Oral History of Lee Felsenstein

Interviewed by:
Kip Crosby

Edited by:
Dag Spicer

Recorded: May 7, 2008
El Cerrito, California

CHM Reference number: X4653.2008

Kip Crosby: Hi, I'm Kip Crosby and I'm interviewing engineer and hardware designer Lee Felsenstein for the Computer History Museum. It is Wednesday, May 7, 2008. Lee, to my mind, you've always been an engineer. I've never known you as anything else, and I suppose I'd like to start with the forces and priorities within your family and your upbringing that made you into an engineer.

Lee Felsenstein: Well, I can be considered a third generation engineer, although not really. I am an engineer in large part because my mother encouraged me in that direction. She was a five-year-old when her father died, William T. Price. He was an inventor who improved the diesel engine, apparently with what they then called solid injection, which is really liquid injection. Prior to that they used compressed air to blow the fuel mixture into the cylinder against a very high pressure. At any rate, before his work the diesel engine was for marine propulsion only. It was about three stories high and it included things like an air compressor and a Model-T engine or something like that to turn the air compressor. We heard stories of this from people, some of these engines survived. But William T. Price was able to make the engine reducible to the size of use in locomotives and ultimately automobiles. He made a lot of money doing this and then he died of medical malpractice in 1920. His family was well funded and I think he got $500,000 for his patents and half of that went to investors but left him with $250,000 in 1920, which was an awful lot of money. So my mother was five at the time he died. She worshiped him as any five-year-old will do and she brought me up to understand that grandfather was an inventor and he had patents. Now, I didn't know what patents were and at one point when I saw an advertisement in the paper for an inventory sale, I got quite excited thinking it had something to do with invention and inventors.

I was encouraged by my father who was a commercial artist by trade and would like to have been, tried to be a designer. He set up shop. He actually was continuing leaving his place of employment and going self-employed, and we would be told the new phone number to call him at during the day, and it would oscillate back and forth because he would not make enough money and so forth. But he always made sure we had drawing materials and lots of paper to draw. There were two other children and lots and lots of drawing. So I began drawing diagrams of machinery, air compressors, whatever, and I do know that I was drawing a system of, rotating a jacket of water around the exhaust pipe of an automobile as a pollution control mechanism when I was in third grade. And I was more or less caught by the teacher who reprimanded me for not paying attention. I said, "I'm not daydreaming. I'm inventing." And so we also had a fragment of a little essay I wrote, had to have been at that age from the handwriting, "My grandfather was an inventor as I will be," introducing that concept. It didn't go on much longer, but it was very clear that I had a direction set from the beginning.

Now, the family, it could be called a bohemian family in the sense that my mother and father, they had lived together for a year. This is 1937, which is not that common, much to the disapproval of my father's mother. And were married December 31, 1938 to take advantage of that tax year, and hung around with various artists, radicals, and so forth. And I was brought up to think in sort of Bauhaus terms about form follows function. That was a favorite phrase of my father's and just generally to be a modernist, and I came to the conclusion eventually that that was really the frame of thought. That which was new was best to him, and the overturning of old ways and hide-bound ways was really of the highest importance. Now, obviously when you're raising a family you can't overturn all the hide-bound ways. We sort of tried that in the ‘60s.

Crosby: There are limits.

Felsenstein: And without wonderful success. So it was a more conventional upbringing than one might imagine under the circumstances. But then again, in the 1940s and '50s, you know, there were not too many experimental families. They drew the line at that.

Crosby: Now, what about the beginnings of your more formal education?

Felsenstein: I attended the public schools of Philadelphia. My mother much later said that my father seemed to take every opportunity to reduce his income. So we were not particularly well off. And the schools were good. I lived in a very large Jewish community in Philadelphia, which to my surprise I found out later was largely a Catholic city at the time. But we had this enclave and the schools, we could take Jewish holidays off. It just never entered my mind that this was unusual. So I attended an elementary school that was really just up the block from where I was. It was a very dense neighborhood, but it never seemed particularly dense to me because I was small, the things were bigger. Stokely School was my elementary school and I entered kindergarten in, I guess that would have been February of 1950, and those times we had two classes a year. In fact, as I went through high school, mine was the last class to graduate in January. My father had attended the Central High School, which was the academic elite high school of Philadelphia. He graduated in 1927. And the school was really one of the first high schools established in the country, really the third high school in the country, 1838. It was rife with tradition. It had its own school song which dated from 1909 as rather like a Whiffenpoof sort of thing. Bill Cosby who also attended this school, I don't know if he graduated, asked people to stand up in the audience who had graduated from this school and sing the song. We all can.

Now, my father had been raised in the same neighborhood. In fact, he moved our family back to that neighborhood. He was born in 1910. His parents were immigrants. His father was a laborer who had been basically driven out of his home at the age of perhaps nine and had made his own way since them. He immigrated in 1902 as did my grandmother on that side, although they were unknown to each other at that time. We recently discovered that. My grandfather, his name was Leibe, L-E-I-B-E, after whom I am named in the Jewish tradition, although I'm not the oldest son. He came over on the same ship with his 19-year-old brother. He was 25 at the time and on the manifest records from Ellis Island, the two are separated. The reason was that my grandfather was a deserter from the Austro-Hungarian Army and basically gave false information except for his name. So in effect he lied his way into the country, which I think is a grand tradition. He met my grandmother, who had come from the same area. This was the area around Kolomiya in the Ukraine now. At that time it was of course Austria-Hungary and it was the area known as Galicia. They met through a mutual benevolent association in New York called the Kolomiya Friends Association, and very strangely and perhaps not so coincidentally, my wife's, Lena Diethelm's grandfather had been a member of that association and she was able to show me some pictures of their meetings from the '20s. The two married and settled in Bristol, Pennsylvania just outside of Philadelphia where my father was born and his older sister. Then they moved to Philadelphia in this area.

So he had grown up on those streets. He spoke Yiddish as his first language. In fact, that's the language they spoke at home although you'd never tell from listening to him. He was therefore the breakthrough generation. He had got into this academic elite school, which was very egalitarian in its admissions policies. However, it did have a grandfather policy. Once he had attended the school and certainly once he had graduated, his sons therefore were entitled to attend, and his grandsons. I think this policy no longer exists, but me, my brother and I, my brother Joe Felsenstein, now a professor at the University of Washington, we both knew from the outset that we were going to attend this high school. That was a given. In fact, I was very hazy on the idea that there were any other high schools in the city. I knew there

was this vocational, technical school that some of the kids in our neighborhood went to, but that was about it.

During the time that we were growing up, the neighborhood became to change from Jewish to black and this was a classical kind of blockbusting operation where the realtors attempted to create scares. We were always getting little mailers saying, "We can sell your house, you know." And the wave of black, as my father called it, in-migrants from the south, this first wave of migration or in-migration. So they were just up from the country and it created a lot of tensions and a lot of indications of neighborhood deterioration. You could tell which house had the black families in it because it had one doorbell button per floor. These were two and three-story row houses because they were broken up into really tiny apartments. These are small houses. My father was instrumental in establishing something that first was called the Citizen's Committee for Law and Order and then became the Strawberry Mansion, that was the name of the neighborhood, Council of Block Organizations, which was essentially a parliamentary organization organized by block, something that would be quite the envy of a community organizer today. And this was in the middle 1950s. And so we had not only a block committee, but we had a junior block committee. We had kids organized. We would go out and clean up the street on Saturday, and paint the trees white up to a certain level just to make it look good. And there were sometimes protests that we would march on and so forth. And this was really a very conventional, you might say, an organization with very conventional goals. They wanted to try to get the zoning of the neighborhood moved down a notch. They were not successful. They were rather politically naïve. So I have this experience from childhood of community organizing and being in the midst of a mobilized <inaudible>. And this is something I turned to my technology later on.

Central High School was from January or February, maybe, the end of January 1959 to January 1963. And Central High School, as I mentioned, is an academic high school. It's really a college preparatory school, and my father had studied Latin. So I studied Latin as my foreign language as this was an optional fourth major, and I credit that education with providing a lot of background for me in the later times, although it's hard to put one's finger on it. It was my only really liberal education, which was broad ranging. When I entered the University of California at Berkeley, of course, it was the College of Engineering. You had some electives you could take and there was the social science course, but that was about it. So the foundation of my education is that high school education. I go back for my reunion every five years. That's coming up this year.

Crosby: Now, let me ask, at what point during this time, I assume it was during this time, were you introduced to electronics?

Felsenstein: I was introduced to electronics at the age of 11, as I recall, and this had to do with a crystal radio kit by Fillmore that my brother had been given. He had poked around with it but crystal radios don’t work all by themselves. They require a long antenna being strung and he wasn't that interested in it. His area was more biology. So he set it aside and I picked it up, and I managed to get it going. I managed to get an antenna strung. Also, it was at 11 or 12 I joined the electronics club at the local recreation center, which was taught by an engineer from Univac Corporation which is in Philadelphia. I failed to make my first vacuum tube radio work just because I had some connections reversed and I still don't know why the instructor didn't set me straight. Perhaps even at that time I was projecting too much of an aura of competence. But the introduction to electronics came at that time and I remember having a magical dream, which I consider probably everyone has when they're introduced to electronics. I don't have any reason to say that except my own experience. And so this dream where everything starts fitting together,

and I suppose I'm still in pursuit of that dream. So I was an electronics experimenter, which meant that I had a basement shop and I would tinker around with things.

And then at the age of 12, 1957 this would be, I was presented with a correspondence course for a radio TV prepaid. A friend of my father's or someone in my father's network of friends had paid for it and then taken some of the lessons and decided it was not for him, and decided to set it down. Now, this was an amazing advantage. It was a series of little lesson booklets and I would very ostentatiously study them in school and so forth. But it also included test equipment that arrived by mail, things that I wanted to have and had no way of feeling I could ever have, a vacuum tube voltmeter. This was really the standard meter of its day arrived like that, and later, of all things an oscilloscope. This was not like the oscilloscopes today which are good for high frequencies, but in its day and for what it had to do it was more than I knew how to handle. So I therefore learned the lessons and they even included lessons on how to run a small business, do your bookkeeping and so forth. And when I was 17 or so, 16 or 17, can't remember which, I think 17, I actually went into business as a radio and TV repair guy except that I had no capital, could not afford the stock of vacuum tubes that you needed because most of the work was simply replacing tubes. But I managed to keep my prices low and I didn't have to support myself with it, so I was actually going to people's home and fixing radios and TVs.

In the whole process, now going back to the age of 13, Sputnik went up in 1957, October 4, and everybody went nuts. We needed more scientists and engineers, and hey there's these kids in school who we need to pay attention to. Now, in 1958 for the Delaware Valley Science Fair, with a friend of mine who was really my buddy in all of these matters, Murray Kaplan, we built a satellite, meaning a model satellite. I actually was, my parents must have had something to do with it, pointing me in the right direction, but you could actually get these acrylic spheres and I got one donated actually. And we built some electronics in there which had the affect of broadcasting beeps to a nearby radio. It was all from the harmonics of that whole thing and Murray was the one who got it working. And we have a little solar cell in there, and a light shining on it. You could put your hand over the solar cell so as you shaded it, the heat rate changed. And so we entered this under my name because it was not permitted to enter something as a group project. Only one person could do it in the Delaware Valley Science Fair, and I won a third division award, which is the lowest possible award, and I was still in junior high school. So I was tremendously jazzed by this. I was an award winner now. I thought I was going to get a lot of publicity and then I opened my junior or senior Scholastic Magazine, the one for kids in junior high school and saw there was an article about a kid who had built a model of a satellite that contained real electronic parts. It didn't do anything and this kid lived in Ohio and I was tremendously embittered by this and figured that you're only as good as your press agent or whatever, and I didn't have a press agent. I, however, continued to enter mostly automatic switching intercom systems in the science fair through high school. Never really got it working. Never won anything, but I was strongly motivated by that first award.

Crosby: Now, just out of curiosity, when did you see your first computer?

Felsenstein: Well, the first computer I saw, let me start that over again. The first computer I saw was a UNIVAC I mainframe computer behind glass at the Franklin Institute Science Museum. The Franklin Institute in Philadelphia is a research institution and they also run a science museum. That's how I learned about them. I had been taken there as a very young child and it was one of my favorite places to hang out. I even paid for a membership in 1957 when I was 12 so I could have free access, and I would bicycle down about the two or three miles, hang out their all day in the cellar. They had had a UNIVAC I for the research organization, and Remington Rand, the manufacturer had paid for an exhibit area with a little gallery that overlooked the machine room. Outside there were adding machines and there was a

memory typewriter which could store text using relays. You could hear them clicking as you went, a line of type, and then print it out again.

Crosby: And I would assume that this memory typewriter was also a Remington Rand device?

Felsenstein: Yes, but that's the electric typewriter part of it. The rest of it was custom electronics or really electromechanical. They also had a binary adder where it would painfully or painstakingly count through the binary sequence, which was really useful with the lights. And that's where I learned about binary. It turns out that after high school and before college, I wound up running that exhibit. I answered a blind ad, but I was the perfect person for it. So for a $1.54 an hour in 1963, I sat at the desk there and untangled the adding machines and so forth.

Crosby: So after Central High and after the UNIVAC, you went off to college in California.

Felsenstein: I went off to college at UC Berkeley. I had been accepted at Purdue and Carnegie Tech, now Carnegie Mellon, but no financial [aid] was offered. I was a Merit Scholarship finalist, but I think, as I recall, that I was the one who filled out the financial information for it. The parent's marriage was breaking up at that time and I felt that I couldn't bother them with this. So I think I blew it on the financial aid end, and so I had to apply to a second tier of colleges, and the UC Berkeley was relatively inexpensive compared with the other two, and had the advantage of being located in Berkeley, in the San Francisco area, where all this interesting stuff was happening with the Beatniks outburst of bohemianism, and I decided I wanted to be there. Now, I was a bit of a political activist at that time. I would go and picket Woolworth's Department Store with whatever group was doing it at the time during the ‘60s, support for the sit-ins that were happening in the South. And I would engage in demonstrations with the Quakers against the Arms race. In fact, did so in one case when Edward Teller came and spoke at the Franklin Institute when I worked there, and I was photographed doing it. It created an explosion of outrage up in the head office and they sent some poor guy down to tell me that they frowned upon this, and he really wasn't, he was more on my side than theirs. But where were they going to get somebody for $1.54 an hour--

Crosby: Who could run that exhibit.

Felsenstein: So I kept my job out of raw technical competence and low salary. So I saw Berkeley as being a place where I could continue such protest activities and whatever, and this was true.

Crosby: And you were right, to say the least, because it was by then 1964.

Felsenstein: No, it was 1963 and in the first month there, Madame Ngo who was the wife of the dictator then of South Vietnam came through town. And there was a little protest outside the hotel, which was the first time there was any idea about a war protest. And I went over to San Francisco and didn't know my way around, walked the picket line. Then I had to get back to class for my chemistry class. Didn't know how to get the buses back so I took a cab and it cost me $7 which was a lot then, and the guy told me all about the Merchant Marine and how when you get your long pants on, sonny, ship out. That to me was sort of the classical San Franciscan. So there was a little group of a couple 100 people who sort of was the general protestors of the time.

And then 1964 happened. Well, that's an entire story in its own right. The civil rights movement had freedom summer in 1964 and that's definitely a part of history. Lots of people, students mostly, went down to the south, many of them got brutalized, a few died. And then the summer was over, and it was time to go back. Now, the University of California had had one area near Bancroft Way where tables were permitted to be set up for solicitation purposes and civil rights was the big issue. And there were local protests that were being organized for fair employment and so forth. Well, the story is told elsewhere. I won't go into it in great detail, but the University decided to clamp down on this activity. Bad decision. They decided that they actually owned that street that they thought was the sidewalk and so they told the organizations they would no longer be permitted to set up tables there. This set off an explosion, a protest that went on for three months and culminated in the sit-in in Sproul Hall. I was at the time away working as an engineering aid on the work study program in electrical engineering, or it was in engineering of all forms. And so I was off on a work period and they were completing their security investigation of me, and that went on for a while. They said, "Come on down in the meantime. We'll complete it while you're down here." It was what's called the confidential clearance, which is the lowest possible grade. But what I did not know, though, was that my parents had been members of the Communist Party until 1954 and so I would check the box, no I don't know anybody and I gave references who probably were also party members, putting the bureaucrats in an untenable position. And so I was told that I could resign and go back to school or something, and you keep your nose clean, sonny, and you can come back in a couple years. I had heard there was some sort of activity going on, some riot or something. This is a 32-hour sit-in around the police car in October of 1964, but I didn't know what the issues were. So I came back into this in the middle of the year, October 16, and the whole place was in an uproar, and there was this serious activity going on, and I had to decide whether or not to sit it out or participate. I decided to participate and so I tried to assist with my attempts at technology for the organization that was, an ad hoc organization that was doing these protests. And I had an experience there that was very formative. I was hanging around the headquarters one night and somebody came running in with a report that turned out to be false, that the campus was surrounded by police. It's a big campus. It's hard to surround it by anything. In my subjective view of this it seemed as if everybody in the room suddenly turned to me, the nerd, and said, "Quick, make us a police radio." It was really only one person saying this, but everybody was paying attention, and I knew immediately that this would have been possible in 1939 because police broadcasts were just above the AM broadcast band. And you could go in and retune a radio to do that, but it's not possible now.

Crosby: Because police radio was FM by then.

Felsenstein: It was FM, 50 megahertz or thereabouts. It's since moved up even higher. So I tried to explain. I said, "You don't understand, you can't do that right away," and again, in my subjective view impression everybody said in unison, "Never mind about that. Makes us a police radio." Now, at that moment I could see that I had made a serious mistake about my position in society. I was waiting for orders. I was there just trying to be helpful and demonstrate that I knew some things about various technologies and waiting for one of those very, very intelligent people who were running the show, who were graduate students in things like political science that I knew nothing about. They would tell me what to do and I would do it, but now it was revealed to me that they hadn't a clue as to what was possible and not possible. And that given the realities of technology development as I even understood them then, it was incumbent upon me to fill the shelves with what I thought might be needed, because by the time anybody else thought they needed something it was too late to go develop it. And of course this was the pre-computer era. You couldn't just whip up a program that did something. So I would have to be able to say, well you can't have that, but here's what you can have. And in doing so, I would define their possibilities. So the initiative lay with me and I stopped waiting for orders, which has been a very successful strategy.

Now, I did build what was supposed to be a police radio. It wound up being an intercom at one point, but that took the time I thought it would take. You didn't need it at that time anyway. It was a false report. So I went on working with the mimeograph machine which I learned how to run already. I learned that in elementary school and participating in things such as an effort to overnight produce a 100 page report from the graduate political science students and so forth, which required that one page per be farmed out to mimeograph machines all over town, distributed, and the paper collected and so forth, and brought back for collation, which was successful and it was a very inspiring illustration that there was a lot more technology around than people gave credit for. In other words, you could, through an information process, organize a large scale production situation, which they did. And it wasn't me that organized it. I just participated in it with running as a courier.

Crosby: Well, as I well remember, the mimeograph machine was just about the only inexpensive, rapid method of printing in those days, and there were tremendous skills involved. How long was the longest document you produced?

Felsenstein: How long? One page at a time.

Crosby: But I mean if you were farming things out to mimeograph machines and pulling them back in, how big were the documents you were producing?

Felsenstein: Well, there was no real limit to it, but this document, you were basically limited by how much paper you can get a staple through. So each page required a stencil and a stencil is prepared on a typewriter, usually. You could draw on stencils but you had to know how or you'd cut them up. And then it went on the machine. It was very messy, black ink, and you could turn out easily 10,000 copies. We would do this with the leaflets for the free speech movement every night pretty much. The stencil would wear out eventually but it could produce 10,000 without too much of a problem.

Crosby: So this was material you were preparing for the FSM [Free Speech Movement]?

Felsenstein: I was participating in preparing and I didn't type it. I didn't write it. I was just the guy, one of several, you know, who could help run the machine. I also had a tape recorder and I tried to produce audio press releases, but nobody wanted an audio press release then. So that idea had to be put aside. So I was a participant in the Sproul Hall sit-in and I was arrested, Case C7628, I think, dash 64, I don't know. That's all been expunged from the record. You can't get an official account of it even though I'm proud of it. And I had to, as I say, make the decision that number one, I was responsible for my technological work, and number two, I had to risk the possibility of not being allowed back into at least portions of the technological establishment. Now, it turned out that I had no problem getting jobs in the work study program. It was necessary to do this to stay in school because I couldn't otherwise afford it, and it was like six month work periods alternated with six month study periods. And so there were lots of various other jobs, and they had no interest in whether I was seen as a subversive or not. The government had a slight interest in that regard and I was able to play on that when I faced the draft in 1970 and basically frightened them away from accepting me.

END OF TAPE 1 / BEGINNING OF TAPE 2

Crosby: You were not much involved with computers.

Felsenstein: My brother, who is three years older than me, had attended Central High School and we overlapped for one year, 1960, when he founded the Central High School Computer Club. He grabbed me and said, here's some books from 1940-- from the library. They were from the 1940s. They had some partial schematic diagrams of things like flip-flops and so forth, latch circuitry. Can you build them? Well, all my life I've never been able to say, no, to my brother. That really wasn't part of the equation. So I said, I think so. And so I attempted to. It was not a success. Perhaps it would have been more of a success if we had gotten assistance from an electrical engineer familiar with pulse circuitry. This could have been done through the school. We had an advisor who was more interested in giving us tests and writing a little paper on who these people were. We were creating pulses by flicking wires on metal clips. There's almost no better way to create a random train of pulses. And so it worked about 50 percent of the time. And by it would be little two-bit counters and so forth. This is vacuum tubes plugged into sockets in cigar boxes as a chassis. So, I concluded from this that computers were too finicky. If you lost one bit, goodbye. Where as in audio and so forth, well, you'd have a little noise but you always have noise. So, I decided to stick with analog electronics, therefore, since I-- although I'd been introduced to a computer as UNIVAC through glass I've never certainly been able to put my hands one or the idea of a program was still even from the computer club we were still working in the bit level. Programs were a little ways off. So, when I made my educational plans and I signed up at the University of California College Of Engineering I chose Course D in electrical engineering, which was the general course. I don't even know if they had a computer course at that time. They might have. I went through the work study program which was a five year program. You entered in the sophomore year. I was close to out of money at that time. But you could get work for six months and relatively well-paying work. And that was what enabled me to pay for about 70 percent of my expenses. Being an out-of-state student I had higher tuition expenses than others.

In 1967, we had a climatic year there with the anti-war activities. We had the Stop the Draft Week where thousands of people surrounded the Oakland Induction Center, army induction center, and closed it down, took over the streets, et cetera. I was a participant in the planning of all that. And after that I had a kind of physiological collapse and went into a state of clinical depression, which shocked me. Suddenly I didn't care about all the things I cared about before, meaning mostly school. I moved myself to my classes and moved myself back, never did any homework and failed all my courses. In fact, it was only one professor gave me an incomplete rather than an F for my course. This is Doctor Smith in electrical engineering and he later turned up. But I was a dropout at that time. I decided to withdraw from school, as I put it, to restructure my motivation. I never considered going to the school hospital where they probably could of put me on drugs or something.

So, I applied for a job as a technician at the Ampex Corporation. They were running ads then. Ampex was a big company then, thousands and thousands of people. They were the company that really owned magnetic tape. They lead in magnetic tape. They developed, first of all, the audio recorder then the video recorder. And so I turned up looking for a job as a technician. They looked at the little resume I typed up with the work-study experience. They said, "This looks more like a junior engineer, would you be willing to take a test?" Taking a test is what I had learned to do in school. And so I aced the test. I finished it an hour short of the allowable time. And they said, "Oh my, great. So we have a number of places where you can go." I didn't get the one I wanted. I got the one that was best for me which was Special Products Division. This was the very small 150 person division at a time when a division at Ampex was about 3,500 people, which was charged with everything else. Whatever didn't fit into the other divisions would be referred to us. If they wanted it a different color we were the ones to paint it. If they wanted something developed from the ground up but only a one-off, small quantity we would do it. We would design it. We would manufacture it and ship it.

This is where I learned the craft of engineering. I entered in January of 1968. And with time off for another dropout period in 1969, I was there until December of 1971. Much happened in that time. I spent the first two years designing analog electronics for high-speed tape duplicators. This is running at 40 times the speed of tape and so the high fidelity at those frequencies took a little doing and I turned out to be able to do it. Then times got a little tougher, actually, they didn't get tougher at that point. They got tougher in 1971. But I had dropped out, tried to somehow make my way and work with the underground press which I had been working with since 1966 in school. And I tried to somehow make a living at it. You can't make a living that way, 25 cents a word-- 25 cents a column inch not a word. So, I ran out of money. I went back to visit my father and had a small confrontation with him in a nice way. And then from there I called my former manager and said, "Do you want another JE, junior engineer?" He said, "I'll work on it, and I do want it, but we'll see if we can do it."

Got the job back. This time, however, it had to do with computers and I couldn't escape it. This was the Pyramid System, which was an instructional system. It was a kind of a mainframe in its own right. It had banks of audio tape recorders which stored audio program material. And then what were called buffer recorders with one recorder for each student position which was a pair of headphones and a display screen and a keypad. The display screen was optional. There was a videodisc, which at that time was a 14 inch platter and it had, I don't know, perhaps 16 heads fixed. And that was a buffer disk. I guess there was a moving head disk. Very difficult to make those work. I fortunately didn't get involved with it. Those were people from video who were always cleaning the surface. So, what it would do is deliver lectures. You would select your lecture at the keypad. A minicomputer, Data General Nova 1200, would direct everything. There were racks of computer interface electronics that would go from digital to analog and that's the keyboard and that's something called a tone detector. Because buried in the audio of the program material were bursts of 55 Hz tones that spelled out a digital word or two. And this had to be picked up, filtered out, digitized and transferred to the computer. Well, that was one of the circuits that I inherited. I was given responsibility for maintaining the product, MPD, maintenance and product design. And some of it was difficult. By using BASIC on the computer I was able to do a set of iterative calculations which ran and ran for an hour or so on the minicomputer and then turned up with no solution. There was no possible way to build that circuit such that you didn't need adjustments given the precision of the components involved. And so I took it in a slightly different direction with automatic gain control, [but] was swatted down at the meetings. Told, drop that. Just freeze the design that this other guy has fixed and do it. I knew that wouldn't work. And I had to sign off on that one. Later I found myself applying for a job at Atari and Al Alcorn, who was the VP of engineering there, had been the one who had to come in and clean up after me. I don't think that I've yet had the full conversation with him about that, he just doesn't seem to want to talk about it.

Okay, so, I learned machine language programming because I had to. It was that or lose my job. There was a layoff in the middle of it all. And I was tasked with setting up a dummy set of student positions, keypads, doing all the programming to read the keypads and create some effect, I guess drive the buffer tape recorders and do the transfer and so forth. And so my first computer program I wrote was machine language on the Data General Nova for this purpose. I was also sent to a Service Bureau-- SBC, Service Bureau Corporation to learn BASIC in a four-day course. It was there that I was introduced to computer networks by the instructors. And they would, with a great air of superiority say, well, you see how the system is just hiccupped and is running more slowly. That's because they've turned off the computer in Los Angeles and switched us over to a computer in Kansas City, which made the point to me that in a computer network everywhere was the same place. Then they pointed out that if you prefaced your file names with any one or more asterisks that would give it one or more levels of accessibility. Three asterisks, anybody in the system could use, could see that file. Two asterisks, only those people in your

group could see. One, was a smaller group. I realized that there was a possibility of building a community of interest on computer networks this way.

And I had been all through my time at Berkeley trying to find the technology of communication that was going to work for the—call it the revolutionized society. I had experienced in the Free Speech Movement-- let me explain this. After the Free Speech Movement in 1964, we achieved our goals of basically freedom on the campus for political organizing and activity. But what happened then was this tremendous explosion. Perhaps 5 to 10,000 students just checked out and went and started the Haight-Ashbury. Others did all kinds of other things. I wrote an essay on how we could, you know, organize a non-centralized free university. Somebody published it in their mimeograph thing and because they blew it of drawing the picture of the cover, the cover came out blank. This was on the center inside fold. There's actually a reference to it in a *New Yor*ker article at the time, an idea essay by Lee Felsenstein. Well, who is Lee Felsenstein? He's a sophomore in electrical engineering. This was happening a lot. People who had never expected they would do certain things found themselves expecting they could do them. And based on the writings about revolution mostly from anarchists this seems to be one of the…

Crosby: Classic patterns.

Felsenstein: …one of the classic patterns but one of the phenomena of what you can call revolution. It really is an internal process. And so I had seen this happen at Berkeley. Berkeley, basically, the lid blew off Berkeley. The underground press got established. I got involved in it and of course anti-war protest began developing and so forth. That was very near to our hearts because the draft was there. Okay, I wanted life to be like that all the time and I still do. But what was it going to take? Certainly an area of media and then the technology of media to make that possible. And I begin pursuing that question. So, I thought maybe underground press, classical little newspapers that were turned out and produced in people's living rooms. And as I learned what it took to make a paper and learned what it was and what it was not, and then I found out about switchboards which were sort of volunteer information referral services. It just took a pile of index cards and somebody was committed to a certain concept that they wanted to organize the switchboard around they could put a notice in the underground press saying if you want this information on this, call here. And they would collect information and exchange it and then they wouldn't have any filing systems, they were not personal filing systems. People would burnout and move on.

I came to the conclusion by about 1970 that if there was some way to help switchboards get their information organized, their filing systems better organized, that might provide this medium of exchange of information that I knew to be necessary because I'd seen it operate in the Free Speech Movement. I'd seen it operate afterwards. But it was sort of a technological issue but then I'm going to treat everything as a technological issue. So, when I may have that experience with learning BASIC in 1970 I realized you could do it with computer networks. You could create a non-hierarchal medium that would be accessible to everyone in theory and everywhere, not limited by geography, not limited by time because communications would not have to [be] synchronous, they would be stored. In fact, at that time you couldn't have a synchronous conversation on a computer network.

Within that remained the question of where are you going to get computers for a computer network? And I didn't have a fast answer for that one. I continued to work out through 1971 and then I discovered that some people had had the same idea. And they had secured the donation, I guess, or long term loan as it was known of a mainframe computer, an XDS 940, actually, it was [an] SDS 940, Scientific Data

Systems, before it was sold to Xerox when it became XDS. I went to them and turned myself in, in effect. And so I took on some responsibility for helping them set up the computer, to do hardware engineering. Someone was going to train me, someone who had worked as a maintenance technician on the SDS 940 was involved in the same group. This was all at a former candy factory in San Francisco that had been sort of occupied in 1970 as living and working space back when that was totally illegal. So, it was rather close. And after I finished, graduated, from the university I went back for six months in 1972, finished up my degree work, got my bachelors degree, I went and lived in that building and worked on setting that computer up. As soon as the computer was set up, the guy who was going to train me disappeared and I was on my own. Unfortunately, I wasn't sufficiently socially adept. I had gotten my head back together through psychotherapy and so forth in the intervening couple of years. That's why I was able to return to school at all. But still wasn't all that capable of socializing, you know, asking people for help, always a very difficult thing for me. And so I just tried my best. It wasn't a lot of fun, I'll tell you. And there wasn't much money available to us even though this is an organization and it had gotten grants that were far above what was available to most others in this area.

We were trying to do a clearinghouse, as we put it, for the switchboards in the Bay Area. And, in fact, the whole thing had originated from the organizational remains of the one-off branch-- offshoot of the Haight Ashbury Switchboard. Needless to say, after several years, their other switchboards, which had a tremendous turnover in the personnel, had completely forgotten about us. But in the meantime, I had brought into the group Efrem Lipkin who was a systems programmer and he had been involved in the Buckminster Fuller World Games of 1971. So he had people there that he networked with and brought in. And we developed the idea of an information retrieval system that was not fixed to a preset [set] of keywords, but could take dynamic keywords. And in fact, Rick Greenblatt, from-- the legendary hacker from MIT, came through town once and he gathered all of the programmers together for this computer, said, "Let's write an information retrieval system in 24 hours." And to my knowledge they did, or at least the beginnings of what became our Rogers Resource One, that was the name of the organization, Generalized Information Retrieval System. We had the software, we had the hardware, now we went to the switchboards and said, "Okay, all you've got to do is rent a Teletype for $150 a month, and enter all of your data, and you've got it all." And they said, "Who are you?" Little failure of marketing there I would say. So, we were left with this and Efrem came up with the idea, "Let's put it out in public and see what collects." And we did so.

In August 1973, we opened what we called Community Memory as a service. We had a Teletype on a podium with a cardboard box that I had built, lined with urethane foam as a muffler with a clear vinyl flap, where you could velcro it up and get the papers setup and get the Teletype unjammed because it was a donated, you know, three-year old Teletype that had gone through its lease period. And two holes in the front where you could stick your finger-- your hands in and use the keyboard. We had a 110 baud modem in the base of the podium and a phone line, Farnboard, [ph?] they called it from an Oakland exchange, which meant a free call to San Francisco. So that phone made a-- one call per day, all day long to a San Francisco number where we had our computer online. And we had somebody standing there that had to be there to help unjam it, and they would greet people coming up the stairs at Leopold's Records, which was a student established record store whose purpose was to drive down record prices. It was successful at that. And it also had a musician's bulletin board, and we were right in front of the bulletin board. People would come up the stairs, they didn't know what to expect. And our person would say, "Would you like to use our electronic bulletin board? We're using a computer." And we had thought that they would be, "A computer here? Wait a minute." But no, they always said, "Oh, can I use it?" Because they could see that that guy was not standing between them and the machine. And all sort of things-- first of all, all the traffic from the bulletin board, the musician's bulletin board, came over to this better technology, plus a lot of other things we never expected, poetry. In fact, a poet selling his wares

with sample poems. Various messages, typewriter graphics, you name it. If you could do it at 110 baud on a teleprinter it would be done. None of this we had really predicted. I consider that in this process we opened the door to cyberspace, or to what I call the 'commons of information.' Now that's a very large term and, you know, we can argue about that.

Crosby: Well, it was true that the SDS 940 was a timesharing computer at a time when timesharing computers were very rare.

Felsenstein: Correct. Only 57 of them were ever built. And they were-- and as a timesharing computer it was really the appropriate technology available at the time. It could handle multiple users and not in the way that the IBM [System/]360 did, which is apparently much more rigid. Nobody ever seemed to be able to put together a system like this on a 360. It's a software matter and I don't know the answers to why. In fact, it turned out this was serial number four. And apparently in a previously-seen service at Stanford Research Institute where it was used among other-- by Doug Engelbart. It was a very interesting pedigree. We added a hard disk drive, a 2314 type with a stack of 14-inch platters that gave us something like 50 megabytes, which is an awful lot of memory in those days, and we built the adapter for a Nova-- Data General Nova controller that we could buy. We had a lot of help from people at the Stanford AI Lab and Xerox PARC. Some of them had worked on this machine before, there's a whole list of names I could give. And there was an operating system lying around for it that somebody had. So this is not the kind of thing that just anybody can do.

It was successful from the standpoint of attracting interest. We opened two more terminals, then it became apparent that some hardware help was needed, meaning that the terminals were the problem. Now we went to a CRT terminal, a Hazeltine 1500, for the next two installations. And one was the Whole Earth Access Company Store in Berkeley, which was loosely connected with the Whole Earth catalog, one on the counter of the Mission branch of the San Francisco Public Library, all done clearly without the knowledge of the higher-ups at the library. The problem with the Hazeltine was first it cost $1,500. Secondly, maintenance, who's going to maintain it? And we had a maintenance contract. The technician came at one point and had a problem with the keyboard. He dropped the keyboard, one of the ceramic TTL chips on it, which had basically a sandwich structure, its lid popped off exposing the silicon inside. I wasn't there. Somebody asked a guy, "Is that going to be a problem?" And he said, "No," and just reinstalled it, which made the-- when I heard about this I said, "This maintenance contract isn't worth what we are paying."

In 1973, in September '73, the TV typewriter burst upon the scene through an article in *Radio Electronics* magazine, which was one of the magazines aimed at electronics technicians. And those who were involved understood maybe-- it was said it could be a terminal. The article said you could use this as a computer terminal. In studying it more, I've discovered it couldn't be used as a computer terminal simply because it was a page display. You filled up a page of text, it would be displayed on a TV screen through a modulator at something like 32 characters per line or 40 I don't know which. And then when you filled up the last character on the bottom of the page the next character flipped the page to a new page threw away the one you were just trying to finish reading and started a new page. I called up the guy, Don Lancaster, who had designed it, he was in Arizona, and asked why he had done this. He said, "Well, people just want to put up characters on a TV screen," which was true, they did. There was a tremendous demand for this, but it was useless as a computer terminal. Then he told me that he was working on a new design that's going to use random access memory. He had designed his using some shift register memories, serial-- sequential access memories chips that he had used on some product-- project for Goodyear Aerospace where he worked. And that had a lot to do with why it was a paging

display. You know, putting-- inserting a character somewhere on this screen in that memory was a difficult task electronically. But he mentioned random access memory and that you could switch back and forth between it. Well, I understood that you could interface that to a computer in such a way that it would appear to be part of the computer's memory. And then when the screen needed it, it would switch and use the memory and it would switch it back to the computer when the computer wanted it. And that was the basics of the design of the Tom Swift terminal, which is the conceptual design I did, more than conceptual, I did a whole specification on it, I didn't, however, have a schematic, that was to come later.

And it was also something that a lot of this information I gathered at the potlucks that were being held at the Community Computer Center in Menlo Park. Now this was the other place where you could have walk-in public access to a computer, but for games. That's what they did. They wanted to get kids playing games on computers as a means of de-mystification of computers. Bob Albrecht was the guiding light behind that… that was a very important thing to him, he had gotten as far as I know fired by Control Data for doing just this with their exhibits. He would bring in school kids to the computer shows and a computer show then was nothing but pompous guys trying to inflate their own importance by saying, "We're computer professionals. You know, this is a profession." And his guy would bring kids in to show how easy it was to use the computer. They didn't want that, but he kept it up and he-- so he established his own place.

Crosby: Do you remember what games they had?

Felsenstein: I remember there was the Wumpus. There was a Star Trek game where the teleprinter laboriously typed out a little tic-tac-toe kind of grid with you in the center and whoever was in the squares around you. That was your radar screen. And you would command sort of like Battleship, you command what you do, where you went, and so forth. And it would print out another grind of the results. Not too thrilling, but it was going to get better.

Crosby: What kind of hardware was this, this other computer?

Felsenstein: They started with timeshared BASIC, but then they got a PDP-8, and Liza Loop still has this PDP-8. Then that was really-- one could argue that the PDP-8 was the first personal computer, but I won't enter into that argument. It cost about $10,000 or something with enough memory to do anything. And programming, it was very rudimentary programming. I would compare the programming on it to the programming on the PIC microcontroller chip, which itself is almost laughable, but you could do a lot with only a few instructions as I much later found out. So they would write their games in BASIC, they had a BASIC interpreter and that's a language they were using, so this was a very informal environment, a storefront, kids would come in and play games. They had to pay few-- fifty cents or something to do it and hang around. And other people would hang around, people who were interested in this whole concept of people using computers hands-on.

One of those people was Fred Moore who really he would define himself as a pacifist activist. He was constantly going and getting arrested picketing one military installation or another, or going on some very long walk just himself in a little cart that he had built to bring his message of non-violence into the world. Well, he wound up in Menlo Park and he hung out there and he thought he would organize a hardware class and learn about hardware because he didn't know anything about it. And you know he probably should have been an engineer. I've seen some of the stuff he designed in terms of little stoves you could make out of tin cans that poor people could make and do much better job at burning stuff. Good

engineering. He then established himself next to the door and would ask everybody for their contact information when they came in, made a list. Well, they thought this was kind of irritating, but they let him do it, and because the list would be a good thing to have in general. When the Altair came out in 1975, and the first one came to the Bay Area, then he and someone else, Gordon French, who had business down the street, and stopped by here to figure out-- find out what was going on and who was a computer programmer professionally, they convened the first meeting of the Homebrew Computer Club. In the meantime, I had been coming down there for their Wednesday potlucks with a dozen people or so, some of whom would come from Xerox PARC or thereabouts. We'd just sit around and talk about what the future could be like with personal computers and why you would want them.

Crosby: Now wasn't this also roughly the era of People's Computer Company?

Felsenstein: People's Computer Company was a direct offshoot or maybe it was the parallel organization to the Community Computer Center. It was the same people-- it was Bob Albrecht's underground paper basically. And it was aimed at people who wanted to use computers in education. Rather like *Creative Computing* was, which started out as a newsletter for educators who wanted to use computers. *Creative Computing* was done by David Ahl out of New Jersey, and this was California. And the tradition of the underground press was if you had some thing you wanted to say bad enough, show up, do all the work, and you get to put an article in their paper. They wouldn't pay you anything for it, but you could get your article published. And I knew about the underground press because I had been a participant for a number of years and I knew a lot of technologies involved. So I fit right in there where appropriate, and at one point was doing a column called, *Hardware Isn't Hard*. So I got a page or sometime-- I don't think I ever got a spread-- center sheet until we did the article on Community Memory. So I would solicit the-- lay out the problem, in this case it was cassette tape storage, and explain what the-- not the Kansas City standard, or it the Kansas City standard.

Crosby: It was.

Felsenstein: But the reason why the Kansa City standard was important, never really got implemented that I know of, it was just you would-- you could embed the clock into the data stream. So as the tape changed speeds and the clock changed time everything would stay in synchronization. That was the idea. What you paid for it was slow data because you had to have 16 events for every bit. So I solicited people to send in ideas given what this was, and then I printed those, and commented on them and we did another iteration. This is the kind of thing that I developed from the Community Memory experience, taking the medium and making it a closed cycle. That is to say-- and it sounds like you're excluding people but you're trying to open it to people. And so getting input from people, printing it, getting commentary, printing it again, and hopefully you get convergence.

Crosby: So, now we're very close to the time of the introduction of the Altair and that was a bit of a game changer.

Felsenstein: Yes. The Altair totally changed the game. And prior to the Altair there were a few efforts like the Mark-8, which was an [Intel] 8008-based computer that really didn't have much in the way of resources and only-- it's hand built and only a few got built.

Crosby: There were also the 4004 and 8008 computers called Intellec's that Intel was building for themselves.

Felsenstein: Right. You would have the Intellec 4 and 8… [they] were development boards for their Intel chips. They were pretty expensive. Intel had no interest in making a personal computer. And Gary Kildall, for instance, was writing his CP/M for those chips for those boards. That's where the funding came from. And the case had been made, I think correctly, that personal computing is owed to Gary Kildall's effort because what he pioneered was interoperability of software through a common operating system and an open operating system like that. I think we should break here, okay.

END OF TAPE 2 / BEGINNING OF TAPE 3

Crosby: Okay. So the Menlo Park operation, so to speak, and the People's Computer Company, led directly to the Homebrew Computer Club which, as I recall, began in Gordon French's garage.

Felsenstein: The first meeting of the Homebrew Computer Club was held March 5th, 1975. I might be wrong on the date, but I think I'm correct, in the garage, at the home owned by Gordon French. 30 people made it into that garage on a rainy night. I was informed of the meeting by Bob Marsh whom I had, first of all, I'd been in the same student co-op with him when I was a student, although he wasn't doing electronics, and met him again through the Community Memory service. And we began talking and meeting, and he actually, in 1974, convinced me to join him in renting a garage in West Berkeley, where we could set up our workshops, and so forth. He then showed me the first *Popular Electronics* article on the Altair. He showed me the picture and said, "Look at that picture. It's clearly a fake, and what you see in that picture isn't what they talk about in the article. There's nothing inside this box except a little bit. And we got to find out more about it and we can make things that plug in." So he started Processor Technology Corporation at that time in this garage, a 1,200 square foot garage. I had my workbench there, and I began doing contract work for him. And then in March was the Homebrew Club. He told me about it, and I drove him down in my pickup truck, at least the one I was borrowing. So we both attended. Steve Wozniak was there. Roger Mellon was there. Marty Spergel was there. He was one of those people who was very much a people person, as well as a junk person. He describes himself as a junk man, and he was very productive in giving people little, you know. He would hand out parts in the hopes that they would come back as bigger things.

Crosby: Circuits.

Felsenstein: He was right. He was right. The reason for having the meeting was that People's Computer Company had been sent a review copy of the Altair 8800. This was the first one to reach the Bay Area. I don't know what the serial number was. It was down around eight. I actually had it for awhile. I showed it to Efren Lipkin. He put it on a coffee table, but as a systems programmer he decided there was nothing he could do with a computer this small. He just used it as sculpture for a week, and then we passed it on. I wrote a review of it, which was unfortunately too optimistic and laudatory, and people began contacting me after I printed it in People's Computer Company, and said, "Wait a minute. There's problems with this here. I'll bring you my machine." And then they decided there were problems, and I printed another, a retraction basically saying well, there are problems. Here's where they are, and so forth. And I began, I guess you'd have to say, marketing a little kit of parts with instructions for how to patch up your Altair to make it a little more reliable.

We had the benefit in those early days of very unreliable hardware. Why do I say that it's a benefit? Because you had to work much harder than you thought you had to understand it, to make it work, and you had to learn a great deal more than you had expected. The TV typewriter was such a design, really

hellacious from a standpoint of getting it to work, and work reliably. Bob Marsh had built his own TV typewriter. It almost worked, and he had learned digital electronics in doing so. The Altair was somewhat similar. You had to do a lot of soldering there, and you wound up with something that wasn't terribly reliable, and for which there was nothing to plug in. You've got 256 bites of memory. You were promised at sometime a 4KB memory board. It didn't work. And that was it. So inadequate hardware, unreliable, means it's easy to see how to improve it, and so the industry was started this way. Processor Technology was started making plug-ins. First was a ROM board for the read only memory for the program memory. Then was a RAM board. Then I think their I/O board, 3P+S. Quite a messy board. I wound up writing the manual for it and drawing the schematics. But they would plug in and work better than what you could get, because you couldn't get any of this stuff from the manufacturer. They had their hands full. The manufacturer was Micro Instrumentation Telemetry Systems [MITS], which had started out its life as a kind of an after hours shop to make little instrument packages for model rockets there in the '60s and so forth. This was in Albuquerque, New Mexico, hardly a center of the industry. But that's where it started, and it's a good example of what Arnold Toynbee refers to as the marshlands of civilization. That is to say, as contrasted with the centers of everything. Progress, Toynbee said, happens in the marshland. His best example is Pasteur, who was not a doctor at all, but a chemist, and had gone ahead and made his discoveries about bacteria and how to avoid bacterial contamination, and so forth, that really revolutionized medicine. But he wasn't a doctor, and he wasn't where everything was happening. And he became the center of things. And MITS was in Albuquerque. It wasn't in Silicon Valley. It attracted Bill Gates and Paul Allen, who sold them a BASIC interpreter, and they moved to Albuquerque. I didn't hear of too many other people moving there. And it was an inadequate design, so all the rest of us had to make it adequate, or we had nothing. And none of us bargained on it, but we all had to learn far more than we ever thought we have to learn. And this is an interesting recipe for building an industry.

Crosby: Then you ended up working for Processor Technology.

Felsenstein: Literally, no. I never worked for them as an employee. I worked for them as a contractor, so I designed, well, let's see. Let's get it in the order of things. My first design for the personal computer area actually was done in 1973, the Pennywhistle 103 modem. And this was done to fill a need that we had at Resource One. In fact, we used the first prototype modem in the terminal installations successfully. It was designed not only to be buildable as a kit, which was something you weren't supposed to be able to do with modems because of all the critical adjustments. But also because it was designed essentially to adjust itself, it could run from cassette tape. It could adjust to the speed of the tape using another approach. And so the intention there was to be able to run a tape loop at the terminal of Community Memory, and then when you're ready to use it, you were online. We never used it that way, but the design was done with that in mind. The kit aspect was less important. I never, didn't really think of it then, but it turned out because it was self-adjusting, it could be made as a kit. That design was brought out of storage for Marty Spergel when he asked me for something to sell in 1970, must have been '76 or '75. And it finally went on the market in '76 or '77, and it knocked modem prices down from $350 to $100. The next design, well, there was the Tom Swift Terminal, which was a bus structure that was intended to start life as a terminal, because it wasn't very clear that microprocessors were going to catch on. They were expensive. The Altair was built around the Intel 8080, and that cost $350 a chip in 1975. Well, that was the list price of it. You don't really manufacture something at that price, but we didn't know that. And I think everybody saw the $297 price of the Altair, and said how could this be? The chips cost more than that. Course they got their chips as cosmetic defects for $75. But, again, that was beyond our experience. I lost my train of thought.

Crosby: Are we to the VDM-1?

Felsenstein: The Tom Swift Terminal. That was it. Yeah. The Tom Swift Terminal was designed not to rely on microprocessors. I came up with the idea that in a computer everything is peripheral to memory, which may be true. And if you think about it that way, you can do interesting things. So you started with a memory board, and then the design had an input board, or input/output board, and a display board. The characters would come in from a keyboard or from the modem to the input/output board, be formatted in appropriate ways and entered into memory, random access memory, with a bus memory structure. And then there would be the display board [that] was constantly interrupting the bus to get more data, to get data out of the random access memory, and display it on the screen. Display of data on a video screen means you have a constant stream of data going there, because it isn't persistent. The screen doesn't save anything. But these two functions and a memory were all you needed. You didn't need a microprocessor for it. So I worked out what the specification would be for this, and then I was going to go about designing it, but then the Altair happened. And I still have, I guess I've given it to Stanford University now, my papers. There are some rolled up schematics, and I was attempting to do a kind of micro-programmed device, without really knowing how. Early on in Processor Technology, Bob Marsh said to me, "We will give you the opportunity to design the Tom Swift Terminal, but you have to do it our way. And that became the Video Display Module, the VDM-1. That had random access memory on it. Had the two-port memory that I had conceptualized for the, starting with the TV typewriter, or what could be made from that. And it was built for the S-100 bus, and produced a video output that could be plugged into a video monitor. It really wasn't adequate. It was too high bandwidth video for TV use. That would have required 40 or 32 characters per stream, and this was 64 per stream.

Crosby: Per line.

Felsenstein: That worked out a mass number. Per line, you're right. Per screen, it's 16 lines, 16 by 64, that's 1,024, and that was a random access memory chip size in those days. The VDM-1 had a very serious effect. First of all, it became the basis of the standard architecture of the personal computer. The shared memory display was how everybody did it after that. And I can make the argument that this defined the architecture of the personal computer. Now, I have to qualify that statement obviously, because architecture's a big term. We started out with the microcomputer as a box, and Ted Nelson called them blinkies or blankies. The blinkie had switches and lights on it, just like a minicomputer did, and it was a miniature minicomputer. The blankie had a single button and it had program in ROM and it would boot up and talk to you. But how would it talk to you? Through a serial port. You had a terminal at the other end of the serial port. So your system was a terminal and a computer together. One of them wouldn't get you where you needed. Using the shared memory concept, the fact that there had [been] the memory in the terminal, but there had to be memory in the computer. Well, if you wanted to save why not merge them? So there was a concept then of taking the two-port memory, putting a window on the random access memory of the computer ROM area of it, interpreting the data into characters, and there's chips that did this, ROMs, and doing the magic necessary with the timing and so forth to produce a video signal. You took two devices, each of which cost $1,500, approximately, merged them together. You got something that still cost $1,500 and outperformed the original system by many orders of magnitude.

We had one magazine where we were running an ad from Processor Technology. One of the magazines where Processor Technology was running an ad sent us a form to fill out. This is an I/O device. What's its baud rate? How many bits per second was the equivalent? So I thought about it some, and I figured, well, if you had your processor putting data into memory, here's how many characters it could get in there in so much of a time. It turned out to be 875,000 bauds, and they're expecting 300 or 1,200. With this display, Steve Dompier was able to write software. They took the little Star Trek game with the three tic tac toe grid from the Teletype, expanded it to 16 by 16, or something close to that, and had all kinds of

things happening simultaneously. They had characters, some of the control characters were represented by little graphic symbols. One, the bell, was a little inverted semicircle and something that looked like two feet coming out from under it. We made good use of that. He did other games. Target had these little spaceships coming across the screen, and you would fire projectiles at them. This became the first computer games, interactive computer games.

Crosby: They became real-time games, interactive games, because you had that internal throughput that you just couldn't beat.

Felsenstein: Exactly. And I think real-time interactive is, in fact, the right phrase. The others were interactive, just not very real-time. So this opened up aspects of the personal computer. First of all, the play aspects, which I think are really critical, because most of what I do, at least, is a kind of play, even if I'm being paid to do it and even if it's not something I was originally interested in doing, if I'm going to do it well, I have to be at play. So that's been my experience. And this ensured that the personal computer was different from real computers. Real computers were used for business. They were used for making money. They're serious stuff. Personal computers, people played with them. We don't understand that, and that's an advantage. Okay. So that was the VDM-1. And not too long after that, Bob Marsh called me into his office and said, "We want you to design a computer around the VDM display." Because he had made an arrangement with *Popular Electronics*, Les Solomon, the technical editor, to provide him with an intelligent terminal that he could put in the magazine.

Crosby: And this, of course, is the machine with which your name is traditionally associated.

Felsenstein: Not as much as I'd like it to be. We haven't got to the Osborne yet, but that will, that's what most people recognize, who recognize anything. This was the SOL-20. There was a SOL-10. It was just the same computer with no keypad on it. Nobody ever bought one. And it was touted as an intelligent terminal because in those days the big advertiser in *Popular Electronics* was MITS. MITS was kind of paranoid about everybody else copying their bus design, and doing without their permission. They thought they were IBM. Every little company that starts up in this industry thinks it's IBM, and some of them make it like Microsoft, but not many. So there was a deadline to meet, which is about the end of the year as I recall, and I did the design in about three months. And we put together, patched together one wired up, printed circuit prototype, and got it to New York. It didn't work there. We brought it back. Found the problem. Took it back again.

Crosby: Was that the one that had the little scrap of wire in the bus slot?

Felsenstein: Not in the slot. It's under a chip, shorting out two video lines and making quite a mess of the display. Some of the shield braid from the coax cable got loose, a little, tiny piece of wire, much smaller than one we would normally expect, and if it's going to do it, it'll do it that way. So that was the time when I showed it to Les Solomon. Showed him there was an S-100 bus connector in there. In fact, we were using it with, we had plugged things in. I don't know if we had it for this demo, but he asked, "What would prevent me from plugging in a ROM card there and running BASIC?" And I just, I had no answer, but I had been instructed not to tell him that it was a computer, so I just had to say, "Beats me." And so he had, of course, a whole new computer to sell ads for. That was a wonderful thing for him. The whole paranoia about that MITS would put the kibosh on the whole thing if they found this was a computing device. That never was true, even though Les would have done it, if they could.

So the Processor Technology SOL-20, the order book was opened at the PC '76 Computer Fair, the first computer fair ever, which was in Atlantic City, New Jersey, Labor Day, 1976. I think that would be 1st of September, in a very old hotel scheduled for demolition. People paid $5 to get in, were very enthusiastic. My father who had been a commercial artist and done display work and so forth for shows, and actually sold folding tables and chairs, he came down from New York, where he was at the time, and helped me out there. And he came away raving about it. He said, "This show is tremendous", you know, it's unlike any of the shows he'd been expecting, he'd been experiencing, and it was quite an event. So the Computer Fair in California wasn't the first. This was the first, and we were taking orders for the SOL then. Apple was still showing the Apple I in a two-person booth, Steve Jobs and Dan Kottke. We were able to start shipping, I think, the next year, in '77. And Processor Tech, as we called it, outgrew the garage very quickly. We had 12 people in a 1,200 square foot garage, which was quite a puppy pile when you think of it. I kept my workbench there, and kept independent, and I had a royalty agreement with them about the designs, so I made $10 on every VDM, and $12 on every SOL, which added up to a nice chunk of change. We made about, I don't know what the total was on the VDMs. It was somewhere around 10,000 VDMs and 12,000 SOLs, so the best money I've ever made. I didn't have to give any of it back, and I worked hard, and we were on our way.

Processor Tech moved to another building. I was dragged along to serve as interim engineering manager, which I felt was a horrendous job, because I didn't know how to do it, and it was just a matter of making a list of all the things that hadn't yet been done, and the management thought they had been done. And it was a company, as many of them were, run really by amateurs. I'm not sure where I sit in that continuum. I knew a little more than most amateurs, but I was still an amateur in management, had no real experience of it. They could not decide what they wanted to have designed next, and I went back into waiting for orders mode.

But actually I began to get interested in some of the video crazies that had accumulated around Processor Tech, with their encouragement. They paid for Bill Etra to come out from New York. He had been the creator of the Rutt Etra analog video synthesizer, who produced a rotating capital dome effect for the *Washington Week in Review* show on PBS. And I learned a great deal about digital video that way from him and his coterie of friends and acquaintances. And, in fact, I took on a contract to develop a rather large digital video system for him, which he then turned into, he diverted my effort into creating some small tabletop boxes doing some of that video, digital video processing that could be controlled by a Radio Shack TRS-80. All of that came to naught eventually, although I did a lot of work, and basically ate up the year of 1978 for me. Processor Tech, eventually I said to them, "What do you want me to do?" And they said, "Well, we don't know. We've been waiting to see what you come up with", which would have been okay if they told me in the beginning, but it indicated their management style was a bit deficient. I could talk for awhile about what they should have done, but it wasn't done, so that's not really historically relevant. That company closed in 1979. I was by that time developing the VDM-2, which would have had 80 characters per line by 24 lines. It would have been a split screen, of which one section was capable of smooth scrolling, and you could split it at any integral line number of the display. It had greyscale. It had flashing and so forth.

Crosby: And 80 by 24 is classic full typewritten page.

Felsenstein: That's correct. I had, in fact, not found out how they did that. I'd assumed that you needed four times the memory if you got past the block that was one memory chip. Not true. You could do it with twice the memory and there's a way of folding it with the address line. Quite simple as it turns out. So there my strategy of trying not to learn the wrong way to do it failed utterly. I had not learned the right

way to do it. The VDM-2 was not complete, and I was standing with it on the floor of the Javits Convention Center in New York City, trying to find Processor Technology's booth in the summer of '79, and they weren't there. I found out the company had closed. I have heard a rumor since, but I don't want to pass on rumors as truth, that it had to do with personal conflict between the CEO and the VP. The VP was Bob Marsh. CEO was Gary Ingram, who's dead now. So I'll leave that for others to investigate. All I knew was, all of a sudden, as I put it in a little article for Dr. Dobb's Journal, Processor Technology's meteoric attempt to achieve greatness through liquidation left me with this design. I tried to sell it. Nobody would buy it. It takes more than a good design. It has to fit into where it's going. So I was at loose ends at that point, and the money was cut off. No royalties anymore.

I began taking on whatever contracts I could, and there was one. I got a contract from Adam Osborne at the Osborne-McGraw. He had just sold it to McGraw-Hill. I don't know whether it was called McGraw-Hill yet, Osborne Associates. He had set up a little hardware development operation with a couple of guys, one of whom, Curt Ingraham, was a guy who replaced me at Ampex when I left, oddly enough. The other guy, Pat McGuire, wound up helping me in the design of the Osborne computer. And so I did a little contract for him, another little contract editing some of the manuscripts. In the Computer Fair of 1980, which would have been the Spring, Adam Osborne hailed me and said, "Lee, I want to talk to you." He was at his booth. I was walking from our Community Memory booth.. And he said, "I want to start a hardware company and really do things right." I said, "You know, I'm up for it", because of course, I had no other source of income. I'll be up for anything. And the idea of doing things right was a great idea. I'd like to try it sometime. This became first Brandywine Holdings Company, and the guy who was contracted to do the business card for it was apparently only given verbal instructions, and turned out a nice business card for Brandy Wine Holders, which was the only sense he could make out of it, and that became Osborne Computer. Adam Osborne claimed to have come up with the idea himself, but as far as I can tell, the idea, the basic design of the Osborne computer, which was a Z80-based CP/M machine with two floppy disk drives, which were then full size, well, mini full floppies, five inch floppies, a five inch display monitor, and enough RAM to do something, serial port, parallel port. This design had been floating around the industry at least since 1978. I have told whomever I can, you know, whoever's interested, what I know about it. A fellow named Blair Newman claimed to have come up with the design, together with Trip Hawkins, when they were consultants to Apple, although Steve Jobs would hear none of it. That design was sort of around, and that's what Trip Hawkins said. That design was around. Everybody says that design was around the industry. There was a connection back to the Xerox PARC. I don't know, remember if it was Sketchpad. That's software. But it was Notepad, I think they called it, which looked a lot like the Osborne, wound up looking like this.

Crosby: [Xerox] NoteTaker?

Felsenstein: NoteTaker. That would have been it. It had a huge joystick in the keyboard. But otherwise, it's not that far different externally. So after, at Osborne's request, I had submitted some ideas of devices to build. He then said, "I know what we're going to do." And he just laid out this design, which he sketched on some grid paper. He clearly wasn't very good at drawing things. It had to fit under an airline seat. It had to be closed up entirely, sealed entirely when it was closed. It had the five inch screen. He wanted 40 characters per line. This is what the Apple II had, and two five inch floppy disks. He wanted it to run CP/M. He didn't know whether that would mean a Z-80 or an 8085. And, in fact, when I did the prototype board for it, it was laid out for either one. We never built them with an 8085. And it had, I built it with 64KB of RAM, because it was populated up to wherever we wanted. But 64KB was the limit for an 8-bit processor. What else? It was going to have pockets under the disk drives for the disks themselves, floppy disks. That was actually quite an innovation on his part. Nobody would

have thought of that otherwise. So that when you closed the case up, you had an entire computer system including software, which came with the computer. The bundling of software was something that IBM had done in the past, but that was on a mainframe basis, rental of the computer. And, yes, you got the software with it, so you didn't go do things like write your own software, or commission someone else to write it and provide print, you know, third party software. They didn't want third party anything. Third party software was really a mainstay of the Osborne. I mean, he could provide a certain number of things. He licensed Microsoft BASIC, Control BASIC, which was a compiled BASIC, and he commissioned SuperCalc, which was basically a clone, an improvement on VisiCalc. And then the fourth one was WordStar, which he licensed from…

Crosby: MicroPro.

Felsenstein: MicroPro was the company, yeah. And all this was done with deals of stock and so forth for funny money, in effect. And nobody could figure out how he could get all of that software at that price. You certainly couldn't buy it at that price. The price point went to $1,795. I don't how he talked up from $1,395. He wanted to make it as cheap as possible, even cheaper. And he also, since he had trained as a chemical engineer, done programming in the area of chemical engineering, he wanted it especially to be able to drive the IEEE-488 control bus, which was only used for instrumentation in labs. And we were able to do that with a generalized parallel port, and some software. But the Osborne was, well, the first ones we made, we made 10 units with metal cases, and a transformer power supply. Now, a transformer puts out a magnetic field. The CRT display picks it up, and the display would shimmy. It was like, I call it a Hawaiian effect, because of the difference between its sweep rate and the magnetic field, which you can't really control. Also, it was tremendously heavy. It was 30 pounds. Some of the first ones used in the first ads, like "the guy on the left doesn't stand a chance ad", were the metal units, and you could see the veins bulging in the hand that's holding it. I know because I had to carry two of them from Sixth and Mission Streets to the Civic Center, Brooks Hall, or was it, I don't know which one it was, Brooks or Civic Center, but for the Computer Fair in 1981. And that nearly pulled my arms out of my sockets. Then at that show, a guy from a manufacturer gave me a power supply. "Here, try this", switching power supply, much smaller and lighter, not subject to the magnetic process. Solved a lot of problems for us.

Osborne Computer had been incorporated, I think at the beginning of 1981. I had been working on the prototype, and Richard Frank of Sorcim, which created SuperCalc, was also contracted to create the ROM BIOS [Basic Input Output System] for it, in effect. And in late 1980, I was traveling down to Sunnyvale, where they had a suite, some office suites at Lawrence Expressway and El Camino Real, and helping out on the hardware where he continued developing software. And we got buildings in Hayward, at least in the beginning of '81. Adam hired a general manger who was this kind of New York street fighter in the way he presented himself, and his resume was actually fraudulent, except for one thing, where he had actually come in and saved Cermetek, the manufacturer of components, from bankruptcy. Under such leadership we were aggressive but we weren't too skilled at putting together a company.

END OF TAPE 3 / BEGINNING OF TAPE 4

Felsenstein: The Homebrew Club evolved from the first meeting where we passed around a list, this was something I suggested and certainly, Fred Moore was going to do it anyway, so people could sign their names and contact information and some indication of what they were going to be doing, or what they wanted to do. This was exactly what Community Memory did successfully-- secondary information exchange, how to contact and some information on why, but don't go into all the details. And that's how I

designed the meetings of the Homebrew Club after the fourth meeting, maybe it was starting at the fourth meeting. Gordon French ran the meetings. And Gordon felt that he had a lot of expertise with computers, which he did, and he was going to try to convey that information to everybody there who clearly needed it. It was the, I don't know, the third meeting, perhaps, second meeting, maybe, at the Peninsula School which is this huge Victorian building which is used for a kind of alternative school, therefore, it has a set up for, you know, a stage and lectures and so forth. Gordon was standing up in front, trying to give a lecture on software and the place was full of people, I don't know, a hundred people or more. And they all, not all, but half of them went outside to the hallway where we were industriously, you know, exchanging information on who we were and what we wanted to do. I saw this happening, I figured this process has to be brought into the meeting. I was given that chance at the fourth meeting when Gordon basically said, "I can't be here, I've got to go to Baltimore to do some work for the Social Security Administration, who wants to handle the meeting?" And Marty Spergel in the audience put my name up for nomination right away. And there weren't many other takers. So I began to experiment there.

Now the idea is secondary information transfer, then follow that with primary information transfer. That was the mapping session for the secondary and Random Access Session. As the name implies, you couldn't keep track of all the interactions there. But you had to have the mapping so you'd know who to contact. People were going to come there who'd never met, had no communication beforehand and needed to meet people that they didn't know they needed to meet. So I decided we'd try this out and we'd do it iteratively, which is how you converge upon a solution, where there is a solution, well, there isn't in this case. I never got them to reconvene after the first Random Access Session. That worked too well. And that's the way the meetings ran thereafter, and it was very successful. By 1978, the time of the second West Coast Computer Faire, I think the one at San Jose, they had two that year, one in Los Angeles, our membership list was a roll of Teletype paper with 3,000 names and addresses on it. That list exists. I'd be surprised if the Computer [History] Museum doesn't have it.

We were meeting in the Stanford Linear Accelerator Center [SLAC] Auditorium after a few meetings at some ancillary rooms there, one of which we decided to call the Homebrew Computer Club. Other ideas were Steam Beer Computer Club, that was a favorite of Bob Albrecht and I came up with 8-bit Byte Bangers, which didn't make it and Tiny Brains. Homebrew Club was fine, Homebrew Computer Club. We didn't have any organization until later. So in 1976 a nonprofit corporation was formed, I was on the board of it. And there were five members on the board. Those were the only legal members of that corporation, therefore the only members of the Homebrew Club. And this is a trick question that can be asked. But the organization, fortunately, was irrelevant to the operation of the club and that was, I think, a real benefit.

Southern California Computer Society didn't go that way. They had a standard organizational structure with Robert's Rules of Orders, they were publishing a magazine, the magazine was making some money, and it all fell apart. The magazine wound up outside the company-- or the corporation, everybody started fighting over the remains, so we avoided all of that by not having an organization. We did it all with voluntary donations, we made a solicitation for the donations at every meeting and I explained that the Homebrew Club does not exist, which meant, so what are we doing here? We are the club, right now, today. And I would use the pointer, the famous blackboard pointer to indicate who should speak next for, supposedly, I said nominal 90 seconds, but selectively enforced. My job, at the front of the meeting was not to direct them in any way, but to prevent them from veering off in any direction. Meaning, if somebody started to give the details of what they wanted everybody to know, I had to stop them, and I'd say, "Do that during Random Access. All you should talk about is what you want to talk about, don't tell us what it

is." And then I told everyone, at every meeting, "Please don't come up to me afterwards and ask who was it that said this or that, I won't know." I assumed my persona that I was developing of a sort of a pompous manager and say, "I'm far too busy, concerned about my image." There were a few other jokes that I would pull in that regard, but that didn't have to really last.

The important thing was that I did not interpose myself in the communications stream except to shut it down, where appropriate [and] move on to the next person. I had a lot of critics in the audience, chief of which was Jim Warren, who'd signal me when he felt is was going-- getting out of hand and <waves hand>, all right, I had to-- I could, of course, see everybody's face. And especially when a back and forth argument occurred, you could see the lights go out all over the audience. I didn't need Jim Warren to tell me that. So my job was to interrupt that argument, usually with a joke of some sort. And this is very interesting training in stagecraft, I must say. If somebody had told me this is what I'd have to do, I probably would have not volunteered for it. But I just found this out along the way.

People still come up to me and say, "You probably don't remember me. I attended meetings of a Homebrew Computer club and you were saying some really important things." Well, the first few times this happened, I tried to tell them, I didn't say anything, you said everything. But it wasn't me. I was there to stop people from saying things and move it on to the next person. And nobody wanted to hear that. So I then decided, what they need is a blessing. And so that's been my response, I'd say, "Yes, we were all saying really important stuff." I always turned it to we, which was true. But I had to say yes, not no and they like it. Even John Doerr of Kleiner Perkins came up to me, and he had been an engineer at Intel at that time and he said the same thing and I said the same thing. And that was probably the most powerful person I've yet run into, who has-- came through the Homebrew experience. We don't know how many people attended there overall. I mean, the mailing list went on, but of course, it's an ongoing thing. I don't know what the mailing list ended up at, or whether it was ever purged, someone's going to have to look into that. But I don't know it.

The Homebrew Club was the place where in the first, certainly, two years, or maybe three years, from '75 to '78 and some arguments can say '79 or '80, where if you wanted to be involved in the personal computer industry, you had to go there. You also should get the newsletter and give a donation which helps with the subscription. There wasn't a subscription rate, but you could get the newsletter and be involved in the information stream that way. Until enough companies got started and specialization began to occur, that was the one place. It was the personal computer user's group, in fact. But it couldn't last that way, because things were growing and software was developing and other kinds of technologies-- communication technologies were developing. And so you might say that right from the beginning it was doomed. In fact, it lasted much longer than it had a real rationale to exist. The last several years, there was nothing but the same group of people who would come just to talk about what was happening and nobody was ever doing anything. And I finally decided to shut it down in December of 1986. But the Homebrew Club was responsible-- or was the venue for which 23 companies that we could identify originated. And this included Apple. I remember Steve Wozniak at the first meeting and his item in the handout, which-- in the signup list was that he had this TV typewriter design, he had done this breakout game and was interested in doing these things, which became the Apple I and then the Apple II. Most of the companies that we could identify are gone now. A few of them have morphed into other things. *InfoWorld*, for instance, came out of that because that was Jim Warren's *Journal of Intelligent Machines*, JIM, that he published. And so that is probably still-- I think *InfoWorld* may or may not still survive, I've lost track of it. But most of the other-- the only other one we found that had survived for a long time was The Computer Doctors in, I think, Palo Alto, which was doing computer repair. I don't know whether they are still in business, I doubt it. Everything else was transitory, but then, that's the nature of an industry

that's developing. The structure was, you know, we don't have a definitive list of attendees, all those things that historians want and business analysts demand, we don't have. But, as the-- I can almost remember the name of the Roman Emperor, he said, "If you seek my monument, look about you." It's where the personal computer industry, certainly not the computer industry-- that was already in existence, in the Silicon Valley where it grew from. And I call it my most productive design, that is to say the design of the meeting structure. Okay, how do we-- oh yes.

Crosby: Micro Expanders.

Felsenstein: Right.

Len Shustek: Talk about the sharing of software and the Bill Gates era.

Felsenstein: Oh, right, sure. One of the most important events in the Homebrew Computer Club history occurred quite early. As various accounts have made it clear, a copy of Microsoft BASIC was brought through the area, I think in late '75, and one copy was lifted. And it turned up being copied around. In fact, the Homebrew Club where the place where you could bring it and, you know, I would say, "Here's the software, bring back more copies of it." Because we all considered the personal computer not to be complete without software of some kind. I mean, what could you do with a box that you could key in a program, this is not very useful. Although Steve Dompier did, in that third meeting at the Peninsula School, demonstrate the computer making music through a radio that was adjacent to it by using the loops in the program to create noise that the radio picked up at different frequencies.

Crosby: "Fool on the Hill," right?

Felsenstein: "Fool on the Hill" was the first one he played and then it went on to "Daisy, Daisy," which of course was the archetypal first computer song, having been done in 1957 by Max Mathews at Bell Labs on an IBM 701 or something. So the Microsoft BASIC was being copied around and because Microsoft BASIC was what you had to pay $500 or more for, from MITS, to make their box finally work, as the way we saw it. And we already paid, not only $500 to MITS, we'd invested far more in terms of our time and brainpower and so forth. So no one was much in a mood to say, "Oh, I'll just come up with another $500 here and give it to them." You know, that box isn't working until it has that software in it, that's, kind of, how we saw it. Well, Bill Gates didn't see it that way. Bill Gates, as Micro “hyphen” Soft in Albuquerque, New Mexico felt that he was being denied sales and he was counting on that $500 from everybody. So he wrote an open letter to hobbyists and we read it to the meeting where he basically said we used $40,000 worth of computer time to develop that BASIC and we want our money out of it. Well, we all knew what computer time-- the evaluation of computer time was the ultimate in funny money. You never pay that much for the computer time and I think that research will show that they were using someone else's computer time; someone else was paying for that. It could have been Honeywell where Paul Allen was working. So we all knew this to be a spurious argument. And I doubt that anyone sent in the $500 that Bill Gates requested from that letter. And this, kind of, delineated a rift within the industry. Well, there's the actual industry where there's trying to make money and there's those hobbyist where we're trying to make things happen.

The industry needs the hobbyists and this was illustrated by what happened eventually. When National Semiconductor, which made their own microprocessor chips in '77 or '78, decided they needed a BASIC to go with the chip to make it work, rather, as we decided ourselves, they asked, "What's the most popular

BASIC?" And the answer was Microsoft BASIC because everybody had copied it and everybody was using it. So we made Microsoft the standard BASIC. National Semiconductor went to Microsoft and bought a license, they were in business that way. This was the marketing function and the hobbyists did the marketing with a complete antipathy of the company in question. There were other BASICs and, you know, some of them might even have been better. So I make a, kind of, ironic comment to this about yes, it's a terrible shame that Bill Gates didn't get his money for those BASICs, the kid could have amounted to something. Well, he did amount to something and it was in a certain measure because of what we did, that he said we shouldn't do, we were thieves to do it, and all.

In 1979, after Processor Technology folded up its tent and I was left without income, somebody showed up, a Swedish fellow named Mats Ingemanson. And he had an idea for a computer and he had some backing for it. It basically was going to look more or less exactly like an Apple II, but was it was going to be a CP/M machine and it was going to have color in its graphics. It was also going to use, I think, Radio Shack graphics, which is a pretty clumsy subdivision of the character into six cells and you can have those dots lit up, so it became a crude graphics device. And he wanted me to contract to design it, so I did and this became the Micro Expander. Mats is one of those examples of the virtual entrepreneur, I'll just put it that way. He had apparently some backing from the Swedish government, as I later found out, although the terms for that, I can't quite imagine what they were. He had no organization at all and as it turns out, he couldn't pay for the production of the machines. So that's where that all ended, 200 of them were build by ManuTronics in Kenosha, Wisconsin under contract. No more than one or two were paid for and there's one of two of them around somewhere, I don't know where the rest of them went, I think ManuTronics tried to sell them, but couldn't. So it's one of the rarest computers there are and I had to turn that job over to Bob Marsh to complete. And Bob, of course, was available having closed the company. So he did the work completing it and documenting it for manufacturing. The Micro Expander was a highly derivative design, let's put it that way. I can't think of anything. It did have 24x80, because by that time I'd learned how to do it, 24x80 character layout. And I believe that it would use S-100 cards, my recollections are not absolute on that score. But the Expander name, of course, implied expansion with cards and they'd asked if we could do that. I'm pretty sure that's what it had.

So that was a interim event, I hadn't yet handed that off to Bob Marsh. By that [time] Adam Osborne showed up and I had started on the design of the Osborne I. So that lasted from sometime late in 1979 into 1980 and was displaced by the Osborne I, in terms of my involvement. In 1980, I was sharing a large cavernous room in a building at 916 Parker Street, I think, in Berkeley, sharing that with Community Memory Project, I was paying the rent. And that was where the first Osborne design was done. That was me and Pat McGuire, who had worked for Osborne Associates. It was suggested that I take him on to help me and he was given the task of designing the control board for the floppy disk, meaning the board that's mounted to the disk drive, the bare metal disk drive and interfaced with the heads and the stepper and everything. And he did an incredible job with that. Adam seemed to think that he could get floppy disk mini-- you know, five-inch floppy disk drives without any electronics, and just slap together our electronics on it and off they would go. Well, there is an alignment step that's necessary to adjust it, adjust the stepper and everything, adjust the head position. He didn't bargain on that. And by that time he had set up in a building in Hayward, in the corporate way, I guess, I don't know what the industrial park is, and it was a space that was to be filled up by marketing, immediately it had to be filled up by benches full of people adjusting floppy disks.

Osborne had tremendous marketing exposure, let's say. It was a good product that everybody wanted to have. I'm not sure who said, maybe Adam, but I don't think so-- most of them, being portable computers, were only carried from one side of the office to the other, but that was enough. It was enough that when

you buttoned it up, everything was in there. So in a way, the innovation in that design pretty much was the marketing aspect, meaning the product conceptualization, the pockets for the disks and the included software. I've been known to say and I guess I'll still say it, that Adam Osborne was the father of the Osborne I, I was the mother. I did the work and he has written that any one of 500 engineers in the Silicon Valley could have designed the Osborne I. Well, I don't know, I think that when it came time to design the timing circuit that controlled the dance between the video and the computer access and did it using the cycle that the Z80 produces, I think I was pretty innovative in that regard. It was done with, something like, two chips and these are small chips. I have reviewed that circuit on a video that the Computer Barn has put out. Even so, I don't have the original diagrams, so I wasn't able to be accurate with it.

As a company, Osborne, as I've said-- as a company Osborne was basically another amateur operation, although pretending to be a professional operation. The general manager was very good at securing cooperation from company's suppliers, without even writing down purchase orders, this is almost unheard of. And he told me that we've got to keep the shipments coming in from the suppliers or the whole thing falls apart. Basically, he had no commitments in writing from any of the suppliers to deliver what had to be done. And there came a time when we began to develop problems with the software and nobody knew what this was. Pat McGuire had, after he'd done the disk design, he'd put together a system of the maximum number of floppy disks he could have, four, with an Osborne board and that became our disk duplicator. All day long people were pushing disks in and copying the software off. Well, even though our manager for production had come from the hard disk industry, nobody thought to clean the heads on the duplicator. And so dirt piled up on them, the recordings became weaker and weaker and suddenly they began failing. Adam and most of the executives were out of town when this hit. George Epsiars [ph?], who was the VP of marketing and very sensitive to issues of quality, demanded that we stop production to fix this problem. I insisted that we would not, and I simply said I won't do it because I knew-- I'd been told that you can kiss the company goodbye if we stop production, and dug in my heels.

And so finally a compromise was developed in which the company would rent the next section of the building over, the building was divided into three sections. The shipments would all go to that building, to marketing. They would be the ones who receive the shipments. And they hired temporary workers to walk up and down the aisle and poke disks in and out and try things, but nobody knew what they were going to do. Eventually, in the midst of this, Pat McGuire sat up and said, "Has anybody cleaned the heads?" And everyone looked at each other and no, no one had cleaned the heads. Basically, we had probably never cleaned the heads and because the duplication was moved over to a commercial service and that was the end of that problem. And we then had another section of the building, we had pretty much all the temporary employees became permanent employees, it's a very haphazard way to develop the disks, even though the projections looked tremendous. The projection had to be reduced at the outset.

Osborne lived on enthusiasm of its employees and of its customers. What's called the Osborne mistake of pre-announcing a product and not being able to ship it, I think, is overrated. The company structure, itself, was really rotten, almost from the beginning. You can only do a certain amount of papering-over problems, in my analysis. And there's a lot of papering-over that went on. I think that the analysis of what happened with Osborne fundamentally is that they were not able to control inventory. And since cash is flowing through the company, any pileups, any blockage in that system, mainly through inventory mismanagement, can put you out of money right away. The Osborne Executive took, maybe, 18 months to get designed, even though the Osborne I took, maybe, seven months to get designed and ready for manufacture.

It was my conclusion that the company had never learned how to put a product into production and the first one doesn't count when you grow the company around the product. By that time, there were some additional layers of management. And I'd heard stories, one related to me by Zenith, who supplied the power supplies, that the power supplies were coming down the line, they needed to know how long to make the wires for the supply. And they talked to some engineer, his name I never did find out, who said, "Well, I know how long to make them, but I don't think I should tell you," sort of, politics. Whereupon the guy who's telling me the story says he turned into someone else and said, "Make them 36 inches long." And as soon as they were received, they got the information they wanted. But the fact that something like that could go on in there is really indicative of the organizational dysfunction. There are many other stories, but I don't think that's really the issue here. The new generation of management was brought in. The new general manager came from the soft drink company, just like the general manager of Apple, the CEO of Apple. So it was a little bit imitative in that way. And at that point, I was no longer informed of when board meetings were occurring. I was the Vice President and I was a major investor because I'd been given 25, actually 24 percent of the company in exchange for the design, plus a small amount of money to keep me alive during the design process. Adam was very willing to use stock as a value. In fact, he even discussed the possibility of shipping stock certificates with every unit sold, or some coupon good for the stock. And of course, no one else in the company would support that. There's just things you can do and things you can't do. So by the time the Executive was introduced-- the Executive was intended to be used with MP/M, sort of, the next version of CP/M, it had 128KB of memory. But [it] was organized in a paging structure that I laid out, which meant that you really only had a little over 64KB for program memory and you could make it accessible from different pages, I don't know quite why, but there was a reason at the time.

Crosby: But if the Executive was running MP/M, was it intended to be an innately networkable machine?

Felsenstein: I can't answer that, I don't know. I'm not at all sure MP/M was ever implemented on it. I think it just went out with CP/M. So that's a question no one will ever know the answer to. It wasn't but what people were thinking, hard to tell. The company was still learning how to do marketing. We finally got a VP of engineering named John Hanne, H-A-N-N-E, from Texas Instruments, who actually was a competent engineering vice president. I can't say I was competent, I was moved out of that position and given a title of R&D Fellow, whereupon I took my vice presidential rank seriously and went and signed a contract for additional rental space elsewhere and set up an R&D operation there, where we developed the Executive as well as others.

Crosby: Did you have anything to do with the Vixen?

Felsenstein: I had very little to do with the Vixen. The Vixen originated with Fred Khoury, K-H-O-U-R-Y, who was a friend of Adam's and someone I'd met through the Asilomar Microcomputer Conference. And he proposed a device, which in theory would all be done in a ROM, which was not that easy to do, and it would be small. It was a great physical case design, the only problem with is was, even though it was using half-high floppies, it weighed almost as much as the Osborne I, 23-and-a-half pounds. And when you make something smaller and it doesn't get any lighter, people perceive it as being heavier. I call that the expectation gap. That design was handed to a consultant who must have been on drugs, I don't know, or crazy, because at one point he disappeared along with the prototype. And I wanted to go after him and find him, but I was, sort of, stopped from doing so. I had other things I needed to do. And eventually after the bankruptcy, the design was restarted. They, in fact, had to find the same flaws that we had found already. The documentation really wasn't adequate that way, so it eventually got out and I

don't know if it would have made a lot of difference, but again, it was a pretty good mechanical design. Otherwise, pretty much, I wouldn't say identical with an Osborne I, but did everything an Osborne I did.

We were supposed to do an IBM Compatible. What Adam said was, "Well, it's just going to be a little co-processor board and there's this company that builds co-processor boards and we'll just go to them and get them to make a co-processor board and put an 8088 on it and it'll just work." So on the Executive we had a connector that was intended for this board, but we didn't know what the board would be like. Eventually, people started learning the hard way how to do marketing product development and deciding, well, what is it that's got to be a compatible. John Hanne came in and organized this process, came up with the maxim that better is different is incompatible. And so we had to keep it identical with the IBM PC version-- which, by that time, of course, had been on the market since 1981-- and resist all attempts to improve. And what he decided to do eventually was to buy a design, which was designed by a fellow named John Babble B-A-B-B-L-E, I believe, or I think it's L-E, for a company called MAD, M-A-D, MAD Computers. He had the design, it was all drawn on one sheet of paper and I rationalized the drawings. I drew it with the proper way and he later asked if he could use my drawing for his, you know, work with MAD, which I agreed to. So we basically took a design that someone else designed, bought it and then fit it to the kind of board we needed. This was underway when the bankruptcy took place. Our VP for finance, or the controller, tried to throw me out of the labs because I'd actually resigned and I was coming in on my own time to keep working on it. I appealed to John Hanne, who made that stop happening and assured me that I would get paid for my time. I eventually got $78 after the, a few years ago.

After the bankruptcy it did emerge from Chapter 11, it put out the Vixen, it put out a, what do you call, a lunchbox computer, which is a–- I think designed by George Mar [ph?], but I'm not sure, it's like the Zenith, which had a LCD screen that would kind of prop up a little bit from the side and a keyboard that would either fold down or come out somehow. I was out of the picture by that time. And so, I don't know what else they might have done or, you know. By that time, September or '83, by October I had announced my resignation and then outraged the VP for Finance, but-- and was, at that time I had been contacted by one of the five Japanese companies that we had been negotiating with about doing a laptop and asked by two of them if I'd like to do a laptop for them. Maybe we can pick up on that later.

END OF TAPE 4 / BEGINNING OF TAPE 5

Crosby: Now in 1979, you started a company called Golemics.

Felsenstein: Yes, Golemics, Incorporated. I sort of took the name from a book by Norbert Wiener, *God and Golem, Incorporated*, which is a little bit more of a philosophical book of his, one of his last books that I read in college. I developed an idea for the difference between robotics and something else, and something else I call Golemics. Now Golemics refers to the legends of the Golem, G-o-l-e-m, not G-o-l-o-u-m from Tolkien. It has nothing to do with it.

Crosby: But G-o-l-e-m from cabalistic mythology.

Felsenstein: Pretty much, yes. Golem in Hebrew means something which is unfinished, and the stories in question seem to date from the middle ages in the ghettos said to be of Prague. And it was about a rabbi who used cabalistic technology to create and animate a clay figure so that it would walk around, and it was to be the defender of the community, which needed defending at that time. And the story we're most familiar with that stems from this is known as the story of the *Sorcerer's Apprentice*, outside of

Yiddish literature. So this is a story where someone who knows something about it creates an animate being, sets it in motion and then discovers he can't control it. And this has to be overridden when the person who knows more about this comes and turns it off. That's a great computer story. Most of us know about the *Sorcerer's Apprentice* from the Disney "Fantasia" cartoon, so I'm not sure how much of it I have to recount. But my point here is that the story of the Golem makes the point that using technology, people are able to get beyond their capabilities, which can be good, but also beyond their understanding, which can be not so good. And we just have to live with this is the point, and find out how to live with it. So that when we create a computer, we shouldn't be surprised when the program goes somewhere else than what we wanted it to do and we have to allow for this. In the very symbolic Jewish literary fashion, the Golem represents man's lower nature. And if we exalt that nature too high, we could have trouble, and so we need to be humble about that and know that even if we think we know what we're doing, chances are we don't. And the question of how far you have to fall to find that out is just the hope that we can learn that in time.

Crosby: And of course, Freud recapitulated that idea with the idea of the Id and the superego, which was an attempt to control it.

Felsenstein: Yeah.

Crosby: Bring your Id up too high, you're in trouble.

Felsenstein: You are in trouble, correct. Well I did a piece that was printed in the *Journal of the West Coast Computer Faire* in 1980 on the Golemic approach. And the important thing about this, I got this really from Steve Dompier again. Back in 1975, he had tried to do in BASIC a crude flight simulator program, because he wanted to deal with data by flying around. Now he was a licensed pilot and so he wanted to treat it as a video game in affect. And that's what motivated him in a lot of the stuff he did with graphics. I think he, eventually, after Processor Technology, founded Island Graphics, where they built most of the paint programs that are in use.

So I took that and said a video game is a very highly interactive system and that's a good way to handle data. Whatever it is, you have to get a feel for the system. I mean it's only a computer and some joysticks or something. But nonetheless, it's got a feel to it and you have to gain that feel before you can successfully fly around, navigate or whatever. So I was looking at how we could look at that, and I stumbled upon the fact that there's the feedback diagram. You have input coming from somewhere outside. You have a box that's the prime mover and that produces force, let's say. Then you have a feedback path going back through another box which has some mathematical transfer function or other, some behavior, and it goes and it modifies the input. And that creates, if properly done, a negative feedback system that will stabilize. So for instance, power steering on a car, you turn the wheel, your pump starts moving your wheels, although-- but I will get to the although in a moment, because that's sort of the Golemic part of it. And then you don't want to turn it too far. The first time I steered a car, I went, you know, in serpentine fashion, but quickly got the feel for the system and was able to realize that if you hold it steady, it goes straight, that sort of thing. Well in general, computer systems, rather than being robotic, which is what the feedback system is, I mean it's the definition of a robot-- and Norbert Wiener did a lot of writing about that because he was there at the inception of feedback systems. The user is outside. The user is generating the input. What goes on inside the system he has really no more control over.

A Golemic system we can define as the user in the feedback loop being presented with processed information like a video game would do, and giving input and having to learn the system. Now there's all kinds of variations that can be made on this, and a lot to be discovered as to how people can work this way. But basically, the control systems people use that are successful are Golemic in nature. So take power steering, as I mentioned. Well, it won't work if you don't have a feel back through the wheel. It has to resist to a certain extent. There's no reason why it should. It's just an input. But without that feedback, that tactile feedback to the user, you've got trouble. You also need to gain a kinesthetic sense of the car as an extension of your body. That's what I had to gain when I was weaving down the street, and finally was able to stabilize. Somebody should be designing things that enhance and work with those capabilities, and that's when I decided that I would be able to do [it], because I was very interested in it.

I was, at that point, experimenting with some crude devices which would be what I call virtual mouse. In this case, it's really just a box with four buttons on the bottom and you could rock it around. And the question is what you did with software to move the cursor, the image or whatever that way. And I filed a patent, which is just expiring either this year or next year, for a technique of control where you have an actuator that gives you no feedback. You just push on it. It just sits there. It's called a force operated joystick or an isometric actuator. It gives you no pressure back. All the information you have about what's happening is what you see on the screen as you move the cursor. There's a principle I stumbled upon of different motion equations for command in speeding versus slowing, which mapped to how we control our own body when we move it. And when you launch your arm, you don't really know where it's going, but then when you start slowing it down is when you become involved in precision control. So that was an example of a kind of Golemic principle that can be applied in a Golemic system. So my concept here was that the robot, as the autonomous device which takes orders from the human, isn't ever really going to work, because we don't understand how to give it the right orders or in the right way that is going to work within the real world with other people. However, the Golemic system, where we are constantly interacting with the operation of the machine and using processed and expanded information through graphics, sound, whatever tactile input – pull on our analog senses. That has been known to work and needs more development.

So that was my idea for what Golemics might do and where the name came from. I incorporated it because when I started getting royalties, I figured well I'm going to have employees now. I'm going to have an invention shop and so forth and from a legal standpoint, it's safest to have a corporation handle that. So I incorporated in 1979. I incorporated Golemics as a chapter C corporation. It was Golemics that actually contracted with Osborne to design the Osborne 1, and Pat McGuire was, I believe, an employee, probably subcontractor. I don't know which one. It was Golemics that held the stock for Osborne. That was part of that contract. But it didn't do anything during Osborne, and was there when Osborne ended. Now in the latter year of Osborne, we were in negotiations with five Japanese companies, I think; OKI, Ricoh, Toshiba-- I'm starting to run out of names here.

Crosby: Matsushita?

Felsenstein: I don't know if Matsushita was involved. It could have been Panasonic, and possibly NEC. And there was a trip that I made with Adam to Japan and we visited all of these companies. Epson was another one. I can remember them more geographically -- Sharp in Osaka. They had people coming to us, teams coming in and they would say, "Please give us your exact specifications and we will quote for what you want us to do." And we said, "We do not have exact specifications. Please, let's discuss what you can do."

Felsenstein: Adam would greet the Japanese teams and shake hands with them and then turn the meeting over to me. I never knew what kind of negotiator he was. He certainly wasn't a technical kind of a person. And they would say, "Please tell us what you want me to do," and I'd say, "We don't know what we want you to do. I want to find out what you can do." So we began exploring what elements of a laptop computer they could provide. And I know there was Toshiba and Hitachi making 3-inch disk drives, so each of them is different. It wasn't till later that the Sony 3.5 inch disk was standardized, in effect, by Steve Jobs committing to it for Apple. And we would put that out and discuss what displays you could have. I wanted, with Osborne at the outset, to do a Dynabook. I said as much. I wrote a little presentation. The trouble is we didn't have the technology available to do a Dynabook, and the Dynabook would have been the equivalent of a laptop computer today. But that was always the intention and this was heading in that direction.

So when the company went bankrupt, two of the companies got in touch with me, OKI and Ricoh and said, "We would like to discuss your designing an IBM compatible computer for us," and I went with OKI, eventually. I went over to Japan again and we negotiated in the Japanese tradition. Apparently, when it's a small guy negotiating with a big guy, the big guy basically sends another guy over to tell you what they will give you and you accept it, and that went okay. They had their own *gaigin*, an English guy named Jeff Hughes to do this. So Golemics undertook a contract to develop an IBM compatible computer for OKI. The value of the contract was $800,000 as it turned out, and it went for about a year, maybe a little more because there were stages to it. This would include monochrome, color, LCD display adaptors, a hard disk controller, ROM BIOS and the CPU logic, and it was all to be designed so that it could be put into LSI chips later. The IBM PC design had certain areas, as we found out when we analyzed it, where they were outside the limits of what they were allowed to do in terms of the timing of the chips, and there were certain places where there were sockets for the chips, not everywhere, but it became obvious that those were the critical chips and they had to try different chips until they worked. So we had to do it otherwise, so that you could cook it into silicon, not get a chance to try anything afterwards. And with the help of Mimi Montgomery, my vice president at the time, we assembled a team of ten contractors, had six in-house employees, and we worked from the fall of '83 through '84 pretty much, and delivered ten units as contracted. It took all night to put one unit together, little portable PCs. We built them in Colby cases, which were these little extruded cases where you could take the innards of an IBM PC and put it into a case, have a handle on it, and made it portable and had a monitor.

They did not know what to do with this in a marketing sense and they killed the project. The guy who made that decision later said he regretted it, deciding at least not to go to the stage where it's put into chips. But it was a very valuable experience. It was the biggest project I've run so far. And after that, they came back and they wanted us to do a plasma panel controller that was IBM compatible and I did that. By that time, the number of people involved was smaller. They used that panel controller to demonstrate their panel for Compaq and they got the bid. They got the contract based on that, and I used a lot of what we had just learned about compatibility at Osborne to define that. Basically, a compatible had to run all the games, because the games had been written in the most slipshod fashion, making maximum use of the hardware, and even assuming that certain bits that weren't connected to anything would behave in a certain way, so you'd better not try using those bits for anything else. This is John Hiney's [ph?] better is different is incompatible principle proven. And we were able to do that and never had any complaints about the compatibility. On the other hand, the system never went to market.

So in '85 and into '86, I was taking on contracts through Golemics, did some work for Britton-Lee Corporation. They made a database engine. We were their backup contractors for their serial port. I had to confront the engineering manager, her idea of who she wanted working on it, had other people working

in a garage somewhere and she wasn't going to be supportive. We had been contacted by the president, himself, and had the pleasure of attending their rehearsal for the rollout in which that same engineering manager makes the announcement that well we have our network. It's RS-232. It was what we were developing as not the token ring network that this other team had not been able to deliver. We went on to do a token ring board for them and that was a living. The products you do in that case, the world never sees them, and you have to do them within a time frame and a money frame that sometimes I was less than able to do. I wanted to get involved in start-ups again of some sort and Ron Jones, who was probably one of the very few black guys in the industry, and he's quite a promoter sort of guy, he had developed a fundamental product which he called Color Blind which would take the color signals that come out of the 9-pin connector on this IBM color graphics adapter and would turn them into gray scale so that you could put them onto a TV and it would not be the mess that people were seeing at that time. At that time, Radio Shack had introduced the color computer, which was a PC. It had a color graphics adaptor and it only had the composite video output. And the composite video output goes to a color set, but the way color is represented in the signals is a series of stripes. And as the stripes change their phase, their position, relative to some stripes you don't see off there in the retrace interval, they change color. Well you put that on the screen of a TV and try to display characters that are smaller than the stripes and it's a mess. You can't read it. And Radio Shack was trying to sell this computer.

Crosby: Was this the one that was known as the TRS-80 CoCo [Color Computer]?

Felsenstein: No, not the TRS-80 Color Computer, per se. That's a different design. I don't know what they called it. I know they called it the color computer, but it wasn't the TRS-80. And so we took that design and I cleaned it up a little bit and we went through some of the FCC testing-- which was really the hard part of all this and I learned a great a great deal in that regard. And by that time, I had a new vice-president, John Boragine [ph?] and he got in touch with Radio Shack and they were willing to put it in their catalog for behind the counter items. In other words, you had to know about it. They weren't willing to put it out as a general thing they were selling. But we had to deliver it. I designed a color, I think, a very good cardboard hanger for it showing with a split screen, showing the difference between the two. The trouble is, we couldn't get any money to do it with and we wound up sitting in a café in a casino in Las Vegas talking with someone who had some connections with the teamsters' pension fund. And he kept talking about a loan, and we kept trying to say we're not talking about a loan here. We're talking about an investment. And fortunately, that discussion never went anywhere and we left town and decided not to go that far to try to seek money. And so I wound up taking all the cardboard backboards and recycling them. I saved one or two, but that product never saw the light of day.

Then there was Upstart Corporation in 1986. I got an idea for a product which would be a workstation on a board, an ISA board. ISA in this industry, standard architecture, is the IBM PC plug-in board. It predates the PCI boards and a few others. So the idea was this [AMD] 80386 was newly manufactured at that point. Nobody really knew it. It was a 32-bit processor. I figured we could now put what they used to call a 3M machine on an ISA board. 3M stands for one megaflop, I think, or million operations per second, a million pixels and a megabyte of memory. And so now things had gotten to the point where you could put that on an IBM plug-in board and basically replace the IBM computer with that one, use the rest of the PC for storage and I/O. And I added my signature element, which was shared memory for images. So now we have a memory that's a 300 dots per inch memory, black or white, which at that point was all you needed, because that's what a laser printer worked at, 300 dots per inch. In fact, you needed a 150 dot per inch display to see it, because otherwise, it was too fine a range, too fine a grain. And so we had that and we built a bitmap in a 300 dot per inch memory, and you can ship it out either to the screen, or on command, you can ship it to a laser engine. Now that's not a laser printer. It's what's

inside a laser printer. The laser engine is simply what writes the image a line at a time, a dot at a time. If you drew it out of the same memory, there was no way that two dots could be at different places between the two images. I called it PHYSIWYG, which is physical WYSIWYG, WYSIWYG meaning what you see is what you get, a nice concept, took a little bit of doing. We did get the 300 dots per image memory. We had a display at 150 dots per inch. We had a circuit that would smooth out the dots and convert from 300 to 150. We were able to print things off on a laser engine. We never did get to the point where we put the actual 80386 on the board. That was sort of pushed out to the future. And the prototype was sort of like a brick-like affair with a whole bunch of little boards sitting on one board. But we did get a promoter who got some preliminary financing for that, so we set up a company. Upstart Corporation I called it, because it was a startup and so why not. And everybody said oh I guarantee that's already taken. It wasn't taken. But we hired, for a CEO, someone who had been the passive half of an active/passive, or some might say manic depressive team in a company, and he seemed to spend all his time in the office incommunicado. We hired a lot of people and paid them, ran through the money that way. They didn't have anything to do and so when it finally came down to it, the final venture capitalist said we're going to pass on this. We're going to buy Sun [Microsystems] stock instead. I don't blame him. So that occupied most of 1986 and left me with about $30,000 in debt, and most of the investment I had gotten from my friends and family was about $30,000 each, so we all had the same pain.

And so by '87, I was in flight from that. The only thing remaining is my license plate which is Upstart, which I move from car to car. So then Golemics became just me and some little rented rooms or little rented offices in Berkeley. And the landlord in this case was Sam Troll[ph?], who was a professor of business at San Francisco State University. And Sam had been investigating a business school in the Soviet Union, which still existed at that time. He found me very interesting, and he actually sent me to the Soviet Union to supposedly research the personal computer industry there. That's what he told me. However, the business school people who had been visiting him and so forth, when we sat down in Moscow, they said well what are the deals you're offering? What deals have you brought for us? I hadn't been given any deal and I told them this. I'm just told to research the personal computer industry. So they basically said thank you very much, goodbye and left the room, but I was still free to come in and hang around, which I did for a couple of days. They didn't care. This was Perestroika out of the Soviet system was falling apart at that time, and it was not a case where they had to keep an eye on you and so I had had some contact.

Mainly, it started with John Draper, Captain Crunch, who had found himself sent to Moscow. This all happened through Henry Dakin and his little organization, which was trying to do video link-ups SF/Moscow teleport, is what they called it, trying to organize interchange between Soviet Union and us. So those people had some contacts over there. Draper went over, told his story. Draper was a crazy guy and everybody left shaking their head and muttering, but I had some contacts that way. So I followed these contacts. These are hackers in Moscow, one of whom lives here now in part because he pumped me for information about what is it like working in the States in software. I could tell him something. But anyway, so I got connected with a certain network of hackers there and came back. I did some publicity and a fellow named Peter Alexander, who is an émigré himself got in touch with me and he wanted to partner with me. He would be doing the sales work and stuff and we'll see what we could develop as a consulting company. And so for a little while, he was going over there. He was dealing with the business school people. They had come out of the USA/Canada Institute. I don't know which ministry it was, but basically, the people whose job was to keep track of the USA. So they set up a business school and I wound up lecturing, going to other classes. When I came back, I turned in what Peter said was a high quality report of my observations, because I clearly had been sent just to watch, take a look at them and just figure out what was going on, but that was never made clear to me. It was sort of made clear at the end.

I wound up going back in 1991. We formed a partnership that we called GLAV-PC. That's G-l-a-v-P-C. Glav is short for *glavni*, which in Russian means 'general,' 'main with implications of big time.' A lot of these Bolshevik kind of bureaucracies were glav this. Glav Lit was the literature agency and so forth. And this got a smile from the Russians that I showed it to. We did cards in Cyrillic as well as English. But we never really raised any business, never really sold anything. So that was in '89 and into '91. Now during '89, I was contacted by a woman named Liz Rich. She had a little company she called Reddy, R-e-d-d-y, Information Systems, and she had this concept of a computer that was wearable. You would hang it on your belt. It had a CD-ROM in it and it drove a display that I call peep show display. It was one by Reflection Technologies. That display used a vibrating mirror and a little chip that had a line of red LEDs in it. When you vibrated that image, the line swept across your retina as a raster and you could do an image. It spun off of the media lab. I don't know what business they ever really did. We tried. So she wanted a computer designed for this and I did.

To make a long story short, I secured a guy who had done design for the Osborne computer plastics. I like to deal with the people who do the work. He worked out a case for it. We got some run-off molds made of it. We were able to show this at the CD-ROM Conference and Exposition in 1991 at which Bill Gates was overheard to comment, "Cool." And it was a wearable computer. It ran MS-DOS. Actually, it was DR-DOS, Digital Research DOS. I had reduced the memory chip requirement for the display down to one memory chip, and you could plug in a monochrome monitor and the image would basically be rotated instantaneously. It's a matter of switching a row and column and _____ in the sequence—technical. But it could display on a monochrome monitor. It was a 256 x 256 image, did everything it was supposed to do with the exception that it had a PCMCIA slot in it, and in those days, PCMCIA was not specified very well. And I just said I'll hook it up to the address bus and we'll worry about that later. I don't think we ever ran it with a PCMCIA card in it. Unfortunately, even though it was the hit of the show, Liz Rich-- she was from New York-- took all the response cards, put them in the trunk of her rental car, returned the car and forgot to take them out. This might have been indicative of something, because she wound up suing me, which I was not the first person she had sued, put it that way. It cost me $12,000--which is actually a low cost as these things go-- to fight her back on the basis that she wasn't entitled to be in court, because she had a Delaware corporation, hadn't filed certain papers in New York. But the whole thing never really went as a business, and I had been paid, but that money had been spent. And so there I was, doing occasional jobs, whatever I could scratch up.

And by that time, I had met Lena Diethelm. I met her in '91 on The Well, which was a bulletin board system which was really sort of where the San Francisco scene gravitated under the auspices of Stewart Brand and the Whole Earth Catalog. She sent me an article from the *Wall Street Journal* that announced the formation of Interval Research Corporation. All right, we're flashing again here, so we could probably break at this point.

Crosby: Yep.

END OF TAPE 5 / BEGINNING OF TAPE 6

Felsenstein: It was in 1991 that Lena Diethelm, who has become my wife since, sent me a copy of an article in *The Wall Street Journal* announcing this research company, Interval Research Corporation, which was supposed to be funded to the tune of $100 million by Paul Allen, who is the other founder of Microsoft. Now, I would have seen the article that came out in the local paper anyway but I credit her with this. I called them up and it turned out coincidentally, which was actually not coincidental, that I was

scheduled to go down and address Terry Winograd's class at Stanford within a few days. I checked this with the principles and Winograd was involved in the setup of Interval Research and this was a setup. So, I said, oh, I happen to be in the area why don't I drop by and talk with you, you know, about David Liddle, the CEO. Well, this happened and Lena wanted me to be a teaser and give him, you know, or send him a copy of *Fire in the Valley* which had told my story up until then, as well as the story of many others, and a Homebrew Computer Club t-shirt, one that I designed for 1986. Well, I said, no, I'm going to hit it with all I got and I did. And so we had this interview which was mostly me talking. And Liddle and Andrew Singer came up to visit me in my shop. We went to lunch. Very shortly thereafter we worked out a consulting agreement and I was basically working again. And it was in Mountain View and so I had to move basically, and did so, and brought Lena along with me. And from '92, this would have been-- I can't quite remember the month. I think it might have been January or it might have been March or April I moved from contract status to employee status around March or April and became a researcher at Interval Research.

Now, Interval probably-- I think it never really got straight what its goal was. This might have been illustrated at a later date. We heard about the wired world that Paul Allen had envisioned. This was several years in and Paul Allen came down and gave us a talk about it. The gist of the talk was, "I have this idea for a wired world, your job is to tell me what it is," which is not a bad management technique, you know, executive technique. But we sort of thought we had been doing that all along. And there are different opinions on what was actually going on. A lot of what we did had to do with the entertainment industry. And there was a spin-off-- I was supposed to generate spin-offs. I would tell people that we are going to develop families of products and spin them off to companies that form around them to produce them. But at least they can be coordinated, and we'll be doing it from a standpoint of research so that we know why we are doing the products. And most of the research that went on at Interval was in fact research about people, about how they dealt with technology, how they could handle it, user interface, that sort of thing, really very important stuff.

I was first told to plan out an engineering department and I did, even the floor plan. And then I was told we're not going to have an engineering department but I will have a project, everything was a project there that was there unit of organization, that would develop prototypes for research and it was to be called Café Design. And so that's what I did. I ran that project. It was a support project for the others and so it would have no real end. And I did a fair amount of design and I managed up to eight people who worked in electrical and mechanical and software stuff.

And I developed what I call the invention strategy, which meant that if nobody is asking you for neat things, invent it anyway, especially, if you can get a hint as to what they want. My best example there was tooning, which was a matter of, means of video compression. It had been tried in software and was published in a book dated '84 and it was one of the technologies that Andrew Singer with his project wanted to do but he drew the line short before that. Now, that to me was catnip. Okay, they want to go there. I think I know something about video, about digital video, let's see where we can go. And so on my initiative, Café Design did a box that would take video in. It would turn it into black and white cartoon, basically, is where the word tooning came from. And that would be really useful for compression and so forth. In fact it turns out if you held up a piece of paper with writing on one side and held it up to the camera because you're looking at edge detection the picture came right up. You could see what the words were, backwards, but he could read it through paper. But also we found that you can identify faces very well and that was the point of the article originally. They would have a caricaturist draw cartoons and they had the computer do this kind of process and they would compare the two. So, this was done unbidden and I rolled it into the meeting, company meeting, and said we now enter the age of tooning.

And he started pointing the camera around at everybody and their caricatures would be up on the screen. Well, it took them several years, it turns out, before somebody came up and said we want to do that, which might be a failure of marketing on my part, I don't know. And by that time somebody had reversed the power supply and all the illogic had evaporated from the circuitry in question. They didn't make those chips anymore so we had a few obstacles to getting it going. But they could do it in software, you know, at adequate speed anyway.

Interval was a tremendous compilation of very good people. I mean we had all kinds of disciplines and that's one of the things that was its real glory was the interdisciplinary of it. It had a very flat and intentionally unworkable, in the words of the CEO, management structure. So, we were supposed to sort of improvise our own management structure. And unfortunately I had a very inadequate set of capabilities to spin anything off to put anything into production or to design a product. The researchers in the project were deemed to have crossed a certain threshold at some time and they were told, okay, now you have to develop the product. Now, these are different disciplines, but while they were given some assistance from a consultant they had to write a business plan. And, guess what? Most of those business plans didn't go anywhere. Now, there was one that did which was Purple Moon, which was originated by Brenda Laurel who for much of her career had been attempting to get games written for girls that weren't just pink versions of boys' games. And Purple Moon did this. It was set up externally. It attracted $43 million of investment. And something happened I know not what but at the point when they were in negotiations with Mattel to sell the company, and I had heard that the sale price had reached $65 million dollars, something happen, Paul Allen turned off the spigot, bankrupted the company. And Mattel wound up walking away with it for $4 million. I'd love to find out more but as part of my severance agreement I signed an agreement saying I will not participate in any story about Interval. Well, I may have already gone too far but I don't know. And others know much more than I do and I haven't really tried to squeeze it out of them because it's a fairly painful topic.

So, Interval represented a great deal of potential, and I made a very good contacts there and I was able to do things like run the engineering lunch which was a monthly meeting just like a Homebrew Club meeting. We would discuss engineering issues and we would serve food to attract people to it. And Interval then became the eatingist place around. They had to hire a food service coordinator after a year, so I can take credit for that. The most I can say about the denouement of Interval was that once the CEO was gone it drifted for a while, a two person executive was created which is never workable. And whatever the discussions were, they were taking place in Bellevue, Washington and not in Palo Alto, that determined the future of it. And so one day we were suddenly called into a meeting and there was Bill Savoy of Vulcan who said he hated to do this kind of thing, it's one the least favorite things to do. And he says the network is down and the company is closing. There's a severance agreement and don't let the door hit you on the way out basically. We were able to at least to take the library contents and make of them what we wanted. I know I got many boxes of books at Lena's suggestion. She's very much a book person.

But I concluded in retrospect, and there were some indications of this in the process, that I was there as window dressing. I was there so they can say we have the guy who ran Homebrew Club and, you know, designed the SOL or something like that or designed the Osborne. It would have been nice if they would have been more explicit about it. I might have been able to make more out of it. But I did learn a great deal about intellectual property management. I was the founding head of the Intellectual Property Committee in which they formed when a patent lawyer had been allowed to roam freely through the halls and it resulted in some patent applications of some fairly absurd things, including a subcutaneous LCD display. There was this one person, Andrew Singer in this case, and his, you know, on the spot fantasy

that wound up in the *New York Times*. And so we had to have a committee now and should have had one all along to evaluate patent ideas and decide what to do with them and how to handle them. So, in April of 2000 Interval closed and I had a reasonable severance package because I had been one of the longest-employed people there.

And I tried to drum up business with Golemics and I managed to do a few things. This was, you know, around the time when the dot-com bubble was collapsing and business was harder and harder to get. I was referred to one outfit that was doing an aura reader, an aura camera, as Aura Imaging in Redwood City. And it was really an entertainment device, is the most reasonable thing that they could say about it, in a box with a palm box. You put your hand on it, several contacts and that provided a kind of randomizing electrical input, the galvanic skin response that was read from that. And they would take your image from a camera and they would enhance it with colors and things like that. And so I was contracted to, you know, get the box design finished up. All along the guy, Guy Coggins was his name, who was head of if, kept saying, "Oh, didn't I tell you about that?" So, this turned into a set electrical panels-- no, I'll say it again, an array of plates of copper on printed circuit material that would absorb an image of the aura. How did you get the aura? Well, on the palm box they had some additional components, where he said, "Didn't I tell you that?" Well, there's supposed to be an oscillator at 100 kilohertz that put that signal onto your skin. So the plates would pick this up and as it went further away you would pick up less and less. So it kind of looked like an aura. You could colorize it and make it look like an aura. Now, the box had another output which is for the helping hand and that was a signal of opposite polarity. When this one went up that went down at 100 kilohertz. And so the operator, who ever this was that was helping you, had a ring where that was energizing their body. Now, if you had the image on a set this person could come in with this opposite polarity charge and between plus and minus is always zero. And it could modify your aura this way. I got it to the point where it would generate the data. They didn't have the software to do it. And someone has just recently contacted me who's contracted to pick it up and finish it. So, that's the kind of thing you get to do occasionally. It's like all on a rather small scale basis. But, you know, I survived through it.

In 2001 I was hired by an outfit known as Pacific Consultants in Mountain View. They were staffing up and they had a military communication system which is a wearable system called Land Warrior. And I wound up working on that. That was just after 9/11 and found myself serving as a supervisor mechanical technician because they certainly lacked supervisory anything there. And the device I was called in to help with I got that working in 24 hours just by mainly telling the younger engineer, "No, don't try to connect to it that way, use the actual connectors they give you." And he had been working on it for two weeks and 24 hours after I started telling him that he had it working, whereupon the problems became the mechanical problems of that helmet interface adapter.

And then in 2002 they got a contract to develop a medical instrument. And there's an involved story about that, but the point of it is that they had never done a complete product development before, and they had been in business for at least 10 years. This is all mechanical consulting mostly and finite element analysis and so forth. And I was a member of a four person team. I was the electrical engineer. We had to take an existing instrument, this was for an infant hearing screener, and not change any of the analog circuitry because they would have to get it re-approved that way, just get it into a handheld function, add to it a digital function that someone had already developed. This was someone who came from the customer company and was going to spin-off a competing product. The company Pacific Consultants was sold at that time to Pemstar Incorporated. They said no spin-off sell it back to them. And so they had an unwilling customer, which can be interesting. And it took a year. We did the design, both of the housing, the human interface, the interaction design, the software development and we got it

together. And that product which was originally-- we were told, "We don't like this, we're not going to support you on it." Those people had gone by the time it was done and this company-- product pretty much saved the company, which is very gratifying. And it gave me experience in medical product development. There weren't any more products except a dock for the motion computer tablet computer and it gave me a good sense of how unnoticed things can be that still take a good amount of work. Nobody thinks about who was it that designed this dock for the computer. You're lucky if they think who was it that designed the computer. They don't really think that anymore. And then Pemstar ran into trouble and basically closed down the operation, and I was laid off in November of 2005.

Now, during that time, well, starting in 2000 according to a receipt I have, first of all we have the 30-year reunion of the place where Resource One had its computer at the converted candy factory. And I met someone there-- I had met someone named Lee Thorne there and he contacted me at this time because he was now working with communities in Laos. He had been a bomb loader on an aircraft carrier in 1966. He had been lied to about what they were doing. And one of his jobs was to run the projector for the films that were made on planes on their bombing runs. He developed a case of post traumatic stress disorder from that experience. And he several years later decided that he was going to try to make amends with people in Laos and made contact and started working to help some communities just with things like water pumps and so forth. After several years the villagers there said to him what we need is telecommunications. We don't have electricity here in this little valley. We don't have cell service. We've tried to run cell phones, it won't work. We need to get into the telephone system so we can bring our products to market in an informed fashion. He came to me with this question after trying some things. And I decided that we know kids can run computers. What he was telling me about the villages everybody works very hard. The only people that have any time are kids. I could put together a Linux system and make it survivable in this very difficult environment. We can use WiFi with parabolic antennas as trunk connections. I mean, somebody was going over there and they did some, you know, walked around and talked to the soldiers, just stopped them and so forth and kind of surveyed, and found that there was a ridge, we needed to get over the ridge with a couple of radio beams. It was all possible to do and would give them a computer for the village and a phone for the village. They now call this, you know, One Telecenter per Village.

So, I did the design. I solicited, well, Lena was the main person soliciting donations and it went viral. We got donations in foreign currencies for we don't know which currency, came in PayPal in odd dollars and cent amounts, it was only like $3. But we raised about $25,000 both that way and by bootstrapping it with foundations that we happen to know some people in. And then in February of 2003 I went over there to try and install what we got. We were not far enough on the software and I don't know whether it's legitimate or not because there's only one person who was present in the room and it wasn't either of those of us who were the principles and supposedly the disk got destroyed by some power surge. So, we had to give up on installing that, go up to the village the next day on no sleep and apologize to them, give a lecture on no notice about what it is we are doing. And then we went up the hill to try to retrieve the stuff that we had hauled up. We got a phone call, our Laotian guy, we had several but this is the man who has headed the foundation in Laos, got a phone call saying the ambassador is going to be there tomorrow at the ceremonies. And it's like, you know, basically word had got out. Well, I'd been instrumental in having an article in the San Francisco papers. Two Americans showed up for our non-installation at the village on their own initiative, and word had got around. And so the villagers had decided there was a budget for a celebration, it was like three cattle that we had given to them. And they decided to slaughter, I don't know, one or two of them so they wouldn't lose face because the world was converging on them or at least many important people were converging on them. And even though the thing hadn't been installed they had to have a party, and this happened. They were in the process-- there was electrification going on up the valley but I was told-- I talked with the engineer of the project at this

celebration. He said, you know, for budget reason there's not going to be power in those lines for a long time. But at the point when we had our little stand up ceremony they arranged to have the trucks that were stringing the line right out in front there make a lot of noise. So clearly we had embarrassed the government. And I think as a result of that the installation was not permitted to proceed. I sent somebody else back, I used up all my vacation time, with an improved system but they were not permitted to do that. Somebody was raising objections behind the scenes. In Southeast Asia you'll never find out what's really going on. So, the system was never installed. Nonetheless, we had created this One Telecenter per Village approach which would-- also these were five villages, there was going to be one for each village and they would have intercommunication capability just by the WiFi direct and maybe it would go through the relay tower on top of the mountain. There was going to be bicycle generators to run it with. That's where they came up with-- the *New York Times* magazine, came up with the term pedal-powered Internet. And the baggage handlers at the airport when it came time to ship 99 pounds of excess baggage said, "What's this for?" And I said, "Have you heard of the pedal-powered Internet?"

"Oh, yes." Amazing. So that's something that-- I turned this over to Bob Marsh again, seems to be a habit of mine, the Micro Expander, and I thought there was something else but I forgot what it was, and it was all the stuff for Processor Technology. He was retiring at this point, and I summoned him and said, "I have an industry that I'm trying to start. Would you like to be in on it?" And he did bring together a team of people to work on the software for the most part that moved out from under the Jhai Foundation which is what Lee Thorne had organized. Organizing, it's a relative term. And they incorporated as Inveneo, I-N-V-E-N-E-O.org which is carrying on this development. They have been installing several systems in Africa mostly. And they've got a very good organization set up and they're growing. So, the design that I did, it survives and is being installed in the developing world.

I still consider the One Telecenter per Village to be my alternative to the One Laptop per Child initiative of Nicholas Negroponte of whom I've become a major critic or of which I've become a major critic. You know, criticism is not of the person, that's irrelevant. But the concept that he counterpoises to this is give every child in developing countries a laptop and make it such that it's a learning instrument and then that's all you have to do to end poverty and bring about education. Well, I began criticizing that as soon as I heard about it, critiquing it, then I published something online. Lena started a blog for me and this has become the fundamental document that is counterpoised to the project statements. In other words, whenever you ask for, well, what are the criticisms of it, that's what gets referred to. A lot of people in the hacker community have told me, "Well, sounds like you don't want kids to have laptops," which is not the case because without infrastructure those laptops aren't going to go anywhere except into the black market or the grey market and they'll go into the cities.

The One Telecenter per Village idea provides infrastructure meaning that if all we needed to do is put up one more antenna on the Jhai PC system for the local use, presto, you have a hot spot, you have the Internet, you have power, you have people who can provide a support structure. But none of that was being provided so my criticism of that project was on that basis that if they were allowed to go forward and they have failed to do so and deliver massive quantities of these laptops, the result would be that nothing that I'm trying to do would be funded. Because the word would get around computers in the third world, we've tried that and it didn't work. No money for that. So, it's being defensive in this regard. But I think the laptop that they did design is an excellent design. And it embodies a number of the things and a number of the problems that remain to be solved, mainly power consumption and so forth, that are going to be necessary for any computer in that environment. So this is in progress now as I speak. And as of today or this week Negroponte has announced that they're going to go for Windows on the laptop. A whole lot of people have bailed and the whole project is in disarray. In the meantime of course a number

of manufacturers have come out with small cheap laptops, I have one, that are okay for many things. So, that if anything is the fruit of that project and I have no problem with that. I have a problem with saying this substitutes for the educational system, parents don't need to be involved, teachers don't need to be involved and it's going to solve every problem. That's overselling it in my estimation. Any questions?

Crosby: Not that I can think of.

Felsenstein: I don't know if I've missed anything but I try. All right, I guess we can hit one thing…

Len Shustek: We have 10 minutes on this tape.

Felsenstein: All right.

Shustek: Do you have any advice to the next generation of engineers?

Felsenstein: Well, number one, recognize that the best, most creative work occurs when you're at play. And most of what needs to be done in engineering is organizing play so that it's supported. I think it was Irving Langmuir who was head of GE Labs in the 1920s and '30s who would go around to his researchers and say, "Are you having fun?" And they would tell him the problems they were facing. And he would say, "No, I'm not asking that. I'm asking, are you having fun?" And they sort of apparently ran GE Labs that way according to the GE Labs official history. Well, that's good advice anyway. The problem comes in convincing other people who are in other disciplines that your play is worth supporting. I don't have a fast answer for that. But I think that the whole direction of technological development has been to empower at the lower, lower level. Like the Homebrew Club did, you need to develop methods of combining one's play, and we can see elements of this happening already online and facilitated online in personal, you know, face-to-face meetings. Everything can't happen online. It does require people getting together because a lot more information transfer goes on that way. Certainly I think we're entering an era in which engineers are going to be more and more important, and I hope recognized for it, because we face so many problems, problems with sustainability, problems with energy. Call it independence but really societal sustainability and the necessity to sometimes radically reorient what we're doing and how we're doing it just so that it can-- you know, we can continue. It doesn't take any grand social theories to do it, but I think it's going to take an awful lot of really good engineering to do it. And the only way to do that I know is as play as sport. The same impulses that drive people to do strenuous things in sport are what drive us I think to do what we do and to do it with virtuosity. And I think we need nothing less.

Crosby: That's perfect.

Felsenstein: That's my commercial.

END OF INTERVIEW

