would he know about the possibility of using computers. But, if you said you could bomb them better than that would get their attention. So, ARPA was the place where the funding was, but

Gary was intent on trying to move that over into something like the National Science Foundation; that it should not be through the military. And, Gary was an ex-Green Beret. I mean he was right in the thick of the Vietnam War.

Damer: NSF is not as much funding, but they certainly would put a lot into higher education networking in the `80s.

Ornstein: Yeah.

Damer: And, that's what built up the...

Ornstein: Yeah, right, but at that time, he saw that most of the funding was going through , and yeah NSF did some.

Damer: Ironically, a friend of mine, Joel Schatz, went to Moscow in 1985, set up the first email system utilizing all the technology from the ARPANET and a man named George Soros , showed up one day to use it to send an email to his wife because you couldn't get a phone connection out of the USSR and that led to the Global Telesystems Group, the first international phone company, which started the opening of the Soviet Union, and then on that basis they did the Citizen Space Bridges where they did live television between Americans and Soviet citizens, which helped in that whole thought. And, when I lived in Prague, in 1991, I sent an email to the Soviet Union, so the internet was creeping into the Soviet Union and helping to connect it to the world and reduce the danger of nuclear war.

Ornstein: Yeah, I guess so.

Damer: Yeah, it really helped.

Ornstein: ...going on right now is a little scary.

Weber: And, two things I forgot to ask earlier or missed the chance. Talking about the early pioneers of interactive computing, Plato was also quite early and interactive. I'm sorry the Plato Educational System.

Ornstein: Yeah, I don't know much about that. I probably did at the time.

Weber: But, that was my question. Did you have anything to do... those guys were on the Iliad [ph?].

Ornstein: No, probably Laura did, was more likely to have something to do with that. That was not, no.

Weber: There wasn't much cross-fertilization.

Ornstein: Not with me anyway, but I mean ARPA, Lincoln ARPA, not particularly.

Weber: Because I know Alan Kay, I believe was...

Ornstein: Yeah, Allen would know a lot more about that.

Weber: And, at BBN during the Nth [ph?] creation, what I didn't ask you... so after delivering the Nth then it was a few months until they started at the NOC as the Network Operations Center.

Ornstein: Yes.

Weber: Just talk a little bit about the beginning of...

Ornstein: Well, I think...

Weber: ...for system administration.

Ornstein: Well, I think it was fairly early realized. I mean we were intent on just making the IMPs, you know, and we had not really given a lot of consideration to what was going to happen more broadly when there were a bunch of them out there. We knew at the lowest level how they would communicate, but that there needed to be an operation center. That understanding grew as the network grew, and the need for all sorts of things that the Network Information Center and the NIC was also something that developed only really as it was needed. The control center at BB&N grew because somebody needed to do that at first because the thing was flaky and it needed to be propped back up. There was a wonderful scene, Ben Barker [ph?], who had become a central guy in the design of stuff, he was the guy that found the glitch in the IMPS in the first place, spotted it or suggested that it was a glitch. But, he had intentional tremors.

Weber: Tremors.

Ornstein: Yeah, even at a very young age, he had that, and so one day we were in the Network Control Center at BB&N and we needed-- there was I don't remember why, we needed to put a jumper on a pair of pins on the back panel of an IMP and the network was running. It was running at that point and the machine that we needed to-- I don't remember why, all I remember is that we needed to put a jumper on and I said, "I'll do it, let me get away guys, I'll do it," and I got down, it was near the bottom of the machine and I got down near the floor and looked at this thing and went like that and missed and brought the whole network down. And, well it wasn't much of a network then, it was probably half a dozen machines at most, but it was a big deal and the operators kicked us out of the way and brought it all back up again. And, we realized that we hadn't taken advantage of while it was down to put the jumper on. So, now we still had the same problem. So, Ben stepped in, and Ben said, "Let me do it," and I looked at his hand going like this and I thought this is a catastrophe, how absurd. But, I had failed so it was Ben's turn and I'd never seen anything like it. He got down there, eyed the thing, his hand was shaking like this, and then suddenly it went shoop. It stopped shaking for just that long and then resumed and he did it. So, there was some way in which he was able to control that enormous tremor. I mean he had a really bad tremor. It just managed for that instant to get it right on.

Damer: What did the Operations Center look like that was just in the...

Ornstein: Oh, what did the Operations Center look like? It just looked like any other machine room. I've got lots of pictures of it. It just had computers scattered around, all of them coffin sized machines, nothing very special.

Damer: The interesting case of Dr. John Lilly.

Ornstein: Oh, he's perhaps best forgotten. He slipped through in deciding who-- I mean there was a lot of competition when the word went out that there were going to be these computers handed out by...

Damer: This is the LINC project.

Ornstein: ...yeah when they were going to be handed out by NIH and a lot of people applied to have a computer in their lab and Lilly was one of them. And, he was, as far as I'm concerned, a nut job. I mean he was just crazy. He arrived, alright I began to suspect it when he arrived there and he had with him a tape recording from his dolphins and he had been listening, but he had never been able to see the sounds and he had a tape recording of the sounds of dolphins communicating. And, he arrived with this tape recorder and he wanted to plug it into the machine, but, of course, the particular plug he had on the thing there was no way to plug it into the LINC and he just simply took his tape recorder and went, tore the cable in half, and put another connector on the end of the thing, but the way in which he just blithely sort of tore the wire in half with his bare hands and then put another connector on it so that he could put it into the machine. He was so frantic about the whole thing, I thought this guy's crazy. And, indeed that was probably a mistake. He was...

Damer: Wes described to me how they went to visit where the dolphin tanks were in the LINC and they realized that the LINC was in danger of getting wet and getting shorted out and to move it, et cetera, et cetera. And, eventually his LINC got pulled somehow.

Ornstein: Yes, I don't know what happened, but that was a mistake. I mean in this program of trying to figure out who-- all the other people were quite legitimate, and in fact some of them, Joe Hind, for example, a guy, a researcher at Wisconsin, became so involved in the computer aspects he basically became in charge of the-- the computer took over his life and he became sort of the manager of using it through the medical school there, and I think his medical work suffered.

Damer: And then the LINC used in an actual live operating theater...

Ornstein: Oh, yeah.

Damer: ...brain surgery and you pointed out in the book that things like the PET scanners sort of are direct lineage of...

Ornstein: Oh, I think the PET scanner was Jerry Cox at Washington University developed that I think. It was an offshoot certainly of the LINC, yes. Yeah, a computer you can't go into a medical laboratory or a clinic anywhere, there're computers in everything, but there weren't in those days. There were none. Are we done?

Damer: I think the only other thing that I was hoping to get in the record is the recognition of not only your work, but the LINC teams work and the LINC itself that we met six, seven, eight years ago and did the restoration project...

Ornstein: Right.

Damer: ...and if you could just describe how that...

Ornstein: Sure, I went to the DigiBarn one day, I think Shannon McElyea, or someone suggested that I should know about it, and so we went one day and you were showing all the stuff. You had everybody there and you were all gathered around in a circle afterwards and I finally spoke up and said, "You ever hear of the LINC?," and you said, "I think I read something about it in a book somewhere at one time," but you didn't know much about it and I said, "Why don't you come over to our place next week and we'll have a little talk," and so you did. And, you were surprised to find out about the LINC, and I don't remember exactly how it then grew from that into the...

Damer: You got in touch with Scott Robinson.

Ornstein: Yes, well yes I guess it was probably I who realized that this little fellow who had been hired by Jerry as a technician, he was a cripple and he had not been able to work prior to Jerry's hiring him. He'd spent his life in the hospital basically and Jerry hired him as a technician, and he worked on the LINC. And, when the time came for the LINC to be obsolete because new machines came in, his whole identity had become so attached to the LINC that he couldn't stand the idea that it was going away and he managed to purchase, I guess, four of the machines...

Damer: Four.

Ornstein: ...or pieces of the four machines for three bucks a piece, which I thought was a wonderful number and he put them in his garage, and that was 25 years before whatever year that was that we did the... and so I called the guys in St. Louis who knew the machine and had worked on it all those years before and said, "Any chance you could extract some pieces from Scott's garage and put together a working LINC," and indeed the answer turned out to be yes. They extracted pieces and kicked all the mice and crap out of the machines and...

Damer: Used the ball-peen hammers to...

Ornstein: Oh, they had a hell of a time. Yeah, the memory which Charlie had been able to just pull out and leave for me with my program in it many, many years before by now, well the memory had been doubled so it was a little harder to plug it in, but they had a heck of a time. Got pictures of them with 2 x 4s to beating it to get the memory in, but they managed to make a working machine, and that machine now resides at the DigiBarn and after we showed it at the Vintage Computer Festival. What year was that?

Damer: 2007 and Ivan Sutherland came and Gordon Bell came.

Ornstein: Yes, and Chuck Thacker said that it was the first time he'd ever seen a LINC.

Damer: Really?

Ornstein: Yeah.

Damer: Interesting.

Ornstein: That was the first time he'd actually seen a LINC. He knew about it, but he'd never actually seen one until that.

Damer: We got a lot of video and we finally sort of brought the LINC story to the light.

Ornstein: Yes, it certainly did and as far as we know it's still working out there. It still can be turned on.

Damer: Yeah, absolutely. Turn it on once a year and then Washington University got involved...

Ornstein: Oh yeah, well...

Damer: ...the exhibit there.

Ornstein: Yes, right, and in fact yes they did a big exhibit at Washington University, which was of course heavily involved in the LINC program and then recently Mary Allen Wilkes, who had written the operating system, first the assembly program and then the operating system for the LINC...

Damer: At her parent's home in the mid-60s, so there's a great picture of her with the LINC in a...

Ornstein: Yeah.

Damer: I think of it as the first personal computer...

Ornstein: It is the first picture of a computer in somebody's actual home.

Damer: ...home, yeah.

Ornstein: And, there's a staircase going up. It's obviously a private home. She had gone after the big burst of activity with the LINC, she had gone on a trip around the world and came back. By that time, we had moved to St. Louis from Boston and when she came back, Wes hired her to work on the assembly program, but she wanted to live in-- stay with her parents in Baltimore so he arranged to ship a LINC to her and put it up and set it up in her living room and that's where she wrote LAP6

Damer: And, had a potted plant on the top.

Ornstein: She's got, yeah I've got a picture of the machine. It's certainly the first recorded picture of a computer actually being used in somebody's private home, I guess. Big deal. I mean these symbols are nice, but...

Damer: I believe I got contacted by the university, the Heinz Nixdorf Museum to get in touch with her...

Ornstein: Oh really? Was that the first contact?

Damer: Yeah, they wanted to do an Ada Lovelace Women in Computing exhibit...

Ornstein: Yeah.

Damer: ...and they also built a display and the group had a wonderful time.

Ornstein: Yeah, oh yeah. Yes, she has now been touted at that computer museum, which is you know that, have you been there?

Weber : Yeah, we cooperate with them.

Ornstein: Ah, so, well I didn't know about it until then, but Mary Allen said "they wanted me to come and be the Ada Lovelace of the 2000s."

END OF INTERVIEW

