CHEMICAL HERITAGE FOUNDATION

JAY T. LAST

Transcript of an Interview
Conducted by

David C. Brock

at

Beverly Hills, California

on

21 June 2004

(With Subsequent Corrections and Additions)

ACKNOWLEDGEMENT

This oral history is part of a series supported by grants from the Gordon and Betty Moor Foundation. This series is an important resource for the history of semiconductor electronics, documenting the life and career of Gordon E. Moore, including his experiences and those of others in Shockley Semiconductor, Fairchild Semiconductor, Intel, as well as contexts beyond the semi conductor industry.

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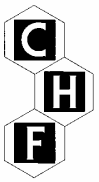

JAY T. LAST

1929 Born in Butler, Pennsylvania on 18 October

Education

1951 B.S., optics, University of Rochester
1956 Ph.D., physics, Massachusetts Institute of Technology

Professional Experience

Shockley Semiconductor Laboratory, Mountain View, California
1956-1957 Senior Technical Staff

Fairchild Semiconductor, Palo Alto, California
1957-1959 Senior Technical Staff; Co-Founder
1959-1961 Head of Integrated Circuit Development

Amelco Corporation, Gardenia, California
1961-1966 Director, Research and Development; Co-Founder

Teledyne Technologies, Inc., Gardenia, California
1966-1974 Vice President, Research and Development

Archeological Conservancy, Albuquerque, New Mexico
1980-present President

Sierra Monitor Corporation, Milpitas, California
1980-present Director

Hillcrest Press, Inc., Santa Ana, California
1982-present President

Think Outside, Inc., San Jose, California
1998-present Member, Board of Directors

Honors

1999 Hutchinson Medal, University of Rochester

ABSTRACT

Jay T. Last begins the interview with a description of his family background and youth during the Great Depression and World War II. He reviews his undergraduate education at the University of Rochester and his graduate work in the von Hippel lab at Massachusetts Institute of Technology. There he completed doctoral research on the structure of barium titanate under an IBM fellowship. He was later invited to join Shockley Semiconductor Laboratory. He soon departed as one of the "Traitorous Eight" to form Fairchild Semiconductor, where he focused on the etching process for the mesa transistor. During this time, Last formed a close friendship with Jean A. Hoerni and began collecting African art. Last then supervised the creation of the integrated circuit. In 1961, he left Fairchild Semiconductor to join Teledyne to create more elaborate circuits. Teledyne mass-produced complex circuits for military, private corporations, and internal use. Last reviews the business climate of Silicon Valley that supported numerous spin-offs and discusses the dynamics of the American and international semiconductor industries. He then recounts his private investments, including that in Intel Corporation, and relates Gordon E. Moore's contributions to Intel Corporation. Last concludes with his personal involvement with the Archeological Conservancy, his African art collection, and publishing.

INTERVIEWER

David C. Brock is a senior research fellow with the Center for Contemporary History and Policy of the Chemical Heritage Foundation. As an historian of science and technology, he specializes in oral history, the history of instrumentation, and the history of semiconductor science, technology, and industry. Brock has studied the philosophy, sociology, and history of science at Brown University, the University of Edinburgh, and Princeton University (respectively and chronologically). His most recent publication is *Understanding Moore's Law: Four Decades of Innovation* (Philadelphia: Chemical Heritage Press), 2006, which he edited and to which he contributed.

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INTERVIEWEE: **Jay T. Last**

INTERVIEWER: **David C. Brock**

LOCATION: **Beverly Hills, California**

DATE: **21 June 2004**

BROCK: This is an oral history interview with Jay T. Last, conducted by David Brock in Beverly Hills, California, on the twenty-first of June 2004. Perhaps we should start at the beginning. I believe that you were born in 1930. Is that correct?

LAST: I was born the week the Stock Market crashed in 1929. [laughter]

BROCK: An auspicious beginning.

LAST: October 1929. Then I realized when I was fifteen that the first ten years of my life were Depression and the next five were war. So there was nothing in my life that was normal up to that point.

BROCK: You were born in Butler, Pennsylvania, is that correct?

LAST: Yes. Butler, yes.

BROCK: Could you tell me a little bit about the family background of your mother and your father?

LAST: My father was German and his father had emigrated from Germany as a boy, and they had a farm in western Ohio. My father had a number of brothers and sisters, none of whom finished grade school except for him. He was the youngest and by then they had enough people working on the farm, so he went on and finished high school and then went on and got a college degree at a small Lutheran college called Capital University in Columbus, Ohio. My mother was from one of the old Scotch-Irish settler families in Ohio.

[PAUSE IN RECORDING]

BROCK: Okay. You were talking about your mother.

LAST: Yes, this was an old Scotch-Irish family. My great-grandfather was a congressman from Ohio, so this is going way back into the 1800s. So the family was well established there. My mother went on and got a college degree from a small school in northern Ohio.

BROCK: Was it a Teachers College?

LAST: No, no. It was called Lake Erie College. She was a very small lady, but she was very athletic, and while she was there she beat some world's record for ladies' hurdles or something like that.

My father and mother met when they were two of the three teachers in a small high school. Between them they covered the whole curriculum. So that's where they met, and after they got married, my father just didn't think he could support a family on a teacher's salary, which was a pretty dismal prospect. So he moved from Ohio, where they were teaching, to Butler, where they were just starting a new steel mill, and went to work there. His planning didn't work out too well. The Depression was very hard on our family.

BROCK: Could you tell me more about that?

LAST: Well, when he was working, the hours in the steel mill then were terrible. He used to work twelve hours a day, except Sunday, and one Sunday you had off, and the next Sunday you worked twenty-four hours. This was brutal. That ended abruptly with the Depression because in the Depression it was just the opposite. My father, every morning, would pack a lunch and go down to the steel mill and learn there was no job, walk back home and share his lunch with my mother. He told me one year he made eight hundred dollars.

So it was a rough growing up, but I didn't know there was anything else, and so I had a very happy, pleasant childhood. I was never hungry or not clothed or anything, and living in a small town, I've always liked hiking and walking and doing what little exploring I could do. Butler was perfect for that. There were always woods I could go to. I was never especially athletic, and I read a huge amount. I was in the Boy Scouts, but no organized sports or anything like that.

BROCK: Your mother then, did she continue to teach?

LAST: No. It was pretty much a full-time job being a homemaker then. She canned an awful lot of the stuff we ate. My father always had a garden and grew lots of stuff, so she'd always can. Delicious stuff. I mean, jams and jellies and berries and fruits. We had a whole cellar full of stuff.

BROCK: Did you have siblings?

LAST: I have a younger brother, Larry. He's five years younger, and got his degree in electrical engineering at the University of Cincinnati. He taught there for a while, and then spent his career working for General Electric. He worked on a lot of interesting projects mainly dealing with aircraft engines. He retired a few years ago, and now spends his winters playing golf down at Hilton Head [South Carolina] and summers fishing in Binghamton [New York], where he's been living.

BROCK: So Butler was a small town.

LAST: It was small, maybe thirty thousand people, and very much steel mill, some other heavy industry. The steel mill dominated the town. It was a coal-mining area. So there was a heavy central European immigration into the town.

It was a pleasant place to go to school. I had a good schooling. I learned to read real fast, and I've always been a very rapid reader, and I always started out the school session very excited, but by the end of the third week I'd read everything we were going to cover that term, and it got pretty boring before the year was out. I just read anything and everything in the public library. It was a good library. I must have read most of the stuff there because I read all the time. I would guess I learned as much on my own as I did in school.

BROCK: With both your parents having been teachers, did they encourage that?

LAST: Very much, yes. We had an interesting thing; we'd have very leisurely dinners. We'd sit around and sometimes just sit and talk for an hour after dinner. That was unusual, and I realize now what a valuable thing that was.

BROCK: Just talking about general experiences, general subjects?

LAST: General topics, and I was always encouraged to—if I'd use a word wrong, they'd say, "Go look it up in the dictionary." So I got that habit of having a great respect for the English language.

BROCK: You were pretty promiscuous in your reading in the public library, but did you concentrate on anything—

LAST: No, nothing special. Just anything that interested me. I'd read a lot of biographies and history. There wasn't that much science writing available then. There was nothing in that early writing that I would say was pushing me toward technical things, although I was always very interested in technical things. I remember I built little electric motors and things like that, had the occasional chemistry set or something like that.

BROCK: So was education and learning sort of a central feature of the home, central expectation of your parents, do you think?

LAST: It was such an expectation, the subject never arose. I would certainly go on to get educated.

BROCK: What about the place of religion in your home and in Butler? Was that a big factor?

LAST: It was a very religious town, about equally divided between the Eastern European Catholics and the German Protestants. My father, which will come as no surprise to you, was Lutheran. My mother was a Presbyterian. My mother was a very feisty lady and didn't get along with the Lutherans very well. She sort of broke away from the church. So religion was never a big thing in our family. I was encouraged to learn about religion, but never pushed terribly hard. I went to the Lutheran church on occasion and I was struck at the time by the very negative aspects of Lutheranism as it was practiced in the German aspect. They were always fighting Luther's battle all over again. [laughter] It was always the negative aspects of somebody else, rather than the positive advantages of your own religion. So I just broke away when I had the opportunity, and in graduate school attended church once in a while with a roommate, but nothing serious. My wife is Jewish and neither of us are practicing actively our religions, although she still has strong, very pleasant feelings about all the Jewish ceremonies, and once in a while I'll participate with her.

BROCK: But from an early age it wasn't a—

LAST: No. Religion was never a major thing in our household.

BROCK: You mentioned your early sort of electrical tinkerings and occasional chemistry set. Were those supplied by your parents or were they things that you got on your own?

LAST: I don't remember. The electrical thing, I just figured out how to build a motor so I got the wires and all that, wound them all, and was very excited when it worked. But it wasn't a major thing in my life.

BROCK: Would you say that it was more your hiking and outdoor explorations, that and the voracious reading?

LAST: Yes, that was the main thing that I did.

BROCK: Could you tell me a bit about your pre-high school education? That was in the public schools in Butler?

LAST: Yes, yes. It was a good, rigorous education. As I say, it was designed for people who were not quite as rapid as I was. I learned the stuff, but it was moderately boring, as I look back on it.

BROCK: Were your teachers accommodating at all to that?

LAST: Yes.

BROCK: They let you do things on your own?

LAST: As much as they could. Not so much in grade school, which is a pretty regimented thing. For some reason, in Butler at that time you were admitted to school either in January or—there were two terms, a January term and then a fall term. I started in the fall term, and in about the third grade or so, they for some reason skipped me ahead half a year.

One incident I remember there, this was the half year where you learned to multiply from five on. So I was just given all this, and then I looked at the multiplication table and said

to the teacher, “Why when you multiply by nine do the two numbers that you get add up to nine?”

She sort of said, “Well, get back there and just memorize it.” [laughter] But I was thinking along that line then. So I picked up all that, multiplication, in a couple days.

BROCK: Was it in high school that your attention turned more toward technical subjects; science, mathematics?

LAST: Yes, I think so. I always enjoyed my science and math courses. I could see that I was more interested in the physics side of things. Just to step ahead, my father had seen something about this optics program at the University of Rochester and he was discussing it.

[PAUSE IN RECORDING]

BROCK: So you were saying your father had heard about the optics program.

LAST: Yes, and that intrigued me, and I just decided that’s what I wanted to do, go to Rochester and do that. I knew at that early time. I remember when I left the house to go to Rochester, I said to my father, “I’m going to go to Rochester and then I’m going to go to MIT [Massachusetts Institute of Technology] and get a Ph.D.” So I had it all thought out.

A very key thing that had happened to me in high school was a chemistry teacher I had, Lucille Critchlow who saw that I may have some promise. There was a research laboratory in Butler run by a rather eccentric Englishman dealing with problems related to the glass industry. You know, why does glass break? There were massive numbers of lawsuits connected with people getting injured by broken bottles, and most of these people would say, “I was just carrying these two bottles and they automatically just spontaneously exploded.” We could point out that they were hit and we could document the fracture patterns.

BROCK: So he was doing sort of contract research?

LAST: Contract and general. He had a lot of freedom because he was very valuable to the glass industry. Lucille Critchlow, when I graduated in January and had until the fall, she strongly recommended to [Frank] Preston that he hire me. He did, and here I was working with nearly everybody there was a Ph.D., and I said, “This is a pretty good life.”

BROCK: Was Preston his first name or his last name?

LAST: Frank Preston. Dr. Frank Preston.

BROCK: How big was his lab?

LAST: Oh, I would guess there were twenty-five people, thirty people. They were manufacturing testing equipment for the glass manufacturing companies and doing a lot, as I said, a lot of law cases.

I worked for a physicist named Jay Glathart who was a very likable guy and very friendly. So I was, as I said, working for him and I was given a lot of freedom to do things my own way. So it was a very valuable experience for somebody just out of high school to be able to participate in a technical activity. I wrote a minor technical paper and I went to Ohio to the glass companies and discussed it with them.

BROCK: In that period of time?

LAST: Yes. Then I worked the whole way through college whenever I had free time. Summers, or sometimes even on vacation, I'd go back there and keep working. I maintained very close relationships with Preston the rest of his life. He was a very interesting man.

BROCK: You said he was an Englishman. How did he come to Butler?

LAST: Butler had a couple of glass companies, manufacturing plate glass. He came here as a consultant for them, and decided he wanted to stay. He was extremely interested in birds, and so he built a big compound a mile or so out of town where he could study birds and have his laboratory. That was a very interesting experience.

BROCK: What were you doing in the summers during high school? Were you working?

LAST: The summer between my junior and senior year I was sixteen, and I think I didn't quite weigh a hundred pounds, and I couldn't get a job, so a friend of mine and I said, "We'll hitchhike to California," which we did.

BROCK: A school friend?

LAST: Yes, one of my school friends. We were in a play in high school together and we started talking about this kind of thing. So we hitchhiked to California.

BROCK: What did your parents make of that?

LAST: Well, this was interesting. My mother later said to me that, "Jay, we couldn't give you much in a material way, but the thing we gave you is the chance to think for yourself." Because I was always pushed into making decisions. My whole life, my mother said, "Well, you decide that." I thought, "Well." So it was a strong push and it made me a very independent person.

BROCK: They gave you the freedom to make those decisions.

LAST: That was my decision, so I don't think they were terribly enchanted with the idea, but I prepared. I went to the Chief of Police and got a letter from him saying I wasn't running away from home, which I needed a couple of times. So I had all that.

So I hitchhiked to California and planned on picking fruit. Got here before the fruit season, so I was sort of living on a nickel's worth of carrots a day for a while there. And that also stood me in good stead later in life. When there's some difficult things, "Well, look, I got through that when I was sixteen, and this is not that bad a problem."

BROCK: Did you go to northern California?

LAST: I was in San Jose. That was right where I ended up. San Jose at that time had something like twenty thousand people, it was a little rural farm community. It was an unbelievably rich agricultural area. Just a marvelous place.

BROCK: So how was your journey out and back?

LAST: I hitchhiked. It took about a week to get to California from Butler. A very interesting week. I had a chance while I was there to go to Yosemite and did the first climbing I'd ever done. That was a very interesting summer. I obviously took a great liking to that area.

BROCK: You must have been interested in California beforehand. Did that come from reading or the general lure of the West?

LAST: Oh, just the lure of the West. I thought, well, what can you do agriculturally? You could work with a wheat gang in Kansas or the Great Plains. That didn't sound like as much fun as going around and picking fruit in California. But I did that, and I worked in a cannery for a while. I don't think I've eaten apricot pie since. [laughter] I made enough money that by the end of the summer I had enough to come home in luxury on the bus. So it was a great formative experience for me.

BROCK: Your other summers were spent closer to home?

LAST: Yes. Reading. There was a rule at the library which was you could only take two books out per day. So I'd go to the library in the morning, take my two books, have them read by the afternoon and wait till the next day.

BROCK: So, very quick in reading.

LAST: Very quick.

BROCK: Were you friends with the librarians?

LAST: Not especially. Authority was a little intimidating. Librarians can be especially authoritarian.

BROCK: They can. Very much so. [laughter]

LAST: I just went there quietly, took out my books and read them.

BROCK: So you had a very important chemistry teacher during high school.

LAST: Yes.

BROCK: Your other instruction was equally satisfactory?

LAST: It was good, yes. I had one math teacher I didn't get along with, but that was for other reasons. But good physics instruction, good chemistry. Very good chemistry instruction. Good humanities.

BROCK: You mentioned that you participated in the school play.

LAST: Yes.

BROCK: Was theater your main extracurricular activity or one among many?

LAST: I didn't have too many organized activities. I was on the school newspaper or did a little bit of plays and things like that. But nothing very active. Nothing athletic, as I mentioned. So it was a pleasant-enough high school experience. I would give the school pretty high marks for the way they did stuff.

BROCK: During the time that I guess your high school career was almost coextensive with the war. I was wondering what sort of impact the war had on you, on the high school community, and on Butler.

LAST: Butler was a steel mill town, and my father went from not working at all in the Depression, to the state where I don't think he took off a day during the war, the whole war. He took no vacations. He worked either six or seven days a week, steadily.

BROCK: The whole community must have been in a similar situation.

LAST: Yes. So it was very geared toward war production. It's hard to realize without being there, but how popularly accepted the war was. Everybody was behind it. Never had a phenomenon like that before or since in America. The country was completely united. My father's duty was to make steel.

I was an air raid messenger. I'd ride around on my bicycle. Everybody in Butler thought we'd be bombed. [laughter] You know, you had to keep your lights out, while there was a steel mill there that you could see from two hundred miles away. But everybody tried.

BROCK: I would imagine the school was involved in efforts also?

LAST: Paper drives and scrap-metal drives.

BROCK: Did the war touch your family in particular in any way?

LAST: No. That was the generation where my father was just too young for the first war, and too old for the second, which was true of most of his relatives, too. So we weren't touched personally.

BROCK: The role that science and technology had in the war with radar, the bomb, other developments, did that reach your consciousness? Was that formative in any way?

LAST: No, not that early. I mean, I had many opportunities to speculate about it afterwards, but at the time there wasn't that much information available. I mean, all this stuff was very heavily classified. You read an account of the atomic development programs, how secret that was. These huge towns that were secret. In Santa Fe now there's a sign "This was the post office box where Los Alamos communicated with the world."

BROCK: Once you had then formulated your plan to study optics at Rochester and then make your way to MIT—

LAST: Oh, before we get into that, there's one last thing I'll say about Preston, because it won't come up again, but I kept working for him, and when I got finished my Ph.D., Preston got a hold of me and said he was looking for a successor for his laboratory. He said, "Jay, you would be the obvious successor, and if you come to work for me, you just figure out what your entire education cost you, and if you come to work for me, I'll give you a check for it."

BROCK: Wow. A very tempting offer.

LAST: I went and told my parents, and my mother said, "Jay, you can do a lot better than that with your life. Get the hell out of this town."

BROCK: Really?

LAST: So, an interesting thing to have happened.

BROCK: It sounds like she was very encouraging of you to be a free thinker.

LAST: Yes.

BROCK: Was she similarly free-thinking herself in her opinions on various subjects?

LAST: Yes, she had a lot of them and she was very outspoken and outgoing. My father was more laidback, quiet. I never heard him complain about anything in his life. He just did, "This is what I'm supposed to do." That's what he did. He did the best he could to support the family, without any complaint. Working in a steel mill is a pretty rough thing.

BROCK: Physically, and also I suppose also rough mentally, especially managing people.

LAST: He was a first-level manager. I learned after his death that some injustice had been happening to some people that he knew about. He went and complained to the high management, and they just put him on the zero advancement track after that.

[END OF TAPE, SIDE 1]

LAST: One Christmas morning when he had been working Christmas Eve, he came home and some steel had exploded and some red hot steel had run the whole way down his back, and he was in horrible pain. That was Christmas morning. I know he just hated the last years at the mill, but he did it. He was just counting the days till he could retire. So they were always encouraging me to go on and do things.

BROCK: Did they stay in Butler for the rest of their lives?

LAST: Yes. They both died when they were in their seventies, early seventies.

BROCK: So then once having set your sights on Rochester, were there any bumps along the way to getting there?

LAST: I'm flabbergasted when I look back on that now, in that I said, "This is what I want to do." There was one special class of scholarships at Rochester. "I'll apply to Rochester for that scholarship and I'll get it." I didn't apply to anybody else, anyplace else or do anything else, except this is what I was going to do. I got the scholarship and I went and enrolled in the optics program.

BROCK: What was it that caught your attention about the optics program, or could you tell me about it?

LAST: I don't know. It just seemed a little more exciting than pure science, and I didn't understand it very well, what I was getting into, but it was a marvelous program. I'm glad I did it.

BROCK: Had you visited Rochester before?

LAST: No.

BROCK: So what was your impression of the school and the town?

LAST: Well, to me Rochester was a town ten times as big as Butler, so it was a big city. I liked it. Due to George Eastman's prejudices, the men's and women's campus were separated by five miles, so it wasn't a very exciting social life, without a car or any money.

So I had this fellowship and I waited on tables and graded math papers and all that kind of stuff. The optics program was extremely rigorous, and optics experiments are very time-consuming. So I just was working steadily for those years.

BROCK: The faculty in the optics program, had they been doing war work?

LAST: Yes, and they'd come out with some pretty interesting anecdotes about the sort of things they did. There was an awful lot of key optical works. Rochester was the only optics program of any size in the country.

BROCK: Oh, I hadn't realized that.

LAST: With its association with Eastman Kodak and Bausch & Lomb that supported the program. The program was started about 1930, and the professors were probably a dozen of the faculty, and also they had access to the key people at Kodak. Rudolph Kingslake, he died last year at age 104, was one of the key optical designers, probably the best the world has ever seen. While working at Kodak he taught our optical design course.

So, as I said, the program was rigorous. Twenty of us started in optics that year, and half dropped out every year. It ended up with five us graduating. [laughter] Optical phenomena still is fascinating to me, and getting in there and being able to measure something to the fraction of a wavelength of light, participating in all these things, I liked it a lot.

BROCK: And they really engaged the undergraduates in research over the course of those four years?

LAST: Well, I, of course, wasn't doing any, but I could see what was going on. It was a small, very stimulating environment.

BROCK: The four other sort of survivors, did they go to work for some of the local optical firms like Kodak and Bausch & Lomb?

LAST: I'm not sure. I don't think so. Certainly not Bausch & Lomb. Optics was so much in demand after the war that there were a lot of other opportunities.

I had, again, a very interesting industrial experience before I got out of school. This was just when the Korean War was starting, and there was a great shortage of optical people. So Kodak said they would hire, in the summer between our junior and senior year, one person from our class to go to work there for the summer. They picked me. They said, "Go to work in our film processing plant." I've always, when I didn't like something, would go try to rectify it. So I just called them up and said, "Look, it doesn't matter to you, I don't think, a whole lot, but it would matter a whole lot to me if you would assign me to your plant where they're working on optical instrumentation, rather than working in the film plant."

They said, "Oh, why not? By the way, the salary scale is higher in the optical plant." [laughter] So I just looked for what I wanted and managed to get it. Had a fascinating time there.

BROCK: What were they working on there?

LAST: I was put in the division—that was involved with troubleshooting for the whole company. So I was just all over the plant. I spent most of the summer working on a B-52 project, was just being developed then. It's amazing they're still using the thing fifty years later. I was working on a huge camera that they were using for photography from the B-52. The lens weighed about a couple hundred pounds. You had to lift it with a crane.

BROCK: Oh, my gosh. So, huge.

LAST: So I got involved in some of the testing on that. One thing in particular, this thing was going to stick out of an airplane, so they had to know how it would behave at 60 below zero. So I spent a fair amount of time at 60 below zero with a big fur suit on, testing this lens.

BROCK: In a refrigerated room?

LAST: A refrigerated room with somebody outside watching me, to make sure I didn't keel over or something. But that was fascinating work, and again, I was working with Ph.D.s, which is the same thing I'd done when I was at Butler, and could interact on that level with people.

BROCK: What did you do with your other summers?

LAST: I was back with Preston. So I was always spending all my summers working with skilled researchers.

BROCK: Do you think that experience working in Preston's laboratory on the glass work also oriented you toward optics?

LAST: No, I don't think so.

BROCK: No connection there.

LAST: I don't think there's any except it was just glass. I don't know what made me so intrigued with optics. It just seemed to have happened. My father had always liked the role of

being a mentor to young people and helping them, help them make career decisions, and he did that his whole life. He was always interested in that. And he obviously was interested in me. [laughter]

BROCK: While the course of study was very rigorous, what sort of extracurricular activities did you make time for?

LAST: Not a hell of a lot. I worked for a little while on the campus radio station and things like that, but I was working seven days a week, very long hours. These lab courses would take, you know, some of them would take a five-hour afternoon, plus maybe another five hours to write up the results.

BROCK: Just because of the precision setup for the optical experiments?

LAST: Yes, they were difficult experiments. These were not trivial experiments. They were very serious optics.

BROCK: In your group of peers and friends, were those from the optics program or from the dormitories?

LAST: Oh, it was just dormitories. We weren't in fraternities, so we had a group of close friends that I've maintained relationships with. We had Rochester's anniversary, and a group of maybe six of us that were close then all got together for dinner, at which we recounted our life, what it had been since Rochester. It was a very interesting thing. So I've stayed close to those people. It was a relatively small group, but a closely knit group.

BROCK: What sorts of things did that peer group go on to do after Rochester?

LAST: They all got doctorates.

BROCK: In the sciences?

LAST: Yes.

BROCK: All of them?

LAST: Bob Hendricks was physical chemistry; Bob Greenler went on and did great work in optics, and was president of the Optical Society. Kay Huntington got an M.D. Bob Anderson got an M.D.

BROCK: Do you think you were drawn together by your technical interests, your scientific and technical interests?

LAST: Not so much. Just happened to be assigned a roommate, and you make a lifelong friendship from that.

BROCK: I did read something that Bob Hendricks wrote, speaking of you, saying, "Of all the people I knew in college, Jay would have seemed one of the least likely to become an entrepreneur at that time." I was wondering why you thought he might have had that impression.

LAST: Well, I was pretty dedicated toward setting up my life for a research career. I didn't have the sort of outgoing nature that you would associate with somebody who's going to end up running a business.

BROCK: What about reading? Did you continue to read at such a pace?

LAST: Well, I read whatever I could read, but not that much. I was working. This was a very time-consuming program, as I said. But I felt that I was going to go on in physics, or physics was going to play a major role, so I took at least a good course in electricity and magnetism, pretty tough physics courses as well as the optics. So I had some preparation for graduate school in physics, although I missed a couple key courses.

BROCK: You had made that decision to attend graduate school and to attend MIT early on. Was it a similar experience going to Rochester, making the move to MIT?

LAST: No. Again, I had a great mentor on the Rochester faculty; M. Parker Givens. I wrote him a while back thanking him for all of this. He was more aimed toward physical optics rather than geometrical optics, and I was asking him what I should be doing in the future. He said, "Well, if you stay here at Rochester and get a doctorate in optics, you'll get about the quickest

and easiest doctorate that anybody got, because you've already taken all the courses here." He said, "You might have the satisfaction of having some of the people who were your lab instructors be theirs." [laughter] But he said, "I would strongly advise you to think of getting a doctorate in solid-state physics, which encompasses optical phenomena, and it's just a growing—just a starting field." There wasn't even a textbook on solid-state physics then; just scattered things.

He really persuaded me that was the thing to do. So I did. So I applied to MIT and to Cornell [University] and to [University of] Michigan, which were the three schools that he could recommend that were doing some work in solid-state physics. So I was accepted by all of them and I needed to get some financing, so I went looking for a scholarship, and I could see those would come pretty easily. So I had a choice to make. Michigan looked a little too big, and they said, "If your name starts with A through C, you'll show up this day to register." I said, "That doesn't appeal to me."

I discussed this with my boss at Kodak, who had a doctorate from Harvard [University], and I said I had these choices, and he said, "Jay, there's no decision you have to make. Everybody owes it to themselves to spend five years of their life in Cambridge." [laughter] I thought, "Well, that's as good a reason as any other," so I just called up MIT that day.

BROCK: Parker Givens, was he a younger man at this time?

LAST: He was then. He was probably—he's still around. He must be in his eighties now, so he was probably in his thirties then.

BROCK: It's interesting to think about why he would be attuned to solid-state developments.

LAST: Well, he had done his—physical optics and solid-state physics, of course, are very close and tied in with solid-state physics. Most of the investigation of it then was by optical means, a lot of it. So he had gotten into that side of it and could see how this was developing. Especially right after the war, I mean, there was so much basic research done in the war that was just now starting to come out and hadn't been exploited, and that's what made this enormous push in the ten years after the war, was just being able to use this whole bucket of technology that had not been developed, and it hadn't been developed in the Depression either. So we were really looking at twenty years of investigation of new physical phenomenon that had not been turned into new products yet. They were just all sitting there waiting. So there was an enormous explosion right after the war.

BROCK: So then you began MIT in 1951?

LAST: Yes.

BROCK: So did you find your boss to be correct, that you did owe it to yourself to spend time in Cambridge?

LAST: Oh yes. Now I was in a big city. [laughter] In a very interesting big city. I liked Boston a lot. It was very interesting to be an outside observer looking at Boston because it's a pretty screwy political system. It certainly was then. Mayor Curley was elected from a—he at that time was in a federal penitentiary, and was reelected. And seeing the strong tribalism of the Irish and the Italians, it was just fascinating. So I enjoyed that a lot.

BROCK: Did you live in Cambridge?

LAST: I lived in a graduate house at Cambridge my five years there.

BROCK: So what was the general atmosphere like at MIT in the physics department or the many physics laboratories, I guess, that must have been in existence at that time?

LAST: They were just getting over the war. A number of these guys had been at Los Alamos. Some of them were sort of bent out of shape because they sort of realized how their scientific work, which they thoroughly enjoyed doing, had been used. There were a number of people not in terribly good shape. But it was just a big time of transition.

BROCK: The radiation laboratory—I mean, certainly the building was still there, but were some of those wartime laboratories still in existence?

LAST: They took all the radiation laboratory stuff and moved it out to Lexington, and so that stuff was gone and it was all classified work which there was an awful lot of soul-searching at MIT, I believe, at the time. Should an educational institution be involved in this degree of classification? Can you give a classified doctor's degree, for example? These were serious questions.

But the old Building 20 where all this took place was demolished three or four years ago. They sent me a piece of it [laughter]. Von Hippel—again, it's amazing. All these people who were close to me died in the last year or so. Von Hippel died at 104. But he had done a lot of the work necessary for the high-voltage breakdown insulating materials necessary for radar

during the war. He'd developed all that stuff, which made him a fair-haired boy with the Bureau of Naval Research or whatever.

BROCK: ONR [Office of Naval Research].

LAST: ONR. So, ONR supported his laboratory work.

BROCK: What was the process like for you and for others at that time of sorting out who it was you were really going to work with? Was that something that you did early, or after you'd done some course work?

LAST: In von Hippel's laboratory, this fellow who later on ended up working with me was Alton Gileo who had one of the laboratories in von Hippel's group, and they needed a research assistant to work there, and he saw my name on the résumés and said, with his optics background, this is what we need here, working in spectroscopy and things. So they offered me that and it looked fine to me. So I worked there.

Von Hippel's laboratory was—I probably learned as much there as I did in the organized curricula, because this was a laboratory that had metallurgists and physical chemists and x-ray people, just the whole spectrum of people. So I got to know them all, what they were doing, and we were all working in the same general area, dealing with the electrical properties of materials. We had a weekly seminar. Von Hippel was of the old German school that tried to keep you there working and working forever. The physics department said, "Well, we're not going to give you any more physics candidates if you don't get them out of here in five years." He'd been happy to have it be a seven- or eight-year, nine-year program.

BROCK: Was he carefully orchestrating a research program then that he was fitting people into?

LAST: He was very interested in the physical structure of ferroelectric materials, like barium titanate which I ended up doing my doctoral thesis on. There were a number of people working on various titanates. You could see the very interesting properties that these materials had and the extraordinary potential for practical use of some of the ferroelectric materials.

BROCK: What were the envisioned applications for these materials, and then what came to be?

LAST: Memory would be the key one. Computer memory which now it looks trivial, but at that time, that was the big drawback in computers. Memory was frightfully expensive.

Von Hippel hired a fellow he had known in Germany. Before the war, in Neils Bohr's laboratory, these guys all knew each other. This fellow was head of research work at Zeiss during the war, and it was fascinating to be able to talk to him. He and I were pretty close. Alexander Smakula. So I got to know him and his stories. He was in the eastern zone, and the Russians were coming. They were trying to move all these top technical people to the west, and he had something like three hours to pack and get out of there, and he said, "I had made the hard choice between leaving all my technical notes or my children's toys, and I took my children's toys."

BROCK: Wow. Because then Zeiss was in the east, wasn't it, thereafter?

LAST: Yes. And he told me fascinating stories, like he had developed the idea of optical coating; you put coating on lenses. He packed up a whole unit of this stuff that was put on a submarine and taken to Japan, which got the Japanese started in the optical coating business.

BROCK: Oh, my gosh.

LAST: He had a lot of fascinating stories to tell.

BROCK: So you had a research assistantship, essentially, in the laboratory then?

LAST: Yes. Well, the laboratory is nominally under the head of the electrical engineering department, but as I said, it was so interdisciplinary, you couldn't tell what department it was in.

BROCK: That was really from von Hippel, wasn't it, that interdisciplinary, or multidisciplinary approach?

LAST: Yes. He wasn't an extraordinarily deep scientist, but he was very broad, and he could see the enormous advantage of interaction between people of different disciplines, which is now the common idea. They're trying to do this thirty or forty years later. But he did it.

BROCK: Would you say that the majority of your time was spent in this research assistantship capacity, or how much time was spent in seminars or course work?

LAST: Well, I don't know how it was divided up. I would guess I spent ten hours a week or so in the research end of things, and later on, that was my thesis, so I was essentially getting paid full time to work on my thesis. But I went through Rochester without some key physics courses, and after I was there, you know, six months or a year, I had to pass a qualifying exam and I had to know, for example, thermodynamics and nuclear physics, which I just had to teach myself.

BROCK: What was that like?

LAST: That was terrible. [laughter] I have no fondness for either of those subjects to this day. But I did it.

[END OF TAPE, SIDE 2]

LAST: I went to one of my advisors, and I said, "Look, I'm not prepared on this stuff. What happens if I flunk these exams?"

He said, "Well, I guess we'll just have to throw you out." [laughter] Truly an inspirer.

After I'd been at MIT for a very short time, I was offered an optics job, a very high-level optics job. I was very flattered and looked at it very briefly, but—

BROCK: Who with?

LAST: This was a company in Ohio that was working on some kind of bombsights or gun sights. I was flattered, you know. I didn't have very high aspirations for a salary, but they were going to pay me what I was expecting to get when I got out of school. So I thought about it, but I went more out of curiosity and to be flattered, and of course didn't follow through on it.

BROCK: That was quite early on while you were there?

LAST: I'd been there four or five months or something, something like that.

BROCK: I guess PerkinElmer was also big in optics at that time.

LAST: Yes. PerkinElmer. I had my first interaction with Beckman, who had made the spectrophotometer that was a little beyond their capabilities, as it turned out.

BROCK: This was the IR-3. Is that right?

LAST: Yes.

BROCK: So that was really one of their very first spectrophotometers, wasn't it?

LAST: Yes.

BROCK: Infrared, I guess.

LAST: Yes, infrared. It turned out that barium titanate, the material I was working with, had some very unusual structural changes when it became ferroelectric. The barium went off center. But this turned out to be almost impossible to detect by x-rays. For some reason it didn't work. So I investigated how barium titanate went through structural changes by looking at changes in the infrared absorption spectrum, which I found pretty interesting.

BROCK: Was that IR-3 instrument already in the laboratory?

LAST: No. Gileo ordered it, and he left just about the time it arrived. So I was stuck there with this big thing that didn't work.

BROCK: It didn't work well.

LAST: It didn't work well at all. So I raised quite a fuss about it, the lack of technical support from Beckman, and von Hippel got a hold of Beckman, and they sent Beckman engineers. So by the time I was done with schooling, all the top people in Beckman knew me.

BROCK: As the problem-maker with the IR-3?

LAST: No, as a problem-solver for the IR-3.

BROCK: Did you suggest some design changes that they made?

LAST: I suggested some minor, more operating procedures than basic design changes. But I used it, and by the time I was done it was working pretty well.

BROCK: What was the main problem with it? I'm curious.

LAST: It was mainly the electronics weren't working. They had a recorder with a magnetic wire, a magnetic wire recorder rather than a tape recorder, and none of the stuff worked terribly well.

BROCK: People had looked at these materials using the x-ray diffraction and hadn't been able to get good results. Was it your idea to bring the infrared spectroscopy to bear?

LAST: No, that was von Hippel's or Gilleo's idea that this was a way to investigate these materials.

BROCK: Had you had any previous experience with spectroscopy?

LAST: No. Well, I took courses at Rochester dealing with spectroscopy. Not infrared work, which was a fairly new area. But I could pick it up without any trouble.

BROCK: Did you enjoy it at all?

LAST: Yes, yes, I liked my graduate research. The course work, as I look back on it, I didn't take that many formal courses. I took quantum mechanics all the way through, and I had to take a minor in math, so I took as many math courses as physics courses. As I said, I had no love for nuclear physics. But I was right in the heart of solid-state physics, and so when it came time for my doctoral exams, quantum mechanics was a requirement, and then I could pick a minor—another area, and if I'd done it in optics, I knew more optics than anybody at MIT, probably. But I said, "No, I'm setting out to be a solid-state physicist, so take it in solid-state physics." So for about six or eight months I just learned solid-state physics on my own. The first book that

came out was [Charles] Kittel's book, first general book, and that was after I was out of school (1). So I just had to read journal articles—it was a great voyage of discovery.

BROCK: Had [Frederick] Seitz written—

LAST: Seitz had written his book (2), and [John Clarke] Slater I took courses from. Slater was a marvelous lecturer. So I had [Victor F.] Weisskopf for quantum mechanics, and Slater for—

BROCK: Not too shabby. [laughter]

LAST: No. I'll just get into one humorous anecdote about Weisskopf, who was a great theorist, but not the world's best mathematician, which he was first to admit. I had a visitor from Princeton one week I had a Saturday course with. I said to my friend, "Come and sit in. Hear a real pro give a lecture." So we went in there, and Weisskopf started out and filled the whole board, kept going and going, and getting more and more confused, and finally said—(this was elementary quantum mechanics). He finally said, "Look, I'm so confused, it doesn't make any sense for me to continue. Let's just quit right now." [laughter] But he was a marvelous human being. Just one of the greats. Very inspirational.

BROCK: To you personally.

LAST: Well, no, just in the physics community in general, the way he turned into a leader, in explaining physics to the world. The title of one of his books is *The Privilege of Being a Physicist* (3). So I found that a very great experience.

BROCK: I think I did see at one point that you held an IBM fellowship. Is that right?

LAST: Yes.

BROCK: What was the story of that?

LAST: IBM could see the potential of ferroelectrics, and so they wanted to sponsor my work, and MIT said, "You can't pick people that we give fellowships to. You have to send us the money and have us do it." But they really wanted to sponsor my work, so they narrowed it to

the IBM Fellowship in Ferroelectric Material. [laughter] I was the only one working on that, so I got it.

BROCK: Was there anyone in particular from IBM's side that used this fellowship as a way to get into a dialogue with you?

LAST: Oh yes. They'd fly me over to Poughkeepsie [New York] on their company plane once in a while, and I'd talk to them about one thing or another. They had hired a fellow that preceded me at von Hippel's lab who was there, so he was the one who was sort of instrumental in this.

When I got out of school, I was talking to him and he said, "Jay, I know you pretty well, and the sort of regimented environment here is one I don't think you would work well in."

BROCK: And this is before they started their research laboratory?

LAST: I don't know how things were organized there, but it was, you know, strict dress code, punching a time clock. He told me an incident where somebody was objecting strongly, you know, having come from an academic background, to punching a time clock, and his boss kept saying, "Well, there's nothing bad about punching it." He said, "As a matter of fact, I sort of like it."

And the guy turned to him and said, "Well, if you like it to do so much, you can punch my goddamned clock from now on," and quit, walked out. [laughter] This was a story that Young had told me. He said, "This is the sort of thing you're going to be faced with here." So I didn't even apply for a job.

BROCK: Although it sounds like they wanted to start an internal program, that would have been—

LAST: Well, ferroelectrics lost out to the magnetic materials in the memory area, so it never did realize its potential. There was always a lot of really interesting possibilities, none of which ever worked out. It was always too expensive to compete with other things, I think.

BROCK: Had the magnetic core memories—

LAST: Von Hippel was making some of those magnetic core materials.

BROCK: Because that was an MIT invention, wasn't it? So to speak.

LAST: Yes, and, again, it was an interdisciplinary thing. You've got Jay [W.] Forrester and that bunch who were interested in it. So it was a great tie-in, all those things.

BROCK: Did you become acquainted at all during these days with what was happening in computing since your research was connected to that?

LAST: No. No, I didn't. The transistor was not in sight yet. It was, but it didn't show up in anything I was reading or that I knew anything about.

BROCK: So during the summers then, you were, by and large, doing what?

LAST: I was just doing what I did the rest of the year. I took a summer course or two. I had to learn French.

BROCK: Were you returning to work in Preston's laboratory?

LAST: No. That stopped when I got out of school. I may have, on a few vacations, gone out there and helped out with one thing or another for a week or two, but nothing very major. It was a full-time job at MIT, so there wasn't any division.

BROCK: Again, a very rigorous academic program. Did you find time for many extracurricular activities?

LAST: No. None at all.

BROCK: I did read somewhere that indicated that your real interest in abstract art sort of developed in this time period, while you were in graduate school.

LAST: Yes. I never had much exposure to art, but I think it was tied in with optics and the perfection of crystals, and I've always to this day been interested in abstract forms. If you walk

around our house here you'll see a lot of mineral specimens and things like that. So my interest in art has always been toward the simple abstract forms. At MIT when we'd go to the Physical Society meetings, I'd go to the Museum of Modern Art and see all this wonderful stuff and took an instant liking to it.

BROCK: Did you start to recognize that as a real interest in yourself at this time?

LAST: No, it was just something that I liked looking at. I never thought of collecting it, of course. But I found Boston, as I said, a very stimulating town. But I realized that while it was fun to observe this bizarre political process as a student, as an outside student, I didn't think I wanted to spend my life raising a family in this Massachusetts corrupt political environment. So I made a conscious effort not to stay in Massachusetts.

BROCK: So, in thinking about these infrared studies that you were doing for your dissertation research, once you had sort of settled your research topic, your problem, what was your experience like with the unfolding of that research? Was it fairly smooth?

LAST: Well, it sailed along. The hardest part was I realized that while these materials were semitransparent infrared, it took an extremely thin crystal to get enough light through. Nobody had ever made a crystal this thin. It was so thin when I got it, I developed etching techniques where I could watch the thickness by interference bands, and when I got down to the last band it would be thin enough. I went through an awful lot of crystals. Etching is with phosphoric acid, and I realized I had to put my hands in the stuff in order to manipulate stuff, so my fingers had some sort of a black, crummy appearance, scaly fingers. And the crystal was so thin by then; the crystal curled. I mean, it's a nice solid crystal, and this thing would curl up like a sheet of newspaper, it was so thin. It was that thin a crystal. So I gave a paper on that, on how you make very thin crystals as another aspect of my thesis. The crystal changes structures three times as it gets into the ferroelectric state, and these happened at low temperature, so I had to develop techniques for putting this thin crystal in there and get it down to liquid nitrogen.

BROCK: And then introducing that into the—

LAST: Spectrophotometer and getting everything lined up. I'll never forget it. When I'm left to my own devices, I like to sleep very late in the morning and work half the night. I remember it was one Sunday night, late, the first time that this worked, and this feeling of absolute elation. This is something that nobody in the world has ever seen before. Just that feeling of scientific discovery is a real exciting thing.

BROCK: Was that the first time when you really felt that?

LAST: By this time I had done a lot of research projects, but nothing that was so completely new. Smakula took me aside once and said, "Jay, you have to realize that scientific research is 95 percent really tedious and frustrating, but that other 5 percent makes up for everything in spades." He's right. And I think it's especially true now with the very elaborate things where there's a hundred people working on an experiment, and you work and work and work, and everybody does their little part, and, zap, there's the experiment.

I was able to work by myself. I don't think I would have enjoyed the way that physics has gone these days, with the big complex experiments where you're playing a fairly minor role.

BROCK: You were more suited to handling all aspects of the work yourself.

LAST: Yes. I have never reacted very well to bosses telling me what to do, so I make up my own thoughts and mind about the way I do stuff. And solid-state physics is a lot better than other branches of physics. There still is a lot of work where an individual can do stuff. Although solid-state physics I feel, in some respects, the classical solid-state physics at least, has turned backwater.

BROCK: Today.

LAST: Yes.

BROCK: Really?

LAST: You've got the nano phenomenon, but I think like work on the solid-state physics of semiconductors, some of that work is not quite as pioneering as it was. That's my observation. I haven't thought much about that.

BROCK: But at the time, it was extremely wide open.

LAST: Yes. I mean, all this stuff for the previous twenty years flowing out, all these unexplained phenomena, because an awful lot of work up to that time had been empirical, and nobody knew why these things worked. Something like superconductivity. I remember reading the Dutch work on superconductivity, and they got into a philosophical discussion and said,

"This is a problem that's beyond the human mind to figure out." [laughter] So it was just an empirical thing, all these crazy phenomena. It took some pretty sophisticated quantum mechanics to get to the heart of it. It's a reasoning that's not terribly obvious.

BROCK: It struck me as pretty soon after having finished your dissertation, that you had an article based upon it published in the *Physical Review*, is that right? (4)

LAST: Yes.

BROCK: That seems awfully fast to me. Was it a quick adaptation for you to submit the article?

LAST: No. I had written a report for the ONR on this, so I had it all written. I had my thesis written and I put it into a report form, and it was just a matter of spending a day to put it into their format, so it wasn't anything.

But another thing I did really before I got deeply into my research, I had passed my oral exams, which, after that, it was just putting in time. You know you're going to get done. I'm always struck by the number of people that did their thesis, all but the research. It takes an awful lot of sticking to it. Twenty-six years old and still doing all the stuff I'd been doing since I was in high school, it wasn't a very rewarding personal life.

But after I passed my oral exams, I saw that there was a fellowship for metallurgists to go to Sweden for the summer. MIT was going to send a metallurgist to Sweden and I went to John Wolfe, who was the head of the metallurgy department, and managed to persuade him. I said, "You know, I have all this training, except I'm very weak in metallurgy, and this would be just a marvelous completion of my education to go to Sweden to work in the Metalografiska Institute." I was persuasive enough that he picked me rather than one of his own students to go to Sweden for the summer.

BROCK: Was it because of a passion for metallurgy, or a passion to visit Sweden?

LAST: Here I could say that it was the first time in my life for a break. I'd been working steadily, year after year after year, and here's a chance I can relax a little bit for a summer. I thought that going to Sweden would be fun to do.

BROCK: Was it?

LAST: Oh, it was great. Yes. I had never thought much about traveling outside the United States, and this came a bolt out of the blue. About three weeks after I got word of the scholarship, I was on my way to Sweden. I was nervous. I didn't know any Swedish, so I got one of John Steinbeck's books, *Cannery Row*, translated into Swedish (5). I just read it in Swedish with the English translation there. So by the time I got there, I knew the Swedish name for all the fishes, so I could order right off a Swedish menu, which just flabbergasted my Swedish friends. But it was great.

The laboratory there closed down the month of July. So I just bummed around Europe for a month, went to England and France and Switzerland and Germany. I had had a German roommate my first year at MIT. There were three of us who shared the room. The other guy was a New Zealander, and it turned out the two of them had fought each other at the Battle of El Alamein. You talk about interesting conversations. [laughter]

BROCK: That's amazing.

LAST: Yes, it was just an amazing experience. This German had been a captain in the paratroopers, and was one of these guys that they'd just dropped in for the first day of the battle and take him out and drop him again. He was pretty badly injured. I didn't realize that he couldn't use his left arm. But anyhow, he was back in Munich, so I visited him. He was working at the Leica plant there. So I had great summer traveling around, and a great time in Sweden, and maintain close ties with Sweden ever since then.

BROCK: Really.

LAST: Not in the last few years, but I've been back many times.

BROCK: For just a pleasure visit?

LAST: No, this was when I was at Amelco, setting up Swedish subsidiaries, Swedish sales organizations and things like that. I had a nice social life in Sweden, so that helped. It made me very interested in going back there.

Are we getting sort of off the track?

BROCK: No, not at all. As your graduate experience was coming to a close, you were realizing that you didn't want to stay in the Boston-Cambridge area, but the IBM situation was

going to be a little bit too rigid for your taste, what were you ideas about where you wanted to go and what you wanted to do?

LAST: Well, this was an absolutely unbelievable time for jobs. I could have had my choice of a hundred jobs without question, and so I could pick and choose. I went to GE [General Electric] and I visited the Hanford plant, which, from a scientific point of view, interested me the most because of the radiation damage on materials, and how graphite turns into a big meringue or something like that. I visited other GE plants. Of course, Bell Labs, which is the place that I would—there were a lot of MIT people there and they were interested in me. I wasn't especially interested in transistors. I thought well that's—the basic work on that is done, and now it's just a matter of engineering. But I would have worked for Ian Ross who went on to run the whole shebang there.

BROCK: At that time was he running the physics department?

LAST: No, he was running a semiconductor-oriented group. Jim Early was in that group, and a couple others. I often wonder what my career would have been like if I'd gone there and I was right under the guy that ended up running it. It was an interesting speculation.

[END OF TAPE, SIDE 3]

BROCK: We were talking about the landscape of opportunities you had in 1956. The jobs were there for your choosing. We were talking about the discussion with Bell Labs, and I was wondering how far into the discussion with Bell Labs had you gone?

LAST: I had pretty well decided that that's where I would go. It was certainly the strongest, and my interest from the von Hippel days was sort of halfway between electrical engineering and solid-state physics. I was always looking at applications. I had misgivings at Bell Labs that the great work has been done here in semiconductors, and nobody could quite realize the potential of what was coming ahead. I hadn't any training in semiconductor technology, other than what I'd read and gotten in Slater's course.

BROCK: Did you consider at all taking a teaching post?

LAST: No.

BROCK: Why?

LAST: It just never came up. I think I realized that I'd start at the bottom of a big hierarchical structure, which didn't interest me, and time constraints were—you were committed to be at a certain place every day for a year. And my experience with industrial research with Preston and at Kodak and at the Metallographic Institute, I knew that industrial research was what I wanted to do.

BROCK: Bell Labs, the Murray Hill [New Jersey] facility was sort of the premier place.

LAST: Yes, that was the premier place, and I was being offered a spot in the premier division there with the premier people, so—

BROCK: Did you make many visits down for these conversations?

LAST: Not that many. We knew each other, so it was a question was I going to make the decision.

BROCK: How did it unfold that you were led astray from going to Bell Labs?

LAST: John Bishop, who was running the Beckman group at that time, offered me a job working for Beckman, working with their spectrophotometers. I said, "I just had a lifetime's fill of this." [laughter] But I said, "I am interested in California."

He said, "Well, if I can be of any help to you here. I can understand well why you don't want to work in spectrophotometry, but if I can be of any help to you, I'll be glad to do it in California," because I'd said I was interested in California from my fruit-picking days.

It was then Beckman signed up Shockley. I have some interesting correspondence about talking to Beckman and Beckman people. So they gave Shockley my name.

BROCK: Bishop gave Shockley your name?

LAST: Yes.

BROCK: How about that.

LAST: Or Arnold Beckman. Probably Arnold. By then they all knew me, so Beckman introduced me. He said Shockley should go take a look at me.

One day I got a phone call from Bill Shockley. He said, "I'm going to come up to MIT and talk to you." He was an extremely impressive guy.

BROCK: So he came to make a personal call.

LAST: Yes, he came, personally visited me at MIT, and I was telling him some of the problems I was having with my doctoral work, and, whack, he just figured it out in a second. Just an unbelievable mind.

BROCK: So that must have impressed you greatly.

LAST: Yes. Then I went down to visit him, another visit in Washington [D.C.] at the Cosmos Club, and he said, "Come down and join me for breakfast." So I took a night train down there, and here he was sitting at a table with, like, Admiral [Hyman] Rickover, Vannevar Bush. Everybody I'd ever heard about was sitting at that table having breakfast with Shockley. [laughter] So I was quite overwhelmed.

Then Shockley got into more interviews. I could see the first signs of this sort of withdrawn personality, in a sense, though I didn't pick up on it. He said, "Well, you know, I've changed my life. I've left Bell Labs, changed my life." Just like that. "Divorced my wife, got a new wife." [laughter] So I could see he was something different, that he was very frank and outgoing. He said, "The way I want to work—," and here again is something that I didn't pick up on the way I should have. He said, "I want to directly supervise your work, be involved in all of this."

And I said, "Well, this is something that since I don't know anything about this field in detail, I'm willing to do this for a while, but it certainly is not a long-term way I would want to work without making my independent decisions." And we just sort of left it at that.

BROCK: What did he describe to you as the goals of his new operation?

LAST: Well, to make commercial devices and, you know, carry on the work he'd done at Bell Labs, only do it under his own environment. He originally said, "I want to set this lab up in

Hawaii," but it was logistically impossible. He said, "I grew up in this area and my mother is here." He was very close to his mother, and Palo Alto.

So he picked Palo Alto, which I could see would close the big circle for me of being there when I was sixteen and coming right back to the area I liked best in the world, being close to the mountains that I could go climbing in, and being close to San Francisco. Although thirty miles at four in the morning can be a very long ride. [laughter] And then I just said to myself, it is impossible to decide what a job is going to be like. It's a wild thing. But something I can define in detail is the geographic surrounding I'm in, and this I know I would like. I've experienced it. I like living around here, and it's close to all the things I like to do. So I made the decision to choose Shockley over Bell Labs.

BROCK: It sounds like also the Beckman group had favorably impressed you as well, not so much the initial workings of their instrument, but—

LAST: Yes. Everybody in our Fairchild group has said many times they'd hire Shockley in a second to be a recruiter, because he's just really spectacular in that role.

BROCK: Just for his enthusiasm?

LAST: Enthusiasm and knowledge and just the whole works. It was, "Here's a guy I'd like to be around." And I think a number of people have made that observation.

So then I told this to the Bell Labs people, that I was almost certain I was going to take the job with Shockley, and they said, "Well, look, this guy has a terrible reputation here. You don't know what you're getting in for." They were right.

BROCK: Was that Ross who told you that?

LAST: I can't remember. It was three or four people. Jim Early was around there, although it probably wasn't Jim. Somebody else would have made that remark to me. But anyhow, it was pretty widespread. In December I decided to go to work for Shockley, and I have some interesting correspondence from him. I was the third person that he hired, and he had hired zero people from Bell Labs, and he never did.

BROCK: That was something I talked to Morrie [Morris] Tanenbaum about, because I mean, he had asked this whole roster of people, and to a man they weren't interested in working with him in that context, which I thought was telling.

LAST: Yes, the stories have come out by now of his competitive nature and wanting all the credit for everything. All the negative sides of Shockley were obvious to the people at Bell Labs, but they weren't to me.

The other jobs that intrigued me, I said I was interested in radiation damage, and Hanford was just the end of the world. I said, "What do you do for a social life?"

They said, "Well, you can drive to Portland in three or four hours." [laughter]

I said, "Well, I just can't." Being single and for the first time going to have what I hoped was going to be a nice social life, Hanford wasn't it.

North American Aviation was the other one. Down here they were doing great work on this. They offered me a job, sight unseen.

BROCK: Doing semiconductor work?

LAST: No, this would have been radiation. Graphite was expanding in one dimension and not another, and the reactors were all being pushed apart by all. To this day I think it would have been fascinating research. But they just offered me a job sight unseen and I said, "Well, I'm not going to take a job from somebody that's sends me back a letter saying, 'You're hired.'" I said, "I think I'm pretty good, but think of some of the jerks they're hiring this way." [laughter]

So it was narrowed down pretty quickly to Shockley or Bell Labs, and the Shockley thing won out.

BROCK: Who had William Shockley recruited, the two other people he had secured before you? Was that Noyce?

LAST: No. Here is a quote from a letter he sent me in January 1956: "You'll be interested in hearing that our recruitment program has been proceeding more successfully lately, and we now have a total of five acceptances. In addition to Leo Valdez and myself, who has been committed to my enterprise since early September, R.V. Jones (Vic Jones), George Barclay DeTolley, and William Happ have accepted offers. Jones is finishing his Ph.D. work at the University of California in physics." So that was it. He's been working at this for a while. Vic and I were the two ones right out of school. The others had quite a bit of industrial experience behind them. DeTolley never accepted the job, he left. Vic Jones had been hired by Bell Labs and Shockley called Bell and said, "Release this guy from his agreement."

So I have quite a bit of discussions of Shockley telling me what was going on before I got there, because I showed up in April. By then he'd hired [Gordon] Moore and [Robert] Noyce. I don't think he'd hired [Victor] Grinich, and he had not hired Jean [A.] Hoerni. I'm glad I kept all my notes.

BROCK: I am too. [laughter]

LAST: You're welcome to browse through any of it.

BROCK: I'd love to.

LAST: At that time, something that played a bigger role later on was, we all had to take a personnel test. Evidently, Beckman had had some engineer that went bananas and went around stabbing people, so they wanted to identify this sort of problem before they hired you. So after my first morning with Shockley, I flew to New York and took this McMurray Hamstren test. I could see pretty much what they wanted me to say. So I did that, and seemed to have passed.

BROCK: But everyone did that, I think, right? Everyone who was recruited.

LAST: Yes, it was a standard thing. Then later on I'd seen the results that said I would certainly—I was trying to convey was that I was very well suited for industrial research, although as far as getting into research management, they had some questions about it. [laughter]

BROCK: And you were deliberately trying to skew it in that direction.

LAST: Well, I did what I could do. Would you rather be the motorman or a conductor on a streetcar? I'd rather be a motorman. [laughter] That level of questioning.

BROCK: That's funny. So you joined him then in April of—

LAST: April 1956. We started Fairchild in 1957, and I was with Shockley for a little over a year.

BROCK: I did notice that you co-published a paper with William Shockley that came out in *Physical Review* in July of 1957, but you guys must have submitted right at the end of your time there (6).

LAST: Yes, I worked on that for about a year before that, almost, before. My contribution was minor, but I went through and cleaned up a lot of the mathematics and things like that. I was really his fair-haired boy at that time. Shockley said, "Let's be co-authors on this paper, and sometime later where you do the major part, I'll be a co-author with you." It was very flattering to be in that position with Shockley. But by the time the paper was submitted, we weren't speaking. That was July of the next year.

BROCK: From very early on, you enjoyed a very close working relationship with him? Would you describe that? With Shockley.

LAST: I would say I enjoyed it.

BROCK: It existed?

LAST: No, I found it interesting, but I was a laboratory assistant, and that's the way he was working with everybody. There was no such thing as everybody getting together in a seminar and discussing what we were doing. Everybody was compartmentalized doing their own work and reporting directly to Shockley.

BROCK: So, no overall picture.

LAST: No. Which is why I'm weak on what happened there, of who was doing what. I was not involved in any diffusion activities. Somebody got the story once that Gordon and I were doing diffusions together. We never did.

BROCK: What were you concentrating on?

LAST: I was concentrating on, as I did later, on the devices after they were made. There were some surface anomalies that were taking place with these four-layer diodes, and so we had to go back to some fairly basic work on the surface properties of materials, especially when there was moisture present. So I worked on that for a long time. I think Leo Valdez had left. I think I was continuing some of his work. I have some notes to that effect, that I did that. So I was

working on surface states of devices, and then on some—when four-layer diodes were being produced, there was an abnormal breakdown that occurred because of some surface-state problems, and I worked on that.

I enjoyed being there. I liked all the other people there. It took me a while to settle down, because I didn't know hardly anything about semiconductors, and the only person who did, it was Bob Noyce who had actually worked with the semiconductor. Bill Happ had, I think. The rest of us had never seen one. To this day I've never seen a germanium transistor. [laughter] Bob said that was a real strength, because nobody knows how easy germanium is and how hard silicon is. He said, "You don't know how easy it was with germanium." Silicon is tough.

So Shockley made the two key correct decisions and that is, silicon is the material to use and diffusion is the process to do it, which had untold applications down the road because it enabled silicon devices to be made in a batch process form, rather than an individual basis, which is the reason that the field has developed. All these other things were laborious; alloying things or the Philco etching from both sides, and plating by reversing the polarity, just all that stuff. And you can see that, how different these technologies were. What's been really striking to me throughout the years is the companies that were leaders in one technology were not the leaders in the new technology. None of the germanium companies survived. Transitron just disappeared. All the silicon companies—TI [Texas Instruments] was the one exception to that. None of the big companies turned into major transistor manufacturers.

BROCK: That's true.

LAST: GE—all these people had everything going for them. RCA [Radio Corporation of America]. They started, but I've really learned a lot, how hard it is to switch technologies. You change your mindset, and you want to tell war stories about the great stuff you did in the past, and not think about scrapping everything you'd done up to that point and starting over again.

BROCK: Because I would think that that would often involve a complete change of personnel.

LAST: Yes. A report I had from RCA once—I really wish I'd kept it. It was from the Tube Division at RCA; they said transistors are doomed, they're a flash in the pan, and it was a formal brochure about all the reasons why transistors were never going to work. That was the tube mentality.

But anyhow, Shockley made the right decision and we were the right people to implement it because we all had a fresh slate. I had a really fresh slate, because, as I said, I didn't know very much about transistors anyhow, so I spent quite a while getting acquainted with the general field.

BROCK: I've read in places where the story is cast that when the Shockley diode project started, that that caused discomfort among some of the people in Shockley's laboratory because they viewed it as a shift from what they thought was the more intriguing or the initial goal of the silicon transistor.

LAST: Oh yes. That's absolutely true.

BROCK: Is that your experience?

LAST: I didn't get directly involved in any discussions of that, but the people that were doing the diffusion work could see—look, after we make a transistor, which is hard enough to make, we have to put another layer on here, and it's a lot more complicated device. It was an extremely intriguing device, and so Shockley felt, "Well, I did the transistor, and that's Bell Labs' thing. Now I'll make my reputation with this." If that had worked, it would have been a switching device that would have had very widespread uses. Shockley was exceptional in figuring this kind of stuff out.

BROCK: At designing or envisioning the new devices?

LAST: Envisioning new devices. He's an extraordinary, brilliant man. I mean, his book on semiconductors, *Electrons and Holes*, he just sat and wrote that thing (7). It was just people filling in the pieces from that point on. Just a remarkable piece of work. But he wrote that real fast because he was competing with his fellow workers at Bell Labs.

BROCK: At Bell Labs.

LAST: And hitting on the junction transistor rather than any point contact device. The key decision. So he made right decisions. He hired a good group of people. So if you look at it, it was right in place here. It was the right technology, the right material, the right group of people to implement it, and wham. [laughter]

BROCK: And just the difficulty with organizing it properly so it would work, or making it work.

LAST: Well, you could see that things weren't proceeding as smoothly as he had hoped. [Eugene] Kleiner talks about developing the crystal-growing apparatus. He had some kind of bolt on it, and Shockley was second-guessing him on the bolt and it really irritated Gene, and that was his strength, was knowing what bolts to use. [laughter] So he was just micromanaging everybody. I, of course, didn't see other people being micromanaged, so I don't know really what Gordon feels now about all this stuff he was going through then.

BROCK: My impression was that it was more on the level of some of these that he thought were more disturbing episodes, not so much about the work, but of things like lie detector tests and these very disruptive things. And also a question about this strategic shift from just making transistors to put two on top of each other that shared—you know, to the diode.

LAST: He had Jean Hoerni working outside the facility in an apartment.

BROCK: On this other sort of device.

LAST: No, no. On developing the—they realized that not that much was really known about diffusion in detail, so Jean worked on developing these real elaborate graphs for time versus temperature, diffusion theory.

BROCK: In an apartment.

LAST: In an apartment down the road, and Jean didn't have any idea what was going on. [laughter] He was there by himself. And he finally rebelled against that and came back and then started working himself on diffusion and turned into a—he had never done all that much experimental work. He turned out to be damned good at it.

BROCK: So it seems that the overall atmosphere was compartmentalization, or not a lot of communication.

LAST: Yes, and the communication was—well, sometimes there'd be a meeting and Shockley would bring his wife in, who was a psychiatric nurse or something like that, and she would sit there and take notes on us and look at our expressions while we were talking to them. Just terrible. But as I said, I was Shockley's fair-haired boy. I'd go to dinner at his house and had very pleasant evenings with him.

BROCK: What were they like?

LAST: Oh, we'd just sit and talk about all sorts of stuff. He was very interested in poetry and we'd talk about poetry.

[END OF TAPE, SIDE 4]

LAST: One time we were at his house, and it was later than I had thought it was, and Shockley wanted to tell me it was time to go home. He pulled out a T.S. Eliot book and started reading, "It's time, gentlemen. It's time." Just that inability to just face up to something like that.

Then I could see more and more signs that he was just not communicating what was important to people. I went to work there, at the time for an average salary, which was six hundred and seventy-five dollars a month. After about three months, Shockley called me in and raised my salary to eight hundred and fifty dollars or some huge raise, after I'd just been there a short time. And he said, "Well, that'll teach you to never sell yourself out cheap again." So he could turn an extremely positive thing into an extremely negative thing, without realizing he was doing it.

BROCK: And you saw that pattern repeat?

LAST: Yes, in all sorts of—and getting steadily worse as Shockley's relations with Beckman deteriorated.

BROCK: With Beckman personally, or with the company?

LAST: Well, Beckman personally, I think, and things weren't happening as fast or as well as Shockley wanted and he had to find some scapegoat to blame for all of this, and personally I started seeing more and more of the negative sides of it. But he had his first, I think, run-ins with Leo Valdez.

BROCK: Yes, that's what I've heard.

LAST: You may have heard Leo calling him in the middle of the night.

BROCK: Yes, that he thought it was Leo or maybe it was—

LAST: It was, but Shockley couldn't face him, so he called Leo's priest and had Leo's priest go to Leo and say what a terrible thing it was to keep waking this poor man up in the middle of the night.

BROCK: I hadn't heard that before. [laughter]

LAST: But that's just his convoluted way of approaching a problem.

BROCK: Was he afraid of conflict or something?

LAST: I don't know. His mind worked so—he was so far ahead of me technically, and so far behind me socially, that there's just no way to communicate that. And you've probably read [Frederick] Seitz's book and he talks about Shockley. It's the most frank discussion of Shockley.

BROCK: I haven't read that, to tell you the very truth.

LAST: Yes, but he and Seitz were very close.

BROCK: Yes, from the early times.

LAST: The early days, and then Shockley came to visit Seitz when he was on his way west, and then he just behaved so bizarrely that Seitz finally washed his hands of him. That's the best discussion I've seen of Shockley behavior. You know this book I'm talking about.

BROCK: Yes, I do.

LAST: Seitz's autobiography (8). Read the Shockley stuff in there.

BROCK: Maybe we could talk a little bit about some of your co-workers at Shockley during that time, to the extent that you had interactions.

LAST: Well, we interacted socially. We had parties and the like. I got along fine with what turned out to be the group that left. I never communicated well with Smoot Horsley, who in his younger days had run a furniture company, so Shockley said he should be the business manager. And Valdez came and went. Tom Sah had joined, but he was pretty much an isolated guy doing his own stuff then. I liked them all a lot.

BROCK: What was your first impression like, if you can remember, of Gordon Moore?

LAST: I found him a very pleasant person, easy to talk to, easy to get to know. We seemed to like each other. I'll show you a picture.

[PAUSE IN RECORDING]

BROCK: We were talking about Gordon Moore.

LAST: We were just looking at the—Gordon and I climbed Mount Whitney together the first summer. Gordon didn't take too well to mountain climbing. He did it, but every time I'd bring it up again, he'd say, "Well, I climbed the biggest one already. There's no point in going climbing anymore." We got along well socially. I liked him a lot. I liked them all.

I got to know Jean well. We again climbed that first summer. We went to climb Mount Shasta, and so that started something that went on for years. Jean and I would go climbing about once a month. Climbed all over southern California and northern Mexico. We did the same thing with Sheldon, who was also a climber. So I got to know Sheldon and Jean well as a result of camping out with them and climbing.

Gordon had a very rich home life, and he went home at night and that was it.

I saw Bob once in a while. I went skiing with Bob. Then I had an unfortunate incident with Bob that I think has been written someplace, so I'll discuss it. This was the next year when my relations with Shockley had really started to deteriorate and I couldn't figure out what was going on. Bob was sort of the *de facto* leader, and I went to him and said, "Look, Bob, in confidence, I'm just having this real problem with Shockley. Can you give me some guidance what I'm doing wrong, or what's happening?"

BROCK: What were the problems like that you were experiencing?

LAST: I'm drawing blanks on this, but I could see I was going to be the focus of blame for things that weren't happening well. This is what happened to everybody eventually pretty much. So I told all this to Bob, and five minutes later Shockley came storming out and said, "What the hell is that you're telling Noyce about?"

I said, "Bob's off my list from now on as far as sharing any confidence with him."

BROCK: And that's early on.

LAST: Yes.

BROCK: So I guess we'll get to that, but you continued to work with him for the next—

LAST: Yes.

BROCK: Four years, was it?

LAST: Yes. But I obviously remembered that incident and his approach to it.

BROCK: Which was just to go right and tell Shockley.

LAST: Right to Shockley. It just flabbergasted me. By then, everything is turning into a circus there, all these other things.

One thing that—Shockley told me a story, and I could see it was more than a joke to him; it was something fairly serious. It was about a fellow in a mental institution who's looking out through the bars and sees a truck driving under an underpass, and the truck gets stuck, and they can't figure out how to get the truck out, and the guy in the asylum shouts out, "Well, just let the air out of the tires a little bit and then you can push it through."

And they said, "Well, how does a guy in a mental institution figure it out?"

The guy said, "I may be crazy, but I'm not stupid." And I could see sort of a tension in his voice when he was telling me. And he told that story to me twice. So I could see something, that he was thinking along these lines that with his brilliance, he had some very

serious other problems. I don't know how much of that he wrote in his diary about his feelings about this. I've never seen that kind of stuff.

BROCK: The material that I saw, it's more of a log than a diary. You know what I mean? It's not very expressive.

LAST: Yes. Phone conversations.

BROCK: Yes. You know, "resigns on this day." Things of that nature.

LAST: Yes, that's what I guess it would be.

BROCK: That's interesting.

LAST: So my initial relations with him were great. When he went to Sweden to get the Nobel Prize, he called me from Sweden to discuss how my work was coming along. I was really at the top of his list. Then as this pin affair developed, I think that was a key moment.

BROCK: Broken pin.

LAST: Yes, a broken pin and he wanted everybody to take lie detector tests, which I never confronted him directly on that, but I would obviously resign before I would go through an experience like that. I started there in April. The Nobel Prize was like November. From then on it was downhill. Shockley was gone quite a bit of the time. He was back in Woods Hole on some kind of government advisory board sort of a thing, and he was running off doing that. Put Smoot Horsley in charge. So things were—November was still good. In February, Vic Jones had had it. I was very close to Vic, and he and I climbed together, too. Vic left, and Shockley helped get him a job as a professor at Harvard.

BROCK: Oh, I didn't realize that.

LAST: That's where Vic spent the rest of his career. I lost touch with him. I have some notes that in January of 1959, after the place had been in business for under a year, there was some group semi-revolt thing, that "We have to have more control over our own life and you can't keep running us this way."

BROCK: In 1957.

LAST: That would be January of 1957. I have some notes in there, and I don't remember. Just some notes I have.

So Vic left in February, and at that time I was still on good-enough terms with Shockley that I realized I had to get out of there. I went to Shockley and said, "Hey, Bill, I'd like to take a year's leave of absence," because I figured after a year he'd be settled down. "Beckman has these offices in Munich, and could I go over there for a year and sort of do the Beckman stuff for a year?" Shockley agreed and started writing letters, and so I was still communicating with him enough to have that interaction. I was looking for a graceful way out.

BROCK: I would like to return to some other questions about the Shockley period, how the group that eventually did leave together coalesced; how that conversation began, because I wouldn't imagine that that would be a straightforward thing to—

LAST: I think it goes back to that January meeting that I'd mentioned where we were sort of putting it out on the line together, and we could see kindred souls in this problem, and the group of us that eventually left together were ones that starting talking among ourselves. Noyce was not a part of this process.

BROCK: Right. Until much later.

LAST: Until much later, until it was an accomplished fact that we were indeed leaving, and then he got it. But it was partially, you know, I think a loyalty to Shockley and a number of reasons. But it was the seven of us that talked, and there would be the occasional party at somebody's house and we'd always get to talk about that a bit. I don't recall why it was, but Jean, Sheldon and I were the three that got on Shockley's list as being the cause of his problems, and my communications essentially broke down at that point.

BROCK: Was that the point in time when he did this Ph.D. production line that a couple of people recall falling on the three of you.

LAST: Yes, he was going to supervise our work directly and want immediate outputs and all that. As I say, that stuff is pretty vague to me now and very painful at the time. But I knew I was going to be out of there sooner or later. Things then just turned into a big morass. The pin

affair was sort of the breaking point, and I realized that here's a man that has some mental problems of some sort, and Sheldon was the one that pointed out to him that the pin fell off. There wasn't some malicious person running around here trying to stab the guy. The messenger never gets a good report on the way his message is received. Jean is a pretty cranky guy, a delightful person, but had a very cranky streak. So the three of us, I think, had the worst relationship with Shockley. Happ and these people just never entered into our discussions. They were in another world.

BROCK: Were there any people more active than others in this sort of discussion among the seven of you?

LAST: I don't recall. Jean and Sheldon and I went climbing and then we had very active discussions about it then. I was very close to Jean by that time. We had a lot of our own discussions.

BROCK: What was Gordon Moore's role? Was he in there with you? Or how would you characterize that?

LAST: As I said, I hardly ever saw him, unless it would be at some party or the like.

I think there was some meeting—I'm very vague on the details—where Shockley, when we were all there, sailed into Beckman. I just vaguely remember that. It struck me as very bizarre. But we could all see that—the group of us that did leave—that we were going somehow or another, it was an intolerable situation and it was getting worse.

BROCK: In some accounts that I've read and in some discussions with folks, it seems like that incident of Shockley saying, "I can take this group and go wherever I want," you know, to Arnold Beckman, that that seemed to precipitate some action, namely, I guess, a phone call from Gordon Moore to Arnold Beckman. Do you remember that development?

LAST: Yes, I remember. I can see that in my mind.

BROCK: Can you tell me about it?

LAST: Yes. We went to lunch, the seven of us, and we said, you know, "We've got to start doing something here." We had our lunch at a German restaurant there. We came back and we were still grumbling, and Vic Grinich said, "Look, we've got to do something right now. Either

do it or quit doing it, but take some action. We've got to call Beckman. Who's going to make the call?" There was a lot of hemming and hawing, and for the first time I saw Gordon Moore's real strength. He said, "I'll do it."

BROCK: Really?

LAST: He picked up the phone. I can still hear the sort of quavering in his voice, but he was the one that did it. He called Beckman and Beckman wasn't in. So then later on, where I was not there, he did it either from his house or Jean's house or someplace. He called him that evening, and Beckman said he was coming up to talk to us.

BROCK: Then there was a series of dinner meetings, was it not, with Beckman. Could you tell me about those?

LAST: It was the first time I'd ever met anybody that was rich and a successful businessman. I was very impressed with him. He was paying for dinner with one hundred dollar bills, and I'd never seen one. After one of these meetings—I got along with him real well. He was a real nice guy. He said, "I feel like a million dollars."

I said, "Does that mean you feel good or you feel bad?" [laughter] He was impressively wealthy at that point. But it was a nice situation. I felt comfortable making a remark like that.

Beckman went through all the things, and "You know, no one person is bigger than the group," and so on and so forth. You've heard this account, I'm sure. It looked like he was going to support our group and really restrict Shockley's ability to do the damaging things he was doing. That went along fine until the final meeting where Beckman said, "Shockley's going to run the place, and if you don't like it, that's tough."

BROCK: That was at a dinner meeting?

LAST: No, that was at a Saturday morning meeting. Shockley was there with his wife, looking for nervous twitches.

BROCK: The whole staff?

LAST: Just the seven of us that were involved in this. It wasn't the others. I went into that meeting—I remember clearly standing outside and saying, "Look, I've got an exit here, because

I'm going to leave and go to Munich anyhow. But I'm telling you if I walk through that door, I'm not going to Munich no matter what happens. So I'm with the group here. Whatever happens, happens."

Then we saw that—my best analysis of it was that Beckman had talks with Jack Morton at Bell Labs, and Mort says, "Look, are you going to back a Nobel Prize winner or seven young dissident punks?" Or words to that effect. I think Morton persuaded Beckman that Shockley was the one he had to cater to.

BROCK: Why do you think it was Morton?

LAST: At the time I thought there was some relationship maybe between Beckman and Morton, or something. Morton was way up in the organization and wasn't directly involved with taking some of the stuff that Shockley was handing out to the people there. Sort of a senior-citizen kind of a guy. I could be completely wrong in all this, but that would make sense—

BROCK: It would.

LAST: —why Beckman changed his thinking.

BROCK: A lot of people speculate that he spoke to someone at Bell Labs who persuaded him to go the other way. So when you heard that, what was your reaction?

LAST: Well, Jean and I—I was just flabbergasted. Jean and I walked right out of the meeting, and drove to Yosemite, and got there late on Saturday night and climbed. Took a very tough climb on Sunday, and came back. But I could see it was over.

As I said, this was extremely painful for me, this abuse from Shockley. I'd go home at night and sort of stare at the ceiling and couldn't sleep. I was just out of school, and here I had great dreams of having a nice research career, and here I was in the middle of this stuff. So it was pretty tough on me. As I said, I have blanked out the worst aspects of it. But Shockley and his wife were a bad combination. I mean, his wife was egging him on and trying to—psychoanalyze—and I often speculated why she would put his papers in the public domain.

BROCK: You mean his papers now.

LAST: At Stanford.

BROCK: Tell me more about that.

LAST: Well, I'm just thinking, she was working hard to—she was extremely protective of him, and it was presumably his reputation, and some of this stuff wasn't going to help it.

BROCK: Yes, that's true.

LAST: But she did. I don't know how easily accessible those papers are, or how well they're catalogued.

BROCK: They're not catalogued at all. Who knows what the discussion was that's led to that situation. It could make it very clear.

So had that group of the seven of you then had discussions about having a common exit strategy then?

LAST: Well, after that horrible Saturday meeting when things had just blown up, we could see that—I have some notes where Beckman said, "If you don't like it, you have to leave. This is the way it is." So we all said to ourselves, "We have to leave." We got together at—I can see the room but I can't remember whose house it was, but it was like on a Friday night, some evening, and we realized that in the group of the seven of us, it represented all the technology. I mean, other people might have been redundant. The fellow who doesn't get all the credit he deserves was Dave Allison. Dave Allison was a great diffusion guy. He joined us right after we left, but he wasn't part of that original group.

BROCK: But he was on staff at Shockley?

LAST: Yes.

BROCK: What was his background?

LAST: I have a bio of him someplace here. He had a master's degree in physical chemistry or something like that. He was one of the leading stars in diffusion both at Shockley and at Fairchild.

BROCK: Did he and Gordon Moore work together?

LAST: I believe they did. By then Jean Hoerni was involved in diffusion, too, so those were the three diffusion guys. Sheldon was working on crystal growing, and as I said, I was good friends with him. Kleiner was a very reserved dignified guy. My relationship was pleasant but not terribly close. Julie [Julius] Blank I was very close with. We were just on the same wavelength, and we were always laughing about something or other. Vic Grinich and I, Vic had just a marvelous sense of humor, and that was the thing that kept us all going together. It was fun being with these guys. There was always a joke or something pleasant happening. It was a really great group. The group of seven of us got together and Gene Kleiner had this idea of—we were saying, "Is there some way that we can all be hired together? We could be a big asset to some company." We weren't thinking beyond that.

[END OF TAPE, SIDE 5]

LAST: So Gene wrote this letter, an extremely well-written letter, to Hayden Stone, and Art Rock, who was a junior person there, and who didn't throw it in the wastebasket.

BROCK: Did Gene Kleiner write that letter on his own and send it?

LAST: I believe he did.

BROCK: He didn't circulate that?

LAST: Well, he might have circulated it, but I could see he was a hell of a good writer, in the way he discussed this whole situation, what it would cost, and they could see the future. Well, he spent most of his life being able to communicate that sort of thing.

So Hayden Stone got right back to us and they came out, and there were a couple of talks, and they quickly pointed out to us that rather than finding a company to hire us, to start our own company, which was beyond my comprehension. I couldn't imagine being involved in a company that I helped run.

BROCK: At this point, had you formally resigned yet from Shockley?

LAST: No. No, we didn't formally resign until September, and this stuff was happening in June and July. In July I went to a technical meeting of the transistor people in Denver, and I took a leisurely drive back and went to the Grand Tetons and climbed the Grand Tetons. But I was calling every day to see what was happening, so I know things were lively. The Hayden Stone people didn't have as easy a time as they thought they would putting this thing together. They went through a lot of people, most of whom, as soon as the lawyers got an inkling of it, shot the deal down.

BROCK: Why was that?

LAST: Stealing trade secrets. I mean, this was also a difficult thing because most of the basic ideas we had came from Bell Labs, and Shockley had an open line to Bell Labs' research papers. They were always around. So that gave us a real leg up as far as technical advances. So we were filling in all the necessary pieces, but the basic ideas of diffusion had been put in practice by Bell Labs.

BROCK: To go back one step, what were your initial impressions like of Arthur Rock, and I can't remember the other partner who—

LAST: Bud Coyle. Arthur Coyle.

BROCK: Thank you. What were your impressions of the two of them?

LAST: Very high. I mean, those guys were Wall Street swingers, and they knew what they were doing, and it was a world I didn't know anything about. They presented themselves well and were very forceful and clear in their thinking. So, a very good impression.

BROCK: You enjoyed a lasting sort of interaction, relationship with Arthur Rock over the years.

LAST: Yes.

BROCK: Could you tell me a little bit—can we trace that line out maybe a little bit?

LAST: Yes, sure. You've done a history on Art, so you know his background. He got to Hayden Stone, and realized he had a real talent for identifying young technical companies and could see that what turned out to be Silicon Valley was the place to work, and he likes San Francisco. He, I think, was a little tired of New York Wall Street life, and California appealed to him. We quickly became good friends climbing. His first weekend here I think I introduced him to some of the climbs in the Sierras. He finally moved out here, and so he and I were very close hikers and climbers together from then on. I was probably for a long time his closest friend.

Art can come across as fairly aloof on occasion, but he's the funniest guy when you get to know him. For example, we would do crazy things like—I once from a realtor got the world's most tasteless Christmas card, and so I just scratched this realtor's name out, put my name on it and sent it to Art for a Christmas card. [laughter] The next year I got it back. So we just exchanged this tasteless Christmas card for several years.

Art was very outgoing. He'd leave town and say, "You want to stay overnight in San Francisco? Here's the key to my apartment." So he was very sharing in that regard. We'd do a lot of hiking, climbing. We bought a Land Rover together one time which we kept down in southern California. Art would fly down, we'd drive around and go down to Mexico. So I got to know Art well. I always enjoyed my friendship with him. We climbed Mount Popocatepetl down in Mexico once together. Did a lot of that kind of stuff.

BROCK: I'm sure we'll return to talking about him and Amelco, the story of Teledyne, but I was interested to know your thoughts about Arthur Rock's place in this very important nexus between developing practices of venture capital and technological development especially in what's Silicon Valley today. He seems to have been a very important practitioner.

LAST: Yes, he just had a vision of that. It was just starting, this idea of funding new companies to do things, and he could see that—first of all, he wanted to live in California, I think, and he could see that whole Peninsula area was just full of opportunities. So he decided to move out here and start a venture capital firm, and managed to raise, I think, eight million dollars with a great deal of difficulty, and was trying to get partners that knew a lot about technology so that there could be good feedback sort of thing. I worked with him a lot on those things, talking to him about one thing or another.

So then that was a big success, and it went on from there for Art. When I moved down here, our paths differed. There was a period there where we were both on a board together and we had a strong difference of opinion as to how that should be handled. That cooled things for a little while, but we got back on the track. I saw him at Kleiner's memorial service and he was extremely cordial.

BROCK: Maybe we could return then to the discussions, going back to the Hayden Stone discussions and getting Sherman Fairchild interested, and the Fairchild Camera and Instrument, your experience of that.

LAST: Well, by then, when it was an accomplished fact that we were indeed going to do it, Noyce came on board as a result of Sheldon Roberts calling him like at two in the morning and persuading him to come to this meeting at eight the next morning. Once he joined, he was enthusiastic about it. He wasn't going to take the initiative in something like that.

BROCK: Because he was still enjoying a good relationship with Shockley, do you think? Or had some ambivalence?

LAST: I think had some ambivalence. I've often thought of him as a Hamlet type.

BROCK: As a—

LAST: Hamlet. You know, has a lot of opportunities but can never quite decide until the decision is pretty obvious. That's my own impression. As I said, I was never terribly close to him. But the group started working. We were really close together and liked each other and were excited about the possibilities of this.

BROCK: And all very young, too.

LAST: Yes. I was twenty-eight then, and I think Jean and Victor and Gene were maybe thirty-two. Because the older, more experienced people didn't join our group.

BROCK: They stayed with Shockley. Did it break along those age lines?

LAST: I think Happ was older a little bit. Horsley.

BROCK: I hadn't really thought of that before. That's very interesting.

LAST: I'm just guessing how old we were. But we were a very compatible group. Hayden Stone did their part in finding us Fairchild, and there were meetings, I think, just when it was starting, where I think Noyce was involved in going to talk to Sherman, maybe Noyce and Kleiner, or Noyce and Roberts. I didn't meet Sherman till the next year when we all were in New York and he invited us to his house for dinner.

BROCK: What was your impression of him?

LAST: Very high. Just a real guy that could do what he wanted to with his life, had a very interesting way of doing it. He liked aerial photography, so he started a camera company and an airplane company. He was the heir to a big chunk of IBM stock, so he had a lot of—really a rich guy. I think it was because of that that Hayden Stone could cut a little more free-wheeling deal than it would be possible if he got all the company lawyers involved.

BROCK: Because they were dealing in a way with Sherman Fairchild himself?

LAST: Yes. While Hodgson and Carter were the—Hodgson was the key guy involved in this, and doesn't get all the credit he deserves, I think. I know the day we finally went to Rickey's and started signing all the papers to put this deal together, Hodgson turned to me and said, "Jay, I hope the hell you guys know what you're doing, because if you don't, I'm going to lose my job." [laughter] But he was looking around; we all looked like kids. I really liked Hodgson, and I had not much respect for Carter.

BROCK: Who I've heard described as sort of more of a conventional type.

LAST: Very pompous, self-centered. Carter came into our plant at Fairchild once, and the secretary didn't recognize him immediately. There was no reason she should. So he said, "I want my picture put in the wall of every reception office of all the Fairchild companies so they'll know who I am."

BROCK: That's one solution. [laughter]

LAST: Yes. And five minutes after he left, I put a sign on the bottom, "Have you seen this man?" [laughter] Which didn't last long.

So anyhow, Hodgson was the key communicator and the one that deserves the credit for making this thing work.

BROCK: So at about this time, then, everybody needed to tender their resignation. Did you meet with Shockley again?

LAST: I never spoke to Shockley after about July of 1957. I was never in the same room with him.

BROCK: Did you send a letter or—

LAST: I think we talked—there was a guy named Maurice Hanafin.

BROCK: The Spinco guy?

LAST: Spinco guy. He was sort of running things, and I think we just submitted our resignation to him.

BROCK: Did you ever speak to Shockley after that?

LAST: No. Once at Stanford we were both going around a corner and just happened to see each other, and we didn't speak. He just ignored me. Sheldon Roberts told me once he was at dinner, a Saturday night dinner with his wife, and saw Shockley, and went over and said, "Hi, Bill," and Shockley turned to his wife and said, "Isn't it terrible that you can't even go out in a restaurant without somebody coming and bothering you." So Shockley just never acknowledged any of us again.

BROCK: So he really took it quite personally.

LAST: Oh, Lord, yes.

BROCK: Do you know, or is there a story about how Arnold Beckman or the Beckman folks reacted to the news of everyone leaving?

LAST: Oh, Beckman took it very hard and said in a memo there that "A black cloud is going to descend upon you guys for your unprofessional behavior."

BROCK: Oh, really?

LAST: Oh yes. It was a strong letter. So he was sort of flabbergasted. He had made the wrong decision and started realizing it.

BROCK: I read in one account that didn't have a source attribution to it, but someone thought that Richard Hodgson spoke to Arnold Beckman before sort of inking the deal to set of Fairchild Semiconductor, to make sure that they weren't going to encounter legal difficulties. Do you know if that—

LAST: I don't know anything about that. I know Beckman got a detective after—have you seen that?

BROCK: Well, I do know that he had their lawyer, this guy Les Dureya look into things to see if—who was, I think, the corporate counsel for Beckman Instruments.

LAST: I think it was just a prudent move on his part to see what we were taking, and there was always talk. Ed Baldwin in later days talked a lot about some stuff he didn't know anything about, that we had taken all our lab notebooks. None of that was true. It was in our heads. The basic ideas that we were using were from Bell Labs, rather than Shockley.

BROCK: During the time that the now group of the eight of you are talking with Fairchild Camera and Instrument, with Hayden Stone about setting up this new company, were you having discussions among yourselves about what your goals were going to be, business goals for the new firm, how you were going to organize it, and—

LAST: It was clear that we were going to make the transistor that Shockley didn't want to make. We didn't know what kind of a transistor it would be. It would be a either a relatively high-power device or a low-power device, and the reason high power won out is a core driver. Vic Grinich was key, and Noyce, probably, in figuring out the specifications of the device that could be made. The thing that I think decided it is when we got a contract from IBM to sell them a hundred of these things.

Our timing was just perfect. We had the technology and it was something the world really needed, and the existing companies weren't in a position to make them.

BROCK: So in early 1958, I guess it would be, or very late 1957, early 1958, I think I have a picture of the breakdown of the different areas that people took, and I understand that this was basically what people were going to work on was an extension of the technology that they had become familiar with in the Shockley period.

LAST: Yes.

BROCK: So Roberts continued then with crystal-growing efforts?

LAST: Yes.

BROCK: Were there other things he was—

LAST: Well, anything dealing with crystals or metallurgy of crystals, and he later on got into some defects that were caused by thermal shocking and diffusion furnaces and things like that. Essentially his first pass was to get us in the crystal-growing business real fast. When I look back, I'm flabbergasted how fast we did this.

BROCK: Well, that's right, because, I mean, you're delivering things within a year.

LAST: By the summer of 1958 we were delivering transistors, about eight months after we went into business. Most of the equipment we had to invent ourselves. Microscopes we could buy, but we had to build our own furnaces. Sheldon built the crystal grower. I got involved in some optical stuff, making thin crystals, making crystals thin enough by polishing. I bought optical polishers and things like that. Jean was focusing more on diffusion pretty much, which would lead to the PNP. Boron was a pretty tough customer to deal with. Gordon was involved, and Dave Allison, in the more standard NPN diffusions, and Gordon got involved in metallization and how you make contact to these devices and all that stuff. Vic was invaluable in dealing with testing the devices and building all the test equipment.

BROCK: I've heard a lot of people talk about the test equipment, but I really don't have a very good picture of what was involved there for that task, to set up test equipment. I guess to test these devices in some volume as they would—

LAST: It started with just using Tektronix curve tracers, you know, and testing them one by one on the curve tracer, and gradually setting up custom procedures so you could make fail/pass tests on various things. But it was all kinds of equipment like that that was needed; measuring frequencies and voltages. Vic probably had the biggest enterprise there. You know, people were building all this equipment. He, as I said, was invaluable. Gene and Julie were involved in just a host of equipment that we needed designed. Gene evolved more in the business management side of it, and Julie was involved more in the plant facility side of it.

BROCK: At this time, we talked about the polishing work, but were you starting to get into development the photo lithography at this time also?

LAST: Yes. Noyce and I were working together on that.

BROCK: Can you tell me about that?

LAST: Well, something that just seemed obvious, but I guess it was a pretty good decision, was to make it a batch process so we could make a whole bunch of devices on a wafer. Wafers at this time were very small. An inch would be a big one. It was probably Noyce's idea to make the step-and-repeat camera, that if you step and repeat, if there's a misalignment on one, it's repeated on the other masks. With my optics background, I could help get this thing built by getting the right lenses. Noyce turned more and more into an outside person, and general concepts rather than getting involved in the lab stuff, so most of the time I was, as I recall, doing this on my own.

We needed special photoresists. Photoresists at that time were pretty crude things, used for making printed circuit boards, and Kodak was developing some higher-quality resists which we latched onto, and turned that into a production process, although it was pretty touch-and-go for a good while there.

BROCK: Did you have to modify the resists?

LAST: We couldn't chemically modify them, but we could suggest to Kodak what we needed. It turned out to be pretty satisfactory, and that kept going for a long time. There were problems in getting the resist to stick and then getting it to come off. So I was involved in a lot of that. By then we'd hired other people that had more specialized skills.

BROCK: Were you also involved with techniques and equipment for making the masks?

LAST: That would be the step and repeat. The product of that was a mask.

BROCK: Okay. I guess I'm getting confused, then. I'm talking about, you know, whatever you would use to—

LAST: Make the mesa?

BROCK: Yes.

LAST: That idea. We could make the device, but how do you make this mesa? So I did that. I got all these waxes and ways of printing waxes through masks, to act as a resist to etch the mesa, and I was such a mess that I kept all these industrial solvents at home in my medicine chest to try to get this black goo off my hands so I'd be presentable for a date that night. [laughter] But I did that successfully.

We had an assembly line that was under my direction. These were very skilled ladies. Most of them had college degrees, but they needed some pretty good supervision. I hired an ex-Navy chief who was just perfect for this, Jerry Lessard. So Jerry ran this line, and he had maybe a dozen ladies working on this line, and they were available for anybody who had made a new device and needed to put it together quickly.

Then we had to develop the techniques for making leads on the devices with terminal compression, which is a wedge. The wedge, as you push down and don't go quite to—sometimes below the eutectic temperature—and this was a Bell Labs—it's probably one of the really key Bell Labs patents. So I realized to do this I needed something that was very highly conductive, like a diamond or maybe stainless steel. I wasn't sure. They had a rounded curve with a radius of about a thousandth of an inch, and I started getting quotes on this. It was just impossible. So I said, "Hey, this is just the size of a groove of an LP record." So I take my least favorite record and put abrasive on it and started playing this thing, and in about an hour I had just the perfect tool.

BROCK: Oh, to wear down the—

LAST: To wear it down to the groove. It was the perfect shape. But everybody was doing that kind of stuff every day without thinking much of it. We were just steadily inventing our way through this whole process.

BROCK: And going to camera shops to get the lenses.

LAST: Yes, I did that, so I could get them all so they had the same focal length, and figure what kind of a lens we needed.

BROCK: How much time was Jean Hoerni spending on his diffusion work versus—

[END OF TAPE, SIDE 6]

LAST: Jean's widow recently sent me a box of Jean's old stuff which finally cleared that whole story up for me. Jean had a patent notebook entry in December of our first year—that would be December 1957, in which he thought about the planar process. But we were all involved in making the first transistor, and the mesa was the circuit device we were going to make, and there was a big discussion; it was going to be an NPN device or a PNP. So again, I have a memo that Gordon was sort of running what might be called the engineering group at that time, and said, "We have make a decision on this." I have this memo that was very carefully thought out about—you may have seen it.

BROCK: No, I haven't.

LAST: "We'll do tests. We'll try to make them on what would be a production basis. Make NPN ones and make PNP ones." You know, not pushing one over the other. Just try them and make some and see what happens. And we did that. Jean chose to look on this as more of a personal contest—

BROCK: Between the two of them.

LAST: —than a business decision. The upshot was, we couldn't make the PNP because we couldn't figure out how to make a good contact to it right away, and a number of other reasons, and NPN won out. So we made it. But Gordon ran that and did it in a very pleasant way and didn't push, but let the facts speak for themselves.

BROCK: Not to keep harping on the planar process question, so he had kind of had those initial ideas, and then really got into the boron diffusion work.

LAST: Boron diffusion, which was going to be essential. Boron was really, as I've said, a tough material. It exploded, and the only way that you could find the parameters where it was going to explode was to push up there until it did. I can still see Jean's furnace when he was doing this. It faced a concrete wall, and when it exploded, this tube would sail into the concrete, and it was dug in by about three or four inches by the time he was done. And boron made the quartz get mushy. Just terrible problems. But Jean stuck to it.

I have it written out here, the timing. This was January of—it would be 1959. It was a year after this, and Jean had worked on a number of other things, and went back to this and wrote out a patent disclosure based on his ideas from twelve or fourteen months earlier. I have a copy of that patent disclosure, with the appropriate notebook entries that went along with it. This was writing it up to submit to a patent lawyer, which he showed to Noyce, and a week later, Noyce was thinking about this and then he wrote his famous patent notebook on how to make an integrated circuit.

BROCK: That quickly? I guess I hadn't realized they were that closely connected in time.

LAST: Yes. This was before Jean had made the first planar device. He needed an extra mask, and I figured out how to jury-rig the step-and-repeat cameras to make the additional mask. It probably would help if I look at this.

BROCK: Sure. Let me pause this.

[PAUSE IN RECORDING]

BROCK: So he wrote up his patent disclosure on 14 January 1959 (9).

LAST: Yes, based on his ideas of December 1957, and this was 14 January 1959, and he wrote it, and then set out to build it. On 20 January Jean had another idea for control of lifetimes, and that one was witnessed by Noyce on 20 January, so I would guess that Jean showed these two things to Noyce probably 20 January, and Noyce's notebook entry, which was his only thing he ever wrote on integrated circuits, was 23 January.

BROCK: Wow. Three days.

LAST: Three days, and he just wrote these ideas down. Noyce had the ideas for interconnecting devices this way, but an equally key thing was how do you isolate the devices one from the other, and he didn't get into that. This was just a general discussion. It happened real fast, and then Jean set out to build it, and that date—I can't remember it exactly but I can document it exactly—it was a week after Ed Baldwin left, so that would be March. Ed left taking what was very quickly an obsolete technology. Had he stuck around one more week and seen the planar device—it was just one of those things. That's the way Ed did stuff.

So it happened real fast, and then we very rapidly saw the potential of this device. This was January of 1959, and by the next year introduced it at the trade shows.

BROCK: Introduced the—

LAST: The planar device. The unflattering picture I showed you from the trade show publication that my father said that only a mother could love. That was March of 1959.

So the whole progression now is clear. I have written about this in the past, and I told Christophe [Lécuyer] a lot of this stuff, and I was convinced that Jean did all this himself, and Noyce's was an independent development; it just happened that they'd both be thinking along these same lines. But I think this is cause and effect, very clearly. Noyce realized the potential of this right away.

BROCK: That makes a lot of sense.

LAST: A lot of sense, yes. But this is all documented now, thanks to Jean's widow sending me this box of stuff.

BROCK: That's great. You have that here now?

LAST: Yes, I have that.

BROCK: Wow. That's great.

LAST: Now, one problem in all of this was that all the stuff was pretty well documented in our patent notebooks, which were by now the property of National, and the guy running that wouldn't let anybody look at them. So that stopped all the research in this direction. He would let anybody look at their own, but not somebody else's. So he made me a copy of my patent

notebook, but I couldn't look at Jean's or Noyce's. I've finally gotten them by now, but this was a couple of years. It was frustrating to Christophe, who still to this day has not seen Jean's notebook. I'm going to send it to him now that he's back from France.

BROCK: Oh, that would be great. I know he'd appreciate that greatly.

LAST: Yes. But it all moved along, and at that time we were having these terrible problems with little metallic particles bouncing around inside the can, shorting out during the tap test, we called it. It was a terrible problem. We were selling these devices based on reliability, and here was this catastrophic failure that was taking place. So the planar device was quickly seen that that would solve that problem.

BROCK: Could we go to getting of that first contract from IBM for these—I guess they were the NPN transistors.

LAST: Yes.

BROCK: How did that contract come about and was the end-use for these airborne computers?

LAST: Airborne computers. The transistor was used to get information in and out of the cores, the core driver, which is a little higher power than if it was just used as a memory on/off switch or something like that. It was a larger device, and it was within our capability. I look now, we were working with tolerances of a thousandth of an inch, which by now have fifty devices in that space. But that was still pretty tough tolerances to be working on a production basis. This was probably Grinich and Noyce that were talking to IBM. As I say, Noyce was spending more and more of his time on this external sales thing.

Christophe came up with the story that he'd seen someplace that Sherman Fairchild got involved with talking to the IBM people and telling them it would be a very good idea if they took us seriously. Even though we were a small company, it was one he was personally involved with. So he added some degree of credence to our ability to make these things.

BROCK: You really did have quite a great amount of responsibility in fulfilling this contract. Isn't that right? I mean, everything from the—you had responsibility for a big part of the production process, did you not, from like the mesa etch?

LAST: The mesa etch.

BROCK: To the assembly, and?

LAST: Some of the assembly. Although with the assembly, they quickly get people from Kleiner or Julie to help with all this stuff, and more engineering people would get directly involved. I was involved in all of these things. But it was such a group effort. It's just amazing, looking back, at how everybody was working with everybody else. If something needed to be done, it got done. Obviously if somebody wasn't doing his part, the thing wasn't going to get finished. But as I said, when you look through these weekly meetings, how fast this happened, because every week there was something new happening, and we were having the first devices out in three or four months from the time we started. I mean things like getting power in the plant was a slow thing.

I laid out the floor plan; which was Sheldon's area, which was Jean's area, and so on. I have some pictures of what this plant looked like when it was just started. I just wish I'd taken more pictures. I have one when we first put the diffusion elements in. As I said, I've got this week-by-week account of the progress we made. You can see how this happened so rapidly and, as I look back on it now, relatively smoothly. But it wasn't smooth at the time.

BROCK: I'm sure not. Was that the main coordination medium, that weekly meeting?

LAST: Yes.

BROCK: That was on Monday mornings, did you say?

LAST: Yes, Monday mornings, I think, we had this meeting. I ran across a guy that was our first accountant, who reported to Gene Kleiner, at Kleiner's memorial service. He said, "That was the thing that really flabbergasted me about that group. There was no organized leader and you all got together on Monday mornings and figured all this stuff out and went off and did it." He said he never saw anything like it before or since.

BROCK: When did the need to get some more structure, get Ed Baldwin in there? How did that transpire?

LAST: We started seeing that we had a company, we were going to hiring marketing people, etc., so we needed a guy to run it. Noyce I think said he didn't feel up to it, or didn't want to take on that role. So we set out to hire a boss. That's an interesting experience. Hire somebody

that's very senior in age and everything else, to be your boss. We talked to some people from Varian, and ran across Ed, I think, through an ad in *The Wall Street Journal*, and he had just what we needed.

BROCK: He had come from Hughes, right?

LAST: Hughes, yes, which was one of these companies that always had great ideas but never turned them into much of a large-scale production, for the most part.

BROCK: With Baldwin coming on board, did that change the working relationship between the eight founders?

LAST: Yes. Our staff meetings became less—well, by then we'd made the first device, and so that spirit of everybody just digging in had disappeared, and you have to have a more formal organization to start manufacturing these things. Ed made some very valuable discussions about—I have a transcript, if I can find it, a meeting with Ed Baldwin where you can see that he outlined the whole structure of the company and all of the functions that were involved, a lot of which never occurred to me. A formal quality control for example. Ed emphasized from the start, the only way you can make a success of this is if you have a very reliable product. When it goes out the door, it has to really work.

I look back on our backgrounds, and none of us had ever dreamed of doing something like this, but Ed got in there and then he very quickly went to the Fairchild management and said, "You have to build another plant for this stuff damn fast." We hadn't even made or shipped anything, and Ed is talking about the big plant we had to build.

BROCK: What was his thinking there for the big plant?

LAST: That this thing was going to explode, it was a device the world needed, and our limitation—and he was absolutely right. Our limitation was going to be our ability to manufacture these in quantities. So we grew into a big company real fast. You can see on here, times and goals and days and names. These are just full of that.

BROCK: It's a great resource.

LAST: Yes. So this would be February of 1958. It wasn't that far along. We were talking about another plant. Then we had the first devices coming out shortly after that.

BROCK: Maybe we could stay with Baldwin for a moment and thinking forward. How long was he there?

LAST: He left in 1959. That was just the week before the planar—

BROCK: The planar process.

LAST: Which was I think about March of—that date we can nail down to the day.

BROCK: What was your reaction to that development, to that departure?

LAST: I was sort of shocked. A number of people went with him, the people that had come from Hughes that he had hired, and they all left. I thought, "That's a pretty strange thing to do." I mean, here he's sitting with a pretty sure bet—we cut him in as an equal partner with us and all these things, but I don't think he ever felt that comfortable in that role.

BROCK: Why do you think that was?

LAST: Well, we had such a strong group attachment and identity with each other, and coming in, we had done it and he wasn't our boss in that sense. He wasn't a full boss with the power to hire and fire us, certainly, because we owned the company as much as he did.

BROCK: Rheem was soon bought out. It didn't have a very easy time, did it?

LAST: No. Ed, later on, I was visiting him—Raytheon bought it.

BROCK: Okay. That's right.

LAST: I forget what the occasion was, but I went over to his place. We were going to have dinner together. This was quite a while after that. He said, "Jay, this is what my life has turned to." It was a big shelf of Raytheon Standard Practices. [laughter] He said at that time, he said, "You know, that was the stupidest thing I ever did in my life, was to leave." He said, "I wanted

the whole pie, run it all myself." He said, "It wasn't very smart." Because, you know, we weren't terribly—is the recorder on?

BROCK: It is. Yes.

LAST: It's hard to explain now, with the way that venture capital is, making a lot of money out of this was not uppermost in our thoughts. People don't believe that, but it was true. I have letters that I wrote saying that, that we wanted to work together and make a transistor and we knew how to do it. I remember Sheldon being pessimistic and saying, "Well, nothing's ever—we're not going to ever make a lot of money out of this, but maybe I'll make enough to buy a house or something like that." Like all lawyers can bring up problems that will probably never exist, but the one that was a key thing that almost stopped a lot of the negotiation was, what happens if this five-year period expires and Fairchild hasn't exercised its option? What's going to happen then? Who owns the shell of this defunct company? [laughter] All this stuff that lawyers just love to talk about.

So none of us were looking at this as a way to make a lot of money. I think a few of the wives were not terribly happy about their husbands leaving the security of Shockley for getting in this strange business, which is understandable. Most of them made the big move to across the country and now their husbands were doing some crazy thing. So that wasn't the key motivation. With my background, a lot of money was sort of an incomprehensible thing to me anyhow.

BROCK: But within a very few years, the company was expanding quite rapidly. Fairchild Camera and Instrument exercised their option at their earliest opportunity, isn't that right?

LAST: Yes. Yes, really it was very quick. So all of a sudden I wasn't the owner of it anymore; it was somebody else's company. That changed gears.

BROCK: In addition to the eight founders, who are some other early key Fairchild staff that stand out to you as having had particularly important contributions?

LAST: I've mentioned Dave Allison a number of times. There were a number of people that came in without—you couldn't hire anybody that had any training in making transistors, so you'd just get somebody who was fairly bright. Bob Robson was one of them who was a foreman. He went on eventually to start his own company. Isy Haas, who I had strong relations with from then on, was working for Vic Grinich in device evaluation. Bob Norman came in probably about a year later, but he was the one that was pushing integrated circuits to the outside world. Long before they were able to make them, he was selling them.

So, it was growing rapidly. I was hiring lots of people, and we expanded quickly out of that first building and got the garage behind it and the building across the street. I was spending a lot of my time recruiting. I realized that it was pretty easy to hire these guys who were very excited about having access to this technology, and so the problem was convincing their family that moving to California was the thing. So I went to dinner after dinner to San Francisco and picked a good restaurant and showed them around town, and this went on and on. So they'd get this royal treatment.

I remember one guy I hired, like he was going to be running the place or something. Then he came into the plant and I took him out to this annex and said, "This is your desk. You're sharing your desk with seven other people." [laughter] So this pointed out that Ed Baldwin was right, that we had to really move along on the new facility.

BROCK: Where were you living during this time?

LAST: I had lived in a couple of apartments, and finally ended up in a garden apartment sort of thing. After my schooling, I had a lot of social life to make up for, and so I had a good life. It was a good pleasant bachelor life that I led there. Most of my life, as I said, was centered around San Francisco. The Peninsula was, and still is, a pretty much family-centered place, and everybody goes to the suburbs at night. So it wasn't a place for a bachelor.

BROCK: Were you living in San Francisco then?

LAST: No, I lived close to the plant, and as I said, I stayed at Art Rock's place a lot.

BROCK: In addition to what must have been a very demanding work life, was the hiking your main sort of hobby outside of work, or avocation?

LAST: Yes. I would do things that just flabbergast me, looking back on them now. Mount Rainier is a fairly difficult technical climb, and I left work on Friday and flew to Seattle and got a car and drove to the base point where you climb the mountain. Saturday morning, met the guide and we started climbing Saturday afternoon and climbed up to what was the last hut by Saturday night, and then got up at two in the morning to start climbing, and climbed through the glaciers before they get messy, when the sun's on them.

I reached the top about noon on Sunday, and then got off the mountain by about six o'clock, got back in my car, and drove to Seattle and got on a plane. I was on a plane with all

my—I can't believe it now, but I had ice axes and I had all my climbing stuff. I had ice axes and crampons and ropes. [laughter] Got on the plane with this ice-axe.

I got back to San Francisco at maybe two in the morning, showed up for work at eight o'clock. [laughter] Had a lot of stamina then. Jean and I would take huge trips over Thanksgiving or other holiday weekends.

BROCK: Can you tell me about them?

LAST: Well, we went down to northern Mexico a lot, climbing mountains, and all over the Mojave Desert. I've been on practically every road on the Mojave with Jean at one time or another. Just exploring and climbing. We took some pretty tough climbs together. That continued into the Amelco days. I can tell you some more anecdotes about that probably at a more appropriate time.

So we did that. We had one climb with Art Rock and Noyce and Jean and me and probably one other person. I have some nice pictures of that. But in general, it was just Jean and me.

[END OF TAPE, SIDE 7]

BROCK: We were talking about your extracurricular interests. I've read that in this period, in 1958, 1959, during some of your business trips to New York City, you visited what was then I think a new museum, the Museum of Primitive Art, and you began to get engaged with African art. Could you say a little bit about that?

LAST: Yes. Well, I always had an interest in Africa from my early days. It fascinated me as a continent, all aspects of it. I was taking very frequent business trips to New York steadily during this whole period, which was the center of African Art dealing at the time, and connoisseurship. It was just developing as a field then, from the standpoint—it was always treated as ethnographic material in the back room, and they'd stick art masterpieces next to some dumb spear or something like that. Just at the time I started collecting, I was there at the right time when it started to develop as an art movement, due in large part to Nelson Rockefeller, who set up the Museum of Primitive Art. It was a personal love of his to start that museum, and I went there to see his collection. I was just really impressed with it. As you can see around the house here, I've satisfied my interest in abstract shapes and forms to my heart's content.

So I started in 1960 making a few tentative purchases and focused on abstract cups from one particular tribe. I didn't realize it at the time, but I realize the extraordinary value of the

serial image, where you're comparing two related things and you see something a lot more than you see individually. So a series or grouping of things is a powerful way to look at them. So I've always collected in some kind of depth, to get alternate examples of something.

But African art was just perfect for me. At that time it was very inexpensive. You could afford to make mistakes. African art started flowing in from Africa with the transportation system developing. You could fly to Africa instead of going by some god-forsaken boat. You could go from Paris to Africa on a weekend and back again. With all the countries becoming politically independent, there was a lot of turmoil, and a lot of old tribal ideas were destroyed, so that material came on the market. So for this and a whole bunch of other reasons, with a lot of material coming onto the market in the 1960s, because nobody had any idea what it was, it was just unknown stuff and it was just great fun to try to make sense out of it. So I could judge it by my interest in the abstract form rather than anything I'd read. There were practically no books written on the subject then. Just like solid-state physics. [laughter]

So I started collecting and my interest gradually grew until it's turned into a major activity in my life. If I had a focus, it was on the art of the Lega people in eastern Zaire who make marvelous small carvings. I built certainly the biggest collection of that stuff that's around, which I've now given to UCLA. We had a show at UCLA which is a traveling show. It's going around now and they did a good catalog, so the material is well documented.

BROCK: Was it the abstract forms in that sculpture that—

LAST: Yes, and the variety and the degree of imagination and the visual puns and the thing looks different in the front and the back. I've had the access to see all the museum collections and the dealers' back rooms, so I had the chance to see them as well as the collector. So I've had a chance to see probably more of this material than anybody else. I had the freedom to travel. So that was a big major emphasis of my own.

After I was collecting a while, my interest in this was known—it's a very small dealer-collecting community, and the dealers knew of my interest. So when an interesting new piece would come on the market, I'd get first crack at it. And working out relations with dealers where I didn't take advantage of them, and I'd pay them on time and I was easy to negotiate with. You pay 10 percent or 20 percent more for something, and then you get offered the next one. So that's always been my philosophy of collecting.

BROCK: You were making frequent business trips to New York to deal with the home office or the headquarters of Fairchild, or was that for recruiting?

LAST: It would be industry meetings, go to electronics shows. I never had anything to do with the Fairchild management as such. By then I had left Fairchild, so I was doing Teledyne work

and just a host of things. We started from our first division, and by the time I left, we had 150 Companies. My job near the end was trying to make sense out of all these various divisions, and so I was traveling all over the place, all over the world for a long period. So I had a chance to fit in art collecting as part of my business travel.

When I was at Fairchild, I left for a month to climb Mount Kilimanjaro, and set that up for a pattern that existed for the next decade at least, where I said to people at Fairchild and then later at Amelco, "I'm going to be gone a month a year, and you have to judge me by my annual output rather than my daily output. But this is something, to revitalize myself, I need to do." So I've traveled all over the world. Looking back on it, I was single so I wasn't that concerned about risking my life, and I got into some pretty interesting stuff.

BROCK: So that is mostly what you would do for that month, is travel?

LAST: I did, yes. I did backwoods Ethiopia where I was using a guidebook written in 1520. [laughter] And nothing had changed. I was way back in the boonies.

So I could combine my interests, and as I became more of an expert in African art—as I say, it's a very small community of serious collectors, so I made friends all over the world. I can go to Paris or Brussels or any of these cities and I have a real good friend. They come here. So it's been a lot more than a solitary collecting experience. Now it's like all these things, nobody realizes how rare they are. They think there's an infinite amount if there's three pieces and two collectors. Then this phenomenon of a very slight change in the external parameters make an enormous change in their output. Like two additional cars on a freeway, instead of going sixty, you're going ten.

So had happened with African art, and it gradually dried up, so now there's essentially no material coming from Africa, and everybody's taking in each other's laundry, and the same piece gets re-circulated so there's a lot higher emphasis on quality, and the high-quality pieces sell for a lot, and you can't give away the lower-quality pieces. But I was fortunate enough to be collecting during this whole period when all this started from ethnographic and gradually settled itself out. So now collecting is not that interesting. I just don't see pieces that intrigue me that much on the market. Once in a while I do see them and they're just horribly overpriced, and the prices have gone up by a factor of 50, at least, on a lot of this stuff. So anyway, it's been a rich part of my life, collecting this stuff.

BROCK: Is that what really brought you to—I guess some topics we'll talk about later on, but to your engagement with collecting the African art, really getting you into other aspects of art history and art collecting?

LAST: Yes. When I came to southern California, then I started seeing my first orange crate labels, and just, again it was looking at these things that were used in the same format, same size from 1880 to 1955, I could see that this was, in miniature poster form, was a documentation of art movements, this whole period, which is the thesis of my book (10). So at that time they were inexpensive, and with my partner, Gordon [T. McClelland], we could track down lots of them. The same thing has happened there.

BROCK: Partly as a result of your book, I'm sure.

LAST: Yes, the book made some. But still it's a very active collecting thing. But there my interest spread beyond the labels as such to the manufacturing techniques and to my present interest of writing the history of color lithography. So just one thing led to another. African art, I've done a lot of writing about documenting this change in 1960 to the present in collecting and changes and all of this stuff, and I've conducted oral histories with the key dealers. Most of them said, "Well, I'm not going to discuss this. But I'll discuss it with you." [laughter] We'd get going. I just have some marvelous stories. So I've taken my interest in history into the whole collecting area.

There's certainly a lot of future writing I'd like to do in all these things that might make some more sense out of all this. But art has always been a rich part of my life. I met my wife, who is the first lady that I'd met who understood African art to some extent, so we hit it off right away.

BROCK: Was she also involved in collecting?

LAST: No, she's an anti-collector. What neatness there is in this house is her "Where are you going to put it?" [laughter] In mine, that's the last thing on my mind. But as you can see, you don't see a whole lot of American ephemera around the house here. That's something I keep compartmentalized fairly well. Also I don't want to look at it all the time. So it's worked out and I've had the opportunity to spend as much time as I wanted to on various aspects of art collecting. As I said, it wasn't terribly expensive and I had the resources to do what I wanted to do.

BROCK: So again, very, very good timing. [laughter]

LAST: Yes.

BROCK: To go back in the chronology to 1958-1959 when you're first getting engaged in African art, you first get engaged in another sort of revolutionary development in the integrated circuit story. In my reading there seems to be a haze of indeterminacy, a ferment at the time in this period about ideas about making integrated circuits. Some people have written about there being a certain buzz in the technical community that Texas Instruments was doing something in this domain. What was your experience of first hearing about integrated circuits?

LAST: Well, to get into 1958, by the summer of 1958 we had made our first transistor and had set up production stuff, and I had written some process manuals about how you transfer stuff to production, so by then it was compartmentalized, and the pre-production engineers were doing it. My role in doing what I could do to help build the first transistor was no longer needed.

Gordon was heavily involved in the engineering aspect of it then, and after Noyce took over general management, Gordon started running the R&D [research & development]. I was more or less at loose ends, and I started working for a while on the parametric amplifier diode that looked like it was going to be a very useful switching device, and I worked on that for a while. So that would be the first months of 1959.

What buzz there was, it was a military buzz saying "We need very small components," and they were going at it, what seemed to me at the time, wrong, and even more so now, molecular engineering where you fabricate components out of the blue by just laying down atoms, or a very sort of watchmaking approach of sticking little components together. There was a lot of talk like that, all of it military-based, which turned out, nearly all of it, both technically and economically unsound. So there was a lot of talk about that.

TI got going in early 1958, and [Jack] Kilby, through his patent, but that suffered from serious limitations. They didn't have a good flat transistor to use, so it was really just a hodgepodge of saying they had the ability—we can put more than one component on a piece of silicon, which is essentially all they were saying then, but they started making a lot of noise about that.

It was at Westcon that year, I remember specifically, which would be August of 1959, Noyce and I had a talk before that. Noyce said, "We have to show the flag at Westcon, and let's figure out how to jury-rig some little device that we can show at Westcon that says we too are in the miniature integrated circuit world."

I built this little thing. It was just a little oscillator. Stuck four transistors on a chip and made some resistors with a lead pencil. But it said what we were doing, and it got a lot of publicity.

There have been discussions of a famous meeting that Noyce had, discussing all the future of this stuff. Moore said he was not at that meeting. I was certainly not at it. Jean Hoerni was not at it. So it just got into the folklore some way, as far as I'm concerned. I had no real talks with Noyce about integrated circuits. I did see one note on this weekly report that in

March I was going to be in one of my side jobs, be looking at miniature circuits or integrated circuits, but nothing ever came of that at the time. So at that time, by then I was sort of—no, it was before that.

So about Westcon, the decision was made that I was going to start running a group to make integrated circuits.

BROCK: Before the meeting?

LAST: It started with making this little jury-rig. But it was just saying that we were going to be in this business.

BROCK: Were there real technical challenges to making that?

LAST: No.

BROCK: Because you're talking about it as very straightforward.

LAST: Well, it was. It was just putting a couple—you had to start with a ceramic plate and stick loose transistors on it and fasten them down and hitch them up with a wire. It would just show that we were thinking along this line.

Then I was given the mandate to set up and run the group, build the group and run it to build the circuits.

BROCK: So, in late 1959.

LAST: That would be starting around September. I hired Lionel Kattner from TI, Mark Weisenstern. Isy Haas joined the group. He had been reporting to Bob Norman, indirectly to Vic Grinich. He joined the group. I built up a group of maybe a dozen people and had them in place by December of 1959, it would be.

BROCK: So was this group, then, in the Fairchild research and development organization?

LAST: Yes. It was just another thing there. Nobody seemed to care much about it one way or the other, understandably. I mean, Fairchild was starting to really explode in its transistor business and setting up a diode plant, and setting up Asian fabrication plants, and getting the price low enough they could get into the automobile market. All of these things. That understandably occupied everybody's attention, and should have. So this was just a side little venture.

Everybody talks about the idea of the integrated circuit that would occur to any thinking person in five minutes if they thought about, you know, you've got these devices and let's figure out how to hitch them up without taking them apart. So the idea wasn't hard, but the thing that stopped everybody dead was the yield question. If you have a 5 percent yield and you multiply that to the eighth power, you could prove mathematically you could never build an integrated circuit.

But we did have the planar technology that nobody else had, and I don't know how the ideas got from Noyce's notebook into the work I was doing. I think it was a fairly indirect—I never saw the notebook. I didn't know that it existed, and I don't recall, other than just a casual talk with Bob about the direction we were going to proceed on this, but I could quickly see that the big problem was not interconnecting the devices, it was electrically isolating one from the other. That was the thing that stopped us dead. Because we had all the metallization and the etching techniques to make all the wires. We didn't have any way to have them overlap or anything, but we could design our way around that. So the big problem was electrical isolation.

BROCK: To go back a couple steps, in terms of the R&D organization, to have a dozen people at this time strikes me as a pretty big group. Is that true?

LAST: Yes.

BROCK: So Noyce did his patent filing in July of 1959 (11). That essentially wasn't in your orbit at all.

LAST: I didn't know that he had filed it till a couple years later. I didn't know it was—

BROCK: And by this time also the planar technology had sort of proven itself with the transistors, so it would have been quite odd for you not to have adopted the planar process.

LAST: Oh yes. Michael Wolf wrote an early article about the genesis of the integrated circuit, and I think Vic Grinich said, "It was just an obvious idea that had been around." As I said, it wasn't the idea as much as it was the serious obstacles to make the thing and make it work.

BROCK: So at this time, had Gordon Moore taken on the role of overseeing R&D then?

LAST: Yes, so I reported to Gordon on this.

BROCK: What was his attitude toward the project to build an integrated circuit; his attitude toward it, involvement with it?

LAST: Well, he was supportive and interested and followed along with what I was doing, but it was not anything we looked on as a commercial—our commercial future wasn't going to depend on it. Gordon, after the fact, made this remark, "Well, now that we made the integrated circuit, what do we do next?" That was sort of the attitude. It was an existence proof without a really powerful commercial application unless it was for extremely specialized, expensive things, which proved to be the case, because it was really five years before integrated circuits started making any mark at all. A very frustrating period.

So at that time we had a lot of money and Fairchild was really booming, and so the question of hewing to a tight budget never seemed to come up, or if there were problems that Gordon faced with that, he didn't burden me with them.

BROCK: Could you tell me the story of working toward making these first integrated circuits? How did you get on top of the isolation problem?

LAST: Well, there were two ways that you could do this. One would be to diffuse a boron isolation the whole way through the wafer, and boron was acting up in a fifteen-minute diffusion, and this would be an eighteen-hour diffusion. So we just couldn't figure out how to keep everything from melting or blowing up or anything. So I set out to make the first device by absolute brute force, which was to take an isolated wafer with oxide on the surface and fasten it to a plate, and on the back etch the whole way through the silicon until you got down to the oxide, and then fill that with some insulating material, which was really a brute-force approach. But that's the way the first integrated circuits were made. There was a famous picture in *Life* magazine of the first integrated circuit, and it illustrates that first device made by that technology.

BROCK: What sort of material were you using for isolation?

LAST: Oh, we tried all sorts. Did nothing. Explored strange isolating materials, epoxies and ceramic-based materials. So it was a brute force, but we made circuits in fairly short order that way. We couldn't make them very reproducibly. We faced problems where we had to line up the pattern on the front of the device with the etching on the back, and we developed an infrared system to look through the wafer in infrared where the silicon would be transparent, so you'd see the front, and we actually built this really complicated alignment device to do this.

Lionel Kattner was actively involved in doing a lot of the layout work, and Isy Haas was doing a lot of work on device evaluation, and made interesting experiments like take reject devices and see if you could make an integrated circuit of them, because a transistor has to be all things to all people and meet twenty parameters on a datasheet, but here you could define the absolute use of the transistor so it didn't have to meet a lot of other criteria and break down voltage and things. You were making them all at the same time, so if it was just a variation in temperature or something, probably you just needed them to match. So all you had to do was find a big enough hunk of silicon that there wasn't some local defect on that particular part that would stop you dead. So with Isy making working integrated circuits from junked transistors, it gave us enough of a feeling that we were on the right track.

BROCK: That happened how quickly?

LAST: I think we made the first device—Lionel laid out the masks in December of 1959.

[END OF TAPE, SIDE 8]

LAST: —but we set out to make a whole family of these. I mentioned Bob Norman that was doing at least a paper a month on the future of integrated circuits, and how it was just around the corner. He pushed the thing forward a lot, and we worked with a direct couple technique that was simple to make, the simplest one to make, although not the most useful one for circuit application, and facing up to the problem that here Fairchild's main customer was the circuit designer, and here we were giving them a designed circuit. So the acceptance of integrated circuits was going to put these guys out of business, and that didn't appeal to the sales department at all. But with the spectacular way that integrated circuits have changed our life, it's just hard to go back and say this was just a little backwater activity and it interested me a lot; and it was of moderate interest to other people there. But it wasn't looked on as something that was going to change the company at all.

BROCK: What intrigued you about it so much?

LAST: I could see that if you could ever make these things, that it would have maybe have a limited market, but it would be a very exciting market, and the technical challenge of being able to make one was exciting to me. So we'd set up a whole family, and we were cranking out by October or so, you know, in the hundreds of these things per month. But I mean, as a production process, you could see that this was just—you know, etching through this wafer and taking off—I discussed this once with Charlie Sporck, and said, "Look, if we had put this thing into production, what would you have done?" And he made some appropriate Sporckian remark. [laughter]

So we were proceeding on that track.

BROCK: Who were the customers at this time for these early circuits?

LAST: It would have been airborne missiles. To the Minuteman people who were buying our transistors, price wasn't an object. Small space, and usually when you can get something small, it's a little more reliable, you know, and you get rid of the vibration problems. And as it turned out, when the integrated circuit did go into production in larger quantities, about 1963 or 1964, the Minuteman was the first use of it. So we were chugging along then.

Then in late summer or early fall, the pre-production group had come up with a new way of dealing with boron diffusion that made it a lot more reproducible and easy to work with. Lionel and Isy—and it's a little difficult sorting out who was doing what—said, "Let's try and go back to this idea of diffusing through the wafer with this eighteen-hour diffusion." To some extent it worked. So we could see that here we could electrically isolate devices, each in its own little well by diffusing the whole way. This was something that Lionel and Isy just tried, and it worked, as I said.

I have a memo that Gordon wrote in November of 1959 in which he said, "We want to start producing these devices, and it still is an open question whether we use the etch-through technique or the diffused isolation." So it was still an open question in October or November, and he said, "If we have to make an arbitrary decision, we'll go now with the etch-through thing." So none of this was clear-cut. I wasn't involved with why there was this pressure to make this a production device or not; that was something between Gordon and the rest of the company. The company was now getting very compartmentalized, you know.

BROCK: Because it was growing so large?

LAST: No. It was just that it was turning into a production thing, and different people took over, and people were shunted aside. You asked why Gene Kleiner left, and that was the reason.

BROCK: When did he leave? He left right around this time?

LAST: He left when I left; the start of the next year.

BROCK: And he felt he was shunted aside?

LAST: Yes, he had been running the production engineering group, and they brought in some hotshot from TI or someplace like that, and sort of put Gene in some side position. He just quit. But it's just inevitable in a big company, and it starts to be run more by the organization person than the entrepreneur. It's just amazing when you look at it—it isn't amazing. It's just—but how few entrepreneurs end up running their company. From a venture capital point of view, the guy that started it, only one out of ten ends up running it by the time it goes public. It's a pretty—

BROCK: Sobering statistic. [laughter]

LAST: It is. Especially if you're the entrepreneur. The motivation is different. I'm certainly an entrepreneur, and I don't like the sort of organization problem you get into in building something up or setting up a quality-control group, all that kind of stuff.

BROCK: So it was in late 1960 that it was still an open question between the etch-through and the—

LAST: We'd just made the first diffused ones about October or November, I think. October or November. I was very close to leaving by that point. At that time I was not at all comfortable with this disappearance of this camaraderie and the group decisions and all this, and I was a couple levels down from Noyce and saw nothing of him. I had no concept of what the overall business decisions were. I said, "I think I'll leave."

The MIT people got wind of this and said, "Would you like to consider coming here and being a professor?" They said, "Why don't you do this? The Ford Foundation gives fellowships for short-term projects. Why don't you come back and give a series of lectures on transistor technology for a number of weeks?"

So I did that in November while a lot of this other stuff was going on. I was in steady contact with it, but I had a strong feeling I was going to be leaving. So I went back to MIT, and I have to say it was quite an experience to go back and give this first lecture, and seeing all the

professors that I'd left two years before sitting in the front row. [laughter] Because I had done stuff that no one there knew anything about. So that was an interesting period.

But then I realized that this would have been an electrical engineering appointment, and I went to the faculty meetings and I said—this is the way the decision-making process is in a university. They would spend an hour discussing how you wrote a letter to somebody to invite him to a meeting. I said, "I'll just go nuts with this." So I said, "This certainly is not for me."

Von Hippel said, "My advice to you, if you want an academic career, don't come in at this level. Wait until you've established your mark at something else and come in as a professor. You don't want to put up with all this degrading crap." [laughter] So that was good advice. But it wasn't what I wanted to do anyhow.

BROCK: In this period of late 1960, had you talked at all to any of the other co-founders?

LAST: Oh yes. Yes, Jean and I talked. Jean, Sheldon, and I, when we were taking our desert exploring trips, we'd discuss this and say, "We're all going to leave," because you know, Jean especially was fairly volatile on this kind of a thing.

BROCK: Did they too mourn the loss of the camaraderie and this hierarchy?

LAST: Oh yes.

BROCK: That was the crux of it, as it changed into this different entity?

LAST: Yes. And whatever rewards we were going to get out of the company we had gotten, and the Fairchild management, in its wisdom, didn't see any reason to try to motivate us to stay there and be happy. There was no concept of options or sharing in the company or being involved in decision making. Noyce was over there and he was running around setting up the Italian division, or whatever he was doing. I'd go down to the big production plant, and it was just like visiting some foreign place. I didn't know the people and had nothing to do with it. This is an inevitable thing with a growing company.

I was all of thirty then, and I had a lot of other stuff to do with my life, I felt. I had made enough—this was not a big sum of money we got out of this. You know, it was ten of us sharing three million dollars. At that time my salary was probably fifteen to twenty thousand, so it was like fifteen years' pay. But it wasn't venture capital payoff today. Fairchild got a real bargain on that. They took an enormous risk for starting something new that nobody had done before, and backing us completely, Hodgson in particular, providing all the money we needed.

Unlike any budget discussion that I was ever around, it was not, "You can't spend all this money." It was just, "Document what you need it for." And it was there. Sherman Fairchild was interested, and Hodgson, as I say, was active. Carter was something else, but he wasn't at least impeding it.

BROCK: So when did you and Hoerni and Roberts start to talk about—did you start to decide that you wanted to work together again?

LAST: Yes. Jean and I in particular had established a very close—we shared an office there, and so we were on the same wavelength. Jean would do the technical thinking by himself. He worked best when he was angry. He was motivated by saying, "I'll show the bastards." He'd go storming off and then he'd come up with just one brilliant idea after another.

BROCK: Could you talk a little bit more for a moment about him and his what seems to me to be quite an amazing string of contributions that he made in quite a short period of time, from the diffusion work that we talked about, to the planar process, of course; but then also I think he was working on epitaxy at this time.

LAST: No, there was no work on epitaxy, not till later. He worked on gold doping where we could control the lifetime and get devices a lot faster. That was a very key advance, and as I say, I've got his notebook entries where he discussed all this stuff.

As I said, we shared an office and discussed technical things back and forth, and we'd have lunch together very often, at the conclusion of which he'd go buy a cheap, smelly cigar and smoke it in the office. I said, "Jean, let me give you an extra five cents a day so you can get a somewhat higher-quality cigar." [laughter]

After I learned he died, I couldn't sleep that night, and I sat and wrote the whole night long and I wrote a pretty moving thing about my remembrance of him, about ten pages, which I later abstracted and gave a eulogy about the funny side of being associated with such a brilliant person.

BROCK: The planar process was quite—that is his singular contribution of just enormous importance.

LAST: That changed—it made the integrated circuit possible and it made the reliability of transistors greater. It ultimately improved the transistor yield. Without that, any of these later things wouldn't have been possible. Again, like all these other structural inventions, the idea was not that difficult to come by. It was buckling down and building it, which was the case with

the integrated circuit. It was solving the technical problems. It was sort of, don't even bother with this, because the major problem with transistors was surface contamination or leakages, and the wisdom at the time was you had to strip all this dirty oxide off which had been collecting all this crap underneath it, clean it off, and then mesa it, or do something else with it.

Jean, as I could see in his early ideas, didn't think that was right; his ideas that went back to 1957. In 1959 we started implementing them. As I said, I helped build a mask for him, and he had one of these things built in three or four weeks, and he demonstrated it to the staff there, and it was just flabbergasting how great this device was.

BROCK: That people had a real immediate sense?

LAST: Immediate. There was no question about it. "This is what we have to do." And within a year we had done it. It led to better diodes, it led to—

[PAUSE IN RECORDING]

BROCK: So at what point did you and he and Roberts decide to try and leave together, leave Fairchild together?

LAST: I could see that if we left together as three guys, the organizational structure would be difficult; three pretty independent guys. So I had an agreement with Jean that he and I would work together and then we'd try and hire others. So Sheldon came in with us being in charge. That didn't last all that long. He did it for a while when we got Amelco started.

Art Rock had been involved in early Teledyne financing. When I was down in L.A. for some meeting in July, he said, "Why don't you call Henry Singleton and George Kozmetsky. They're starting some new business." I didn't get around to it, or wasn't that interested. So that just dragged on. It was always, "You call Henry," or to Henry, "You call Jay." Neither of us did it.

I remember very distinctly—this was just before we had our company Christmas party, that day I got a call, I think from Bud Coyle. He said, "I called Henry. He's sitting at the end of the phone down there. Call him." And I did. I was not big on Christmas parties and exchanging gifts and all that stuff, so I said, "Count me out of getting a gift, and I won't bother getting in this." Just at that time, they had arranged that I was going to be the Santa that distributed all these things. [laughter] So I wasn't in much of a company mood that day anyhow.

I called Henry, and this was just before Christmas. He said, "Why don't you come down to L.A. and we'll talk about this." So Jean and I went down, drove down New Year's Eve, and I talked to Henry the day before New Year's. To jump ahead a bit—we can go back and discuss some of the details of all this stuff—but we did indeed work out an agreement in fairly short order, and I left the end of January of 1961. The integrated circuit at Fairchild was an accomplished fact by then, but it was far from being turned into a production process. And I didn't feel that I could take any of the integrated circuit group with me.

BROCK: For what reason?

LAST: For just ethical reasons. With the exception—Isy Haas, when it was announced that I was leaving, Isy came to me and he said, "Jay, I don't know where you're going or what you're going to do, but I quit too, and I'm coming along." So there, I obviously hired Isy. As time went on, we gradually hired other people, but it was never a—I got a letter, a standard letter from a lawyer, but there was never any—I was doing different stuff than Fairchild was doing and I was still well thought of there, evidently, so there was never any legal problem until down the road when the lawyers started looking at licensing or something like that. I can tell you that story, too, if you remind me.

BROCK: From the time you went to MIT to give this series of lectures, was it sort of common knowledge among the other co-founders at Fairchild that you were thinking of doing something else?

LAST: No, I don't think so. I didn't share it with—Gordon had been the only one, and in later years he said, "I was sort of surprised when you said you were leaving." He said, "I would have thought Jean would leave, but I didn't think you would." So he was sort of surprised when I announced this, so he said later.

BROCK: How did the organization react when you announced that you were leaving?

LAST: Well, it wasn't an earthshaking event. Some of my personal friends there, one of the secretaries who was a receptionist, every time I'd haul another box of my books out, she'd start crying. [laughter] But I think it was sort of inevitable; there was just too much talent for this company and it's turning into a company run by sales and manufacturing and not technical innovation. We'd done our technical innovation, all we'd need for a long time. The innovation was going to be, for the most part, in making a broader line. We made 706 a lot smaller device. But the challenge of starting from scratch to do something nobody ever did before was over.

I toured the Intel plant down in Albuquerque a couple years ago, and I said, "My God, everything that they're doing here was stuff that we were doing." With the exception of the ion implantation and the epitaxy and some of that stuff, but the basic fundamental idea was the one that we introduced. That was a funny thing to see.

BROCK: I am sure.

LAST: The degree of technical complexity flabbergasts me. Thousands of man-years just cranking it down another notch every year or two.

I had an incident with the marketing people that has been recounted in print someplace.

BROCK: Yes. This is Tom Bay?

LAST: Tom Bay saying, "Last has pissed away a million dollars on this."

[PAUSE IN RECORDING]

BROCK: Bay was—

LAST: Understandable. I mean, I was going to take his customers away and this was going to be a device that was going to require a whole new concept of selling and something nobody wanted. The customers didn't want it. He didn't want to sell it. This was probably in, I guess, October or something, before I took my short trip to MIT. And nobody said anything. All this stuff happened at the meeting and nobody rose to my defense or said anything one way or the other.

BROCK: This was at a meeting with other folks?

LAST: This was with the whole—for some reason, we got essentially the whole senior people together in one of our rare meetings, you know, a dozen people in the room, something like that. Tom came out with this blast and sort of shrugged, and everybody shrugged, and I said to myself, "I'm outta here." [laughter] I have trouble putting together the timing on these various things, but an incident like that you remember.

BROCK: Do you think that that was reflective of the general attitude that you maybe disagreed with, that the integrated circuits were just seen as quite a secondary concern?

LAST: Oh, yes, it was quite a secondary concern, and stayed as quite a secondary concern for the next four or five years, three or four years. It was not a major thing. They tried making them, but it was sort of getting people's attention rather than making them in large quantities.

BROCK: And you really wanted to get on with trying to do that.

LAST: I liked that idea. In later years, I had dinner with Gordon and I said, "Well, you know, this meeting sort of upset me," and Gordon made some comment: "Oh, well, it was certainly a mistake I made not jumping into that." If he remembered much about it at all.

BROCK: He did mention it in an interview.

LAST: He did?

BROCK: Yes, sort of how he didn't know quite how he let that one get past him. So he does remember that.

LAST: But that was a turning point for me, certainly. My relations with Gordon stayed just great, always.

BROCK: You still retain that very friendly relationship?

LAST: Yes. Very friendly. Gordon is outwardly easygoing and friendly, but I realize that he has, inward, a very determined agenda, but he will work at it in as easy a way as possible not to take personal credit for it or anything else, but he just wants to see it get done. I don't think I'm expressing that very well, but—

BROCK: I understand what you're saying.

LAST: I can only remember one time when I had a—the only time I ever exchanged an angry word with him, was we'd hired some hotshot from TI who was the one that put TI

organizational stuff into the company, and this thing turned out to be TI's greatest weakness rather than its greatest strength, with all this reporting and setting up group goals and all that stuff. Gordon took this and circulated it to all of us, and we were supposed to do it. I just got incensed. I took this thing and rolled it up and took it in and threw it at him and said, "You fill out this [pause] thing." [laughter] Ten minutes later he was in my office, conciliatory and running things, and I think that probably continued through at Intel.

[END OF TAPE, SIDE 9]

BROCK: How would you describe his main contributions across the board at Fairchild with respect to the R&D organization, with his own technical contributions?

LAST: Well, in the early days he was technically involved with the diffusion. Gordon certainly took on the role of evaporation and the metallization stuff. That was a problem that really bothered us, how we could make electrical contact in both N- and P-type silicon. Again, he could prove that he couldn't do any of these things.

Gordon gives a lot of credit to a conversation he had with Noyce. Noyce said, "Why don't you try aluminum," which worked. But the standard gold ideas did not. So Gordon made a lot of contributions there. He was very well organized and sort of took on the pre-production coordination of engineering, so he took the devices and got them to the point where we could make them and get ready for production. He did all that stuff in a very organized way.

I've always had enormous respect for him and the way he worked and conducted himself in that environment, doing what had to be done and trying to deal with a number of prima donnas that could be difficult, and avoiding the conflict that Jean Hoerni steadily wanted to set up. [laughter] Jean was something else. I could go on by the hour about him. But on Gordon's case, I hold him in very high respect.

I remember an incident a number of years later when the state historical commission put a plaque on the building, and Gordon was there and he gave an appropriate talk. I went up to him afterward and said, "You know, Gordon, you're standing up there giving all this credit to Noyce, but I know damn well and you know the enormous contributions that you've made that are going unrecorded here." I said that to him.

BROCK: What did he say?

LAST: He didn't say much one way or the other. But he knew how I felt about it, and I do.

BROCK: Why do you think he did that, or does that?

LAST: I think he's looking at the goal rather than his personal acknowledgement of his contribution to it. I think if he can avoid confrontation, he'll do it, but as I said, he was the one that had the guts to call Beckman and he was the only one that did. He saw the goal there. I've always had a great admiration for him and the way he conducted himself, and still do. I'm glad now, as time has settled and Noyce's image has receded, that Gordon is getting his fair due for his enormous contributions. Our relations are very cordial and I'm always glad to see him.

BROCK: Perhaps we could return to the discussions with Singleton and Teledyne about what they were looking to do at the time. I think we were mentioning before, this was only six months or so after they had organized.

LAST: Well, Singleton had great ideas for building a big systems company and military systems, and you could see that integrated circuits were going to play a key role in that, and he discussed this with Art Rock, and Art knew that I would consider the idea of leaving. Although before I even hinted to Art that I was going to leave, he said, "Why don't you talk to Singleton?" He was trying to promote something there, I think. So Singleton and George Kozmetsky and Jean, as I said, and I went down there together. I just hit it off. Here's a guy who was just the opposite of the attitude at Fairchild. He said, "I really need integrated circuits, and I need you to build them." It's what I wanted to do. I was satisfied by then we could build them. I could see that, as I'd said earlier, a new technology needs a new environment to really flourish, and Fairchild was transistor- and diode-oriented, and understandably. I mean, the company was just beginning to reach its real growth phase, and the last thing they needed was a complicated thing like this as a major activity.

So Singleton needed them and I wanted to build them. Jean and I very quickly—he was very frank with me, and I was extremely impressed with him and still was the whole time I was there, because, as you can gather, I don't take well to somebody being my boss, and I willingly worked for Singleton for twelve years.

BROCK: His background was also from MIT.

LAST: Yes.

BROCK: In electrical engineering?

LAST: Electrical engineering, yes. He spent the war years working on demagnetization of ships, and he went back and finished his doctorate after the war and had Jerry Wiesner as his junior lab partner or something like that, and then Wiesner went on to run MIT. Singleton went, I think to GE, and then he went to Litton and built up their inertial guidance system, and was a very determined guy.

He said, "Our biggest customer was on Long Island, so every Sunday night I took the red-eye there and saw what they were doing on Monday and then flew back Monday afternoon. So I did that for months and months."

I said, "You want to build another Litton?"

He said, "Hell, no. I want to build another GE." [laughter] But we talked frankly, Jean and "Koz" and Henry and me, for four hours or something like that. I just wasn't seeing that many negatives, except they said "We want to put this in L.A."

I said, "This is a non-negotiable thing. This has to be in Silicon Valley for a large number of reasons."

BROCK: What were they?

LAST: Well, the logistical infrastructure that had been built up. You get the right chemicals by then, and we were using chemicals that when we started Fairchild, you'd buy 100 cc bottle of it, and we were by then getting carloads. We had tank cars of these very corrosive acids. You don't develop that or how you get rid of them. We just, you know, poured them down the drain, a lot of them. That whole Palo Alto sewer system is just loaded with gold, probably rich gold.

I also knew that I'd be hiring other people. Patent lawyers were there. The whole thing—

BROCK: The infrastructure.

LAST: To go back to the Fairchild days where we had to work with research materials and equipment on an industrial basis, I needed some special kind of an oil as a lubricant for polishing wafers to get them thin enough, and this was an oil that refineries dealt with all the time, but nobody who was going to sell me, you know, a couple gallons of it. That's all I needed. So I just called the oil company and said, "What's your carload price for this oil? Send me a sample 100-gallon drum," which just showed up, this big drum. It was enough for all the years we did it.

But trying to work with the existing structure to get the chemicals we needed, like microscopes, we needed these stereomicroscopes, and I called Bausch & Lomb and said, "What's your price for twenty of these microscopes?"

They said, "We make four of them a year." [laughter] But they rose to the occasion and scaled up, but we were taking laboratory essentially chemical processes that were done on a micro scale, and turning them into mass production. I mean, starting to work with a production line with hydrofluoric acid, which is a horrible corrosive acid, not the least of which you don't notice until you've been attacked by it. It doesn't hurt when you put it on there, and pretty soon you get a big ulcerous, incurable wound. How you enforce discipline on people and make them wear a mask and how you get a rubber glove that doesn't have little holes in it. So from the chemical engineering point of view, there was an awful lot of work that took place steadily in getting boron compounds and all these other diffusion compounds, and getting extremely pure water.

Something that got a very bad name recently is trichloroethylene. We were concerned about this, and Gordon probably told you this, but he went to some chemical engineers at Stanford or Berkeley and said, "What are the health problems of using lots of trichloroethylene?" The answer he got back was, "The only thing we see is if you have a big enough tank of it and you fell in, you'd drown." But that was the existing climate for that kind of chemical use. Nobody knew these things.

Now, as I was saying earlier, these things are overblown now, it's gone 180 degrees the other way, and I feel that the biggest cause of pollution is more and more sensitive instruments, because now you measure a part per billion and nobody knows the difference between a part per million and a part per billion, and it looks like you could pick up anything and find probably trace amount of something horrible in it. So these ideas just took a long time to develop and we under compensate and overcompensate. So it's been steady development. Now with our legal system that nothing is anybody's personal fault or responsibility, and society has to take care of it, these problems have gotten a lot worse. Lawsuits, class-action lawsuits for trivia, are a serious problem, I think.

But we did the best we could, and I remember we were having trouble with this corrosive mixture eating out drainpipes and stuff, and it was once when one salesman said, "I've got the ideal material for drainpipes." When it came in, put it in the drain. I poured the stuff in and it never even slowed down. It went right through this pipe in just no time. [laughter] So that was the sort of practical problems we were facing in scaling-up here. Getting the chemicals, disposing of them properly, using them properly was the major problem.

BROCK: Having worked with that scale-up, I guess that really set the infrastructure in place that would make the location of the Amelco facility nonnegotiable.

LAST: Yes, that's right.

BROCK: Building on that previous work. So Teledyne's real—it was integrated circuits for their systems, for computers.

LAST: Yes.

BROCK: Was Amelco formed as a subsidiary company or a division?

LAST: It was a division, and the reason it was called Amelco was that Teledyne's first acquisition down here in LA was called Amelco. It was a division that had tax losses. And Kozmetsky said, "You know, if we give it that name, we can move their tax loss to your company," and all that sort of thing. So it's a name I've never been very excited about, but it made sense at the time. Later on it was changed back to Teledyne, years later.

Singleton was very forceful, and I could see that he wanted to do what I wanted to do. Something we didn't clear up all that well—I mean, Teledyne was pretty much underfinanced, and I said, "This is going to be a pretty expensive operation. I'm going to build optical equipment like the world has never seen before," and I did. I built the step-and-repeat setup. The first step in it was a bed camera twenty feet long, and they had to put these things on granite blocks to keep the vibration down. So it was an expensive undertaking.

Singleton said, "We're up to it as a company." But we never cleared up this—if the systems people needed something, that was the first priority, was to make it for them. If they didn't need it, the priority was to support ourselves with outside products. You can't turn this on and off. And that was a fundamental weakness with the Amelco organization, was the need to satisfy these two masters.

BROCK: Because you couldn't predict when the demands from the system would come?

LAST: Well, you can't have them come in and disrupt the production line when you've promised product to somebody. When they couldn't get it, they'd go complain to Singleton. It was a never-ending problem. But Jean and I were very taken with Singleton after our first meeting. After the meeting, Jean and I went out to the Mojave. This was New Year's Eve. We still had our business suits on. Each of us had one good suit, so it was our negotiating suit. We used the phrase many times, as a group, "Put on your negotiating suit." [laughter] There was a bar in San Francisco then that had—they said every night was New Year's Eve, and they passed out noisemakers. So Jean and I were standing there at midnight in the center of the Mojave blowing these noisemakers with our business suits on. [laughter]

I had a number of other questions to ask Singleton, but we quickly resolved those. I had one set of questions that still remained, you know, about Fairchild's role in integrated circuits. I had talked to Noyce briefly about that and he said, "Well, you know, a systems company is not the place to do this sort of thing." He was pretty negative about what a systems company would do. He was right in some aspects of this.

But finally I got down to where I had one set of questions I wanted to ask Singleton, and I wanted to ask Noyce the same questions. I called Noyce, and he was busy with an Italian negotiation and his secretary said, "He can see you in two days." I called Singleton and he said, "Well, it's ten o'clock. I can be up there by about eleven-thirty." And I said to myself, "Well, that answers the question."

BROCK: Yes, on where they felt the priorities lay for integrated circuits.

LAST: Yes. And here, they gave the opportunity at Amelco to do some marvelous technical advances. We made some really spectacular products there, in small quantities that disappeared into the classified world so there's not much known about them now. I don't know some of this stuff—a lot of this stuff.

BROCK: We've talked about Isy Haas several times but I don't think we've talked about his background. Could you tell me a little bit more about him? Because he was one of the first people in the Amelco Division.

LAST: Yes. He was born in Turkey. His father was a Jewish merchant in Turkey. But he got educated at Roberts University, so he was educated in English. He came to this country and got his, I think, master's degree in electrical engineering, and turned into this marvelous breed between a circuit designer and fabricator and an electrical engineer that understood the end use of the product. He was extremely valuable, and I worked with him all during this period.

BROCK: In some ways it strikes me that the business strategy for the Amelco Division was in a way almost the opposite in a number of respects from the Fairchild business strategy.

LAST: Yes, it was.

BROCK: It was integrated circuits over transistors, and it was sort of more limited, special-purpose customers or projects rather than these mass market—

LAST: Yes, and the idea of military support for our development activities.

BROCK: Oh, you did do that as well.

LAST: Yes, at Amelco. I mean, that was our customer. I know at Fairchild I had a delegation, a pretty high-level bunch of guys from the military come in and say, "Why don't you ever bid on our contracts?"

I said, "We want to be able to control our destiny." I was fairly abrupt and said, "There's just no way we're going to do this." Because I started thinking, the company that scared the death out of me was a company called Pacific Semiconductors. I don't know what happened there, but they had some damn good technology. I thought when we were starting out, they were the ones that would most likely give us a lot of trouble. I started looking; they were taking government contracts for some really sophisticated transistors. There was going to be one in the system; it would be a driving transistor and run everything else. So that took military development. Whereas we were looking at the hundreds and thousands of transistors that were going to be the integral part of the computers, and I said, "We just can't use our scarce resources building these one-of-a-kind things," at the way Fairchild was set up. So we just never bid.

But when we got into the Teledyne thing, one, we didn't have that much money; and, two, we could start developing some of the stuff with the government. I started seeing the terrible inefficiency of government contracts.

BROCK: In what way?

LAST: It takes a lot of work to write a contract like this. Say a company is going to bid a fifty thousand dollar contract. You have a dozen companies each spending ten thousand dollars to submit the proposal. It's a terrible waste of resources. So I bid on a few contracts and got them. Alton Gileo, who'd been my predecessor at MIT, came to work for us and he and I worked on optically coupling devices, four decades before their time. I wrote a paper about that once.

BROCK: Did that also make sense because for the Systems Division their main customer was also the same group?

LAST: Yes, the same customer.

BROCK: The military.

LAST: Yes. So I got to know my way around the Pentagon and the Dayton Air Force Base and Fort Monmouth and all those great places. [laughter] They had some good people in those places. Jim—what's his—who later went to be a professor at Stanford, came out of that environment. I'm drawing a blank on his name. If I said it, you'd know it.

BROCK: Were you co-managing the division?

LAST: We started out that way. Jean and I were co-managing it, which was not a comfortable role for either of us. Jean's approach was to get down on the floor and invent new stuff or work on field-effect transistors or the like. I said we have to have somebody that's overlooking, taking a broader financial view of things. Whereas Fairchild was—I mean, Singleton was supporting us as well as he could, the money was very slim, and it was slow to come through. So I was working on that aspect of it. As we started developing products, Jean had a better rapport with his marketing people and he finally said, "Because of a lot of the marketing considerations, I want to be the manager."

I said, "That's fine with me. My interest is in this other stuff anyhow."

In starting Amelco, I was very lucky in getting a guy named Bob Lewis, who is an optical engineer, excellent optical engineer. He just came in one day and said, "Hey, do you folks need an optical engineer?" With his active development work, we built just a spectacular optical setup. There was nothing like it in the world.

BROCK: For integrated circuits.

LAST: Yes so we could make integrated circuits that were beyond other people's capabilities, make elaborate circuits. We were probably limited by diffusion technology and we were very slow on epitaxy. We didn't get into that. It was just too big an investment. So that ultimately slowed us down a lot when the integrated circuit world turned into an epitaxial way, which solved all of my initial problems with isolation because you didn't have to worry about this. It eventually led to the MOS approach to things.

BROCK: What was Sheldon Roberts doing in the early period?

LAST: He was spending a lot of his time working on high-quality solar cells, which was a great interest of his when he was leaving Fairchild. That's something the world really needed, was a higher efficiency solar cell. They had sort of mixed efforts there and he was helping with

various materials problems as they arose. After a while this was not a satisfying relationship for him, so he left.

Kleiner left Fairchild about the same time and came to work with us on a consulting basis, and helped us get the business side of the thing put together.

BROCK: I hadn't realized that.

LAST: Yes, so he'd come in every so often and help set up all these various procedures you know. All the things that I had not had to deal with at Fairchild, but was certainly going to have to deal with at Amelco and he helped educate me on that. He was very helpful. This was before—he was getting ready to start in the venture capital role at that time. He was very helpful to us.

BROCK: With this very advanced optical system that you and Bob Lewis developed, was the—

[END OF TAPE, SIDE 10]

BROCK: What impact did your design and did your work for the optical system have in other firms?

LAST: I don't think it had any, and finally the other firms caught up with us. A couple of years or something, I think, we could do stuff, and especially this took the form—Fairchild was aimed for the digital world. Certainly in the first transistors they were making were digital circuits, and I felt at the time that the world would be an analog world. Again, I was decades ahead of things, because now there's a lot of analog circuitry being made. But I felt with the idea that you had to take an analog signal and then digitize it, and then at the other end get it back to an analog form, that if you could make circuits on analog basis, it made a lot more sense.

So we made some really great operational amplifiers. I look back in awe at some of those early circuits we made, and we sold a lot of them. They went to some unknown bottomless pit with a Westinghouse plant in Maryland. So I never knew the end use, but we made a lot of them. For some of the Teledyne contracts we could envision very large arrays, you know, twenty circuits at a time that you could interconnect some way or another. The IHAS program was one that we made a lot of prototype things, where in one flat package we'd have twenty sophisticated integrated circuits and we figured out how to hitch them up and stack them. I was working on multi-layer ceramics where you'd have ceramics with a metal layer in between that you could use to stack these things on, and that turned into the world's most

unsuccessful potato chip factory. [laughter] We could never solve the problem of keeping them flat enough, so that was a disaster. But we tried.

I would realize that in fancy packaging the Japanese were way ahead of us, and I couldn't get Americans to bid on this stuff. So I went to Kyoto and met a small company that was just starting up, called Kyocera, and they had one little plant there outside of Kyoto. Inamori was running it. I went there on a Saturday afternoon. He said, "You want to see our plant? It's about twenty minutes outside of Kyoto."

I said, "What's to see on a Saturday afternoon?"

He said, "It's just another day for us." It was a real energetic company. He broke all the Japanese rules.

BROCK: In what sense?

LAST: Rising by merit rather than seniority. All this kind of stuff. The way you marketed stuff. He didn't go through these various multi-layer trading companies.

I learned then that you never ask a Japanese manufacturer if he can make something, because he would feel ashamed if he said no, he can't make it. So I'd read enough books on Japan. I learned the way to phrase this is, "I know this is a product that you can make. If you would honor me with bidding on it, I'd be happy to receive the bid." If the bid came, he could make it; if it didn't come, he couldn't. But I wasn't confronting him on it. I learned a lot of things like that. But the Japanese, as far as all of the advanced packaging that took place at Teledyne, I was able to get Inamori's help on. I had no dream he was going to end up setting up a plant in San Diego and taking over this whole thing. He was a real go-getter.

One thing, a steady problem was being underfinanced, and I'd once in a while write bad payroll checks on Friday, because I learned quickly you can't delay a payroll check. Giving them out after lunch rather than before lunch on Friday is a disaster. I learned that once the hard way, but after that I'd write it and I'd hope enough stuff would come in over the weekend or I'd go to the bank and grovel, or do whatever it took, but I did that.

BROCK: That was because of financial problems with the parent?

LAST: Yes. One day I just said, "I can't take this anymore." I just got up out of my office and went to the airport and got on the first plane to L.A. and just stormed into Singleton's office. "I need one hundred thousand dollars right now to keep this thing going, and you said you were going to support this thing, and now I'm here. I need it."

He mumbled something to Betty Denton, his secretary, and she came back in ten minutes with a check for sixty thousand dollars. He said, "I'm giving you sixty thousand dollars rather than a hundred thousand dollars because that's all the money there is in this whole goddamn company." [laughter] This very great Texas accent he had was a big help in discussions like that. But he did what he could do and we did what we could do. As I said, this fundamental goal difference presented steady problems.

BROCK: Between the broader markets and the sort of internal market?

LAST: Yes, so we developed a lot of broad-based products, a standard transistor line to meet this, at which point we started getting into some conflict with Fairchild. But there was never major—

BROCK: Conflict or competition?

LAST: Well, Fairchild had patents on the stuff that we didn't. At one point Noyce approached me and said, you know, "You've got to take a license on this stuff."

I said, "I'm not terribly inclined to." But it got to the level where the lawyers got involved, and so Singleton came up for a meeting with Noyce for lunch. We sat there and had a very cordial lunch, at the end of which we had been talking around the subject, and Singleton turned to Noyce and said, "You know, one thing I really believe in is our patent system and the value of owning patents." He said, "But in your particular case, I don't think your patents are worth a good goddamn, and I will personally go back and find prior art that blows your patents out of the water if you give us any more trouble on this." [laughter] And Noyce was just flabbergasted. That's the last I ever heard of any patent problems. [laughter] These are amusing things to think back through. I think I remember them fairly accurately. I know the mind plays funny tricks, but I certainly know that that one happened roughly in that way.

I want to take a break for a minute.

[PAUSE IN RECORDING]

BROCK: We were talking about the problem of the underfinancing, really. I suppose I had understood that initially your strategy was really for the Amelco Division to provide products to the Systems Division.

LAST: Yes.

BROCK: Was it partly because of this funding problem that you started to address the broader—

LAST: Yes. And I should have seen it earlier, that you can control your own destiny if you're making your own money, but if you're depending on somebody else's largesse to do this, it's not going to ever work out, no matter how much lip service is paid for doing that. Teledyne was run very lean, and George Kozmetsky, who was working with Singleton, was really something else as far as doing trivial things that would save some money.

BROCK: For example?

LAST: He said, "You can only check out one pencil at a time from the storeroom." Somebody recounted that they went to Kozmetsky once, who had the bad habit of chewing on pencils, and he said, "So I can only take out one pencil at a time, and you're sitting here eating the darned things." [laughter]

So Kozmetsky and Singleton, eventually there was a conflict of egos, and George left. But to his credit, the first day I met him, at that famous New Year's Eve meeting, he said, "This is not my long term—what I want to do with my life." He said, "I want to go and run a business school eventually." He said, "I'm going to do this for a while." He did. He went down to run the University of Texas Business School.

BROCK: And he knew it at that time.

LAST: Yes. And he said, "I went down there and they had all these deans, you know, scattered around. They all had their own Xerox machines. So I just put all these guys in a bull pen outside my office." [laughter] That was George's approach to it.

He was a very quick study, and he could remember numbers. I said, "George, wouldn't you be happy if everybody was called by their Social Security number?"

He said, "Yes, of course." He'd come back from Washington and say, "Bill told me this."

I said, "Bill who?"

"Well." He couldn't remember. But I would go back to Washington and give technical talks to the military people or whoever it was, and the next week he'd get up and he'd give my

talk. He just remembered all this stuff and was very quick-thinking. He had a bad habit of bidding on stuff we didn't have a ghost of a chance of making. But once in a while we'd say we couldn't, and then we did.

BROCK: So he was doing a lot of sales work, if you will?

LAST: He'd be in Washington for a month straight sometimes.

BROCK: Who were the big competitors at this time? I guess it was IBM.

LAST: Well, for what we were doing, it was Litton that Singleton had come from in inertial guidance systems where he'd hired some very talented people, Joe Smead, Tech Wilson, and Art Helmer, I guess it was. But these were great systems people, and then they were just competing with the general run of whoever bid on government contracts, depending on the particular product. But as the company grew, the systems company was a smaller and smaller part of the whole conglomerate that was being put together.

BROCK: With the comment that we talked about earlier, Singleton saying he wants to make another GE, was that conglomerate model at all explicit in the early days?

LAST: Not in the early days. He was acquiring companies and so we have to acquire pretty second-rate companies because we can't afford anything else. But the acquisitions came in slowly and the only division that started from scratch was a systems company and the Amelco Division. The rest were all acquisitions and combining various things after they were acquired. This Harvard analysis of that is just spectacular.

BROCK: I really have to get a hold of that.

LAST: Yes. Pointing out that as our stock started taking off in the market, it was a high PE stock, and we could buy a foundry or something, a very low PE company. You take a company that has a PE of 6 fitting into a company with a PE of 30, and after it gets in there its PE turns into 30.

So Singleton really thought this through, and then he started acquiring. He said the money's in insurance companies, and insurance companies were cheap then and he bought a bunch of those which gave him access to vast amounts of money to invest. So he really had thought this through. He was a master chess player. Played blindfolded chess with groups.

BROCK: And would just remember the placement of all the pieces?

LAST: Yes.

BROCK: Oh, my goodness.

LAST: There was one time he was playing chess with Tech Wilson, and Tech made some comment, and Henry looked puzzled and he said, "Hey, you told me the wrong move three moves back." And Tech had.

BROCK: That's pretty impressive.

LAST: I got to know Claude Shannon, who was on the board of Teledyne.

BROCK: Oh, really? I hadn't realized that. Had Singleton worked with him?

LAST: Yes, they worked together at MIT, and they had a very close personal relationship. Singleton's wife, Carolyn, told me they'd get together and play chess around the clock with a timer, just like the Chinese water torture—this thing going off all the time, and she said once they quit on a Sunday night and they'd taken a subway uptown, and they got separated from Claude on the subway, and Singleton said, "We'd been playing chess so long, I could figure out what stop this guy was going to meet me at." [laughter] Which he did.

But Shannon was just a brilliant guy and he just fell between two disciplines where they give Nobel Prizes, or he would certainly have won it. But he wasn't comfortable in large groups, and we'd have Teledyne meetings and they'd always put me next to Claude because he and I could yuk about one thing or another that we enjoyed. So I got to know him pretty well. He was really an amazing guy. But Singleton once said, "I want a technical guy on the board, and I know when companies get larger, it's hard to put them on, but I'll do it right at the start."

BROCK: Did Shannon stay on for a while?

LAST: He was on for a decade or something like that. Art Rock was on the board, so as far as the board interaction goes, I don't know much about it, but I know Art certainly knows that stuff.

BROCK: In thinking about this period, sort of the 1962 period, were you doing a lot of active recruiting of people from Fairchild, from other companies?

LAST: Fairchild, TI. Got a lot of people from TI. Other companies. Jean was very good at persuading Fairchild people to join us.

BROCK: Did you find it fairly easy at that time with your reputations for the—

LAST: Yes, we had a good reputation. The company grew. We had close to a thousand people. It was a major company by then, and we were pretty self-supporting, had all this product stuff. Jean had a run-in with Kozmetsky and left.

BROCK: Around 1962, 1963?

LAST: Yes.

BROCK: Can you tell me a little bit about that?

LAST: To this day I know practically nothing about it. I just know that Jean quit in a huff and Singleton felt real bad about that, and said, "If I'd gotten involved, this wouldn't have happened." But I don't know the details to this day.

BROCK: Did it happen very abruptly?

LAST: Yes. And Jean had a steady career pattern after that. Every three years he'd also storm out of the place he was at and start something else.

BROCK: Then he went on to found the semiconductor works for Union Carbide?

LAST: Yes, he did that, and then he left that and started Intersil and a couple more—probably about four of them. So then we were business competitors for the first time, and something that I recounted when I delivered a eulogy, of my close attachment to him, was that there was the mountain range east of Inyo Valley in California, there's a valley called the Saline Valley not much above sea level, and in between there's a mountain range that goes up about ten thousand feet. Jean and I, our goal was to climb that from the Saline Valley side. At the bottom it's hot desert and at the top it's freezing. So the only time you could do it was the time of the full moon in May.

Jean and I had tried this two years and failed, but we felt we knew how to do it from that point on. Jean quit just about two weeks before we were going to take this climb, and relations were very frosty on a business level, but, "Jean," I said, "we're good friends. Let's put that aside and take this climb." And we made it to the top and we got hit with a horrible, horrible cold front that came in. We had traveled up pretty light to get there. So Jean and I had to lie there and hold each other all night to keep from freezing, and the next morning went back and got into the barrel again with the lawyers. [laughter] So it just shows the mixed relations that I have. Jean was sort of—that was the way with a lot of people. There was a love-hate relationship. You'd get real angry at him one time, but he'd turn into a real charmer the next.

BROCK: One thing we haven't talked much about to this point is the developing sort of technical and business culture and community on the Peninsula in the late 1950s, early 1960s, and what that was like.

LAST: Well, there was too much technology usually for one company to absorb. There were too many ideas, and there were spin-offs. You've probably seen these flow charts of spin-offs. From Fairchild, there were about two hundred companies, just this vast number. That was happening everyplace. By then, venture capitalists were getting involved, and the whole climate changed from the early days where you just wanted to make something to where you wanted to make a lot of money doing it. The emphasis turned more onto the business model, and there was no stigma to failing.

BROCK: By the early 1960s?

LAST: Say mid-1960s. But if you failed, you just went and got some more money and tried it again. So there was a steady influx of venture money.

For the semiconductor industry as a whole. it was quite a bit later than that. I tried to trace out the investment in the semiconductor industry from the start of Fairchild through like the mid- or late 1960s, and I rapidly concluded that more money was going in than was coming out, for that whole decade. The same thing is happening now in other areas. Nanotechnology is—money will just flow into this and nothing's going to come out. But that was true of the

transistor. There were a couple notable successes. Fairchild was coining money for a long time there. But a lot of these other start-ups, you know, they'd raise money and didn't make that much, or get bought out by somebody else. It was an interesting phenomenon, and you were dealing with an investment community that didn't know a semiconductor from a piece of Swiss cheese, so that didn't help. There was no technical appreciation, for the most part, of these things.

BROCK: What were the sort of informal information exchange and news networks in the community, in the technical community around semiconductors? For example, a lot has been written about these different bars.

LAST: That was a very active social thing. Every Friday night, those of us that were so inclined would get together, and the guys that you had worked with, or were still working with, or would work with sometimes, it was a very friendly, not especially competitive environment. Everybody was young and liked each other, and it was a lot of fun.

BROCK: Do you think in part that was due to this technological abundance?

LAST: I think so, yes. That hasn't been discussed in much detail, I think. But it was just like the resources of the U.S.; we could always expand by going west or something. Here you could expand by starting a new company, and people weren't that concerned about you leaving because they had more on their plate than they could deal with anyhow. So it just grew. But Fairchild was spinning off all sorts of companies, most of which failed, but they turned into the industry leaders in a lot of cases.

BROCK: In 1962, as Amelco starts to get more into the commercial products, I guess, you were very early in producing field-effect transistors. Isn't that right?

LAST: Yes.

BROCK: Who were you competing against in that area at the time?

LAST: There was hardly any competition. Jean had always been fascinated by field-effect transistors, and realized that this was a niche market for a high-impedance device rather than a low-impedance device, and it would be a good market if we could make them, which we did. That was a good source of income for a long time.

BROCK: And with the bipolar transistors where you were competing against lots of other—

LAST: Then it was just having a broad enough product line, and our salesmen had some ammunition to go in and could take a broad-based order rather than trying to sell one or two products. Isy Haas was instrumental in getting a lot of that stuff put together, or just getting a product line and figuring out what products we could make easily and how much of this was just a different number with the same device in it, and the slight ways of sorting the devices to do this. So we turned into a pretty broad-based company.

BROCK: So in just the space of two years you were up to like a thousand—

LAST: No, it wasn't that fast. I guess a thousand would have occurred in 1964 or 1965. As I say, Christophe can fill in some of the numbers that I've got in boxes down in the cellar, he's been through that stuff.

BROCK: But it was a fairly rapid growth, nevertheless.

LAST: It was a steady growth. With all of these semiconductors companies, including Fairchild, there was also a down period. You know, it was never a steady upward thing. It would drop precipitously and then go back up. Right after we built our new plant, we had our first general layoff.

BROCK: In this early 1960s period?

LAST: Yes. But then it picked up again a few months later. It's never been a steady market; it's either ups or downs, sort of watering a delicate flower with a fire hose or something.

BROCK: How did the competition between Union Carbide Electronics and Amelco play out?

LAST: There was never any major competition. Jean went on and did other things. For a period, I sort of saw very little of him. He was doing his thing, I was doing mine, and then finally he got more interested in European businesses. He was spending a lot of time in Europe with the Swiss watch industry and places like that. He moved to Idaho. So there were many years I saw very little of him.

Later in his life, I saw a lot more of him again. He was pretty ill, and he and I were sitting talking about some of these old days, and his wife came in and said, "Oh, God. You guys should have a tape recorder on." She could just see the stuff that was being said then. Well, it's lost forever now. But we'll all make up for it.

BROCK: The best we can. [laughter]

LAST: At least when there's only one person recounting it, you don't get conflicting stories. [laughter]

BROCK: Consistency. Not accuracy. [laughter]

[END OF TAPE, SIDE 11]

LAST: (Development work for the IHAS program.) But while we were doing the development work for it, we did a lot of this very large-scale packaging work, which turned—the original Teledyne plant on Panama Street, the Amelco plant, started making these things as special circuits, and kept going. It's still going to this day, and its sales are up like a couple hundred million a year at one point, making these big arrays that started with the development work for the IHAS program.

BROCK: And those applications today are for—

LAST: Medical electronics. A lot of military work still. With Teledyne being split up now, it's a separate division, I think it's probably fallen on pretty hard times now. For decades, a couple decades, it was a big technical business for Teledyne Systems.

BROCK: Did you and your co-workers have to get security clearances for your work?

LAST: Yes.

BROCK: Was that different from colleagues at other firms?

LAST: Well, I don't think somebody in strictly transistor manufacturing would get into that because of your broad-end use, but as you got more and more into something where the end-use of the product was specified, for example, what particular frequency is being used to transmit this information. I went through, when I was in the Teledyne corporate office, went through a bad incident where one of the divisions of our company had inadvertently released some classified information to the world, and the military took this on as a very serious offense.

[PAUSE IN RECORDING]

BROCK: —talking about the division who had inadvertently—

LAST: Oh yes. I was a vice president, which is something that Singleton had put in shortly after Jean and I joined—he made us vice presidents so I could act for the company. This was a case where they needed a vice president to go grovel. So I had to go through this thing of going to apologize to the military and, you know, put this all back together again. They said, "Well, what I think you should do is, you personally should go to Security Clearance Procedure School for six weeks." [laughter] I just barely got out of that. That was the sort of military approach to things.

I remember one incident with Joe Smead. We were making very interesting products for the Livermore Laboratories for lock systems to make sure you didn't shoot off an H-bomb accidentally. It was a complicated locking system. It was either that program or one like this that was being done at Livermore up at Berkeley, and Joe Smead, who was the head of the systems company, and I had got into another one of these hassles with the military and we had to go there and they just roasted us for the afternoon.

Joe is just a marvelous guy, very resilient, and they finally just sort of threw us out and told us not to do this anymore. Joe looked at his watch: "Hey, we've got another half hour. Let's go down the hall. I think we can get some more business." [laughter] But that was sort of the systems approach; you just muddled through somehow. It was a world I was never terribly comfortable with.

As the space program developed and Teledyne was involved in this all over the place, we made like the stuff for the Doppler system that told you how close you were getting to the moon surface, and the last hundred feet, and there were probably a dozen different things that came out of Amelco that ended up on the moon, you know, in quantities of three. [laughter]

BROCK: Can you tell me about the move from the Bay Area facilities to Los Angeles in the 1966 time period?

LAST: Yes. I had continued—Jim Battey came in as general manager, and I kept running the R&D through 1963, 1964. I spent a fair amount of time with our European stuff. As I mentioned, I spent time in Sweden. I was at seminars there, including one interesting thing where I was as impressed as Gordon was with what turned into Moore's Law phenomenon, and I was looking at it both from linear and analog circuits, with a lot of detail. I did this essentially—this Moore's Law thing was about that time, and it's printed in Swedish. [laughter] And I don't begrudge Gordon, but it was pretty obvious that this sort of a thing was happening, and Gordon said to me that the reason that he put this out was that integrated circuit sales were just still not taking off in the mid-1960s, and he said, "We have to convince the world that this is a much cheaper way of doing things. That was my real motivation." He may have told you that.

BROCK: Yes, that it was really an economic argument.

LAST: So I was spending more and more time—by that time, Teledyne was very active in an acquisition program, really active.

BROCK: That was after acquiring the insurance companies?

LAST: No, it was probably before, but the waterpicks and shipyards and zirconium factories, and everything that made economic sense, if not technical interaction sense. George Roberts had come in as president to run it, and he was up visiting me and could see that—I had written to every division and gotten all their data sheets and saw how the companies were interacting, and he realized this was something he really needed in L.A., and finally persuaded me to give up my role at Amelco and move to L.A. and do this. About this time Singleton made some very poor choices of people to run the Amelco company.

BROCK: As general manager.

LAST: As general manager, and the company started on its way downhill. Singleton was never in a position to put enough money in to get into big mass production, which was not his interest anyhow. So it was not a happy thing for me to look back on, how the company sort of declined.

BROCK: After that period.

LAST: Yes, my interest shifted to my life here and I just kept close ties with a few people, but it wasn't the happiest day. I mean, it was a lot better than what happened to Signetics.

BROCK: Which was?

LAST: Well, the Signetics people were the group that I had working for me on integrated circuits that I didn't feel like I could hire, so they went off six months later and started Signetics. Again, Dave Allison was a key contributor there and they developed a much superior integrated circuit, diode transistor logic instead of the direct coupled, and that was the great product while Teledyne was still doing this older stuff.

So by then, integrated circuits were showing a lot more promise, and Teledyne considered this a serious competitor, so they'd gone in the Signetics business, and as Charlie Sporck points out in his book, he said, "We set out deliberately to put them out of business and cut their price so they couldn't compete" (12). And that was tough, and Signetics went to Corning as support, and it was not a very good understanding of the problems, and the company left a pretty bad taste in everybody's mouth. Kattner left and came back to run a lot of stuff at Amelco, finally.

So that was a much sadder story than what happened to us at Amelco. The company's still there. It was bought by somebody a couple years ago and it's still chugging away up there, doing its stuff, without getting into the mass production things.

I built a factory there. We had this small thing when we started, and I saw the need for this and went to Singleton, and he and I went and got the money from Trammel Crow to build what was a 60,000-square-foot building which I enlarged to 120,000. It was a pretty good-sized facility. That was fun to sort of get involved with that. I had some good plant engineers to help me.

BROCK: In the Fairchild and in the Amelco experience, did you do any setting up of groups or facilities in Asia? We talked about you doing some in Europe.

LAST: Yes.

BROCK: Could you tell me about that?

LAST: Jean had tried to work out something in France, and after he left I tried to pick up the pieces, but it wasn't that easy for me to deal with the French, and nothing much came of that. Teledyne—we bought Continental Devices that had plants in India and Hong Kong, and we started using those. And Singapore.

BROCK: For assembly, mostly?

LAST: Yes, strictly assembly. India was terribly frustrating.

BROCK: In what way?

LAST: Just the bureaucracy. This was when Continental Device was still setting this up. India is just loaded with engineers. I mean, you put an ad in the paper and you'd get a couple hundred or a thousand people responding. But they didn't have the built-in infrastructure of the skilled technician, and they had this stultifying bureaucracy. I know at one time Continental sent over all the production equipment they were going to need and it ended up on the Bombay dock, and there was a misprint in the manifest, and that sat there for several months and the only way they could rectify it was to ship it back to California, rewrite the manifest, and send it back again. Which explains a little bit why China has succeeded so much better than India. But our stuff was Hong Kong and Singapore, mainly.

BROCK: Can you tell me a little bit more about the offer or the description of the job that Roberts was offering to you in the 1966 period, to entice you?

LAST: He said, "You can just sort of write your own ticket." He said, "I see what you're doing, and I just need help in this whole area of technical understanding of what we're doing. Why don't you call yourself Vice President for Technology, and come down and join my staff." Which I did.

BROCK: How was that? You must have had a high regard for him.

LAST: Yes, I did, yes. And a very high regard for Singleton, except Singleton not understanding the commercial business or not understanding the implications of the low-priced transistors, but as far as letting me do my own thing and seeming appreciative of what I was doing, it was a good environment. It worked well with George Roberts. George is the one who's commissioning this book on the history of Teledyne that I'm starting to get actively involved with.

BROCK: What sort of a change was it to come to Los Angeles?

LAST: I wasn't terribly keen about moving to L.A., but I could see this was an opportunity. I was still single, and I came down here, and within less than a year I met Debbie. We got married, so my life changed. When I left Teledyne four or five years after that, by then we could move and live anyplace I wanted, and I decided I liked it here better than anyplace else I could live. So we're still here.

BROCK: So you left Teledyne around 1970?

LAST: I left Teledyne finally about 1974, I believe, 1973, 1974, and my transition to move down here, that would be 1967 or 1968, dragged on for, oh, six months or so. I was still working up north and down here. Every time I'd come down I'd bring something else. So I moved down on the Pacific PSA, doing things like carrying a floor lamp on the plane with me. I was back and forth a couple times a week for maybe six months, doing stuff at both ends. I finally realized I had to really make the cut. All my clean shirts were always four hundred miles away. [laughter] So I just settled down here, and as I said, I met Debbie, and it's worked out very well.

BROCK: What would you say that, in that period of 1968, 1969 to 1975, while you were mainly working on this sort of technology assessment, perhaps is the way to say it—

LAST: Whatever problems came up that required a technical solution, like our patent pool was large—we had acquired all these companies, and Bell Labs was still after me after all those years. I was one of the very few who never took out a Bell license, and I said to them, hinted to them what Singleton had told Noyce, that I know the weaknesses in some of these patents, and I did, and I said, "I think it's better that you just don't do this." So it turned into—every time when the weather was bad in the East, they'd always schedule a visit out for January and we'd have a very cordial lunch and talk back and forth, and they'd go away for another year.

Some of the key patents by the late 1970s, I thought the patents were expired, and these were patents that I'd seen at Shockley in 1956, and some were compression bonding, some of the basic diffusion patents were still—but they were getting ready to expire, so I just outlived the patent. I never had any problem with Bell. They understood my position and the fact that I knew an awful lot about the weakness of some of these patents. They just didn't want to make a fuss about it.

BROCK: So you handled some of those—

LAST: I would do that kind of an issue. One day Singleton came to me and said, "There's a company we've got that doesn't fit, or some part of it doesn't fit," and he said, "Go do

something about it." So I went up and looked at it and sold it. [laughter] You know, there was some management there that wanted to buy it, so I just sold it to them.

I didn't see Singleton for a couple of weeks, and he said, "Hey, what ever happened to that company that I was telling you about?"

I said, "I sold it."

He said, "Okay." [laughter] I always had great relationships with him.

BROCK: Sounds like he really trusted you.

LAST: He trusted me and my judgment, and let me do what I wanted to do. Then I was traveling around visiting all the new acquisitions, and there was one week I started in Virginia and visited a company a day, ended up in Massachusetts, and that week we had bought six new companies. [laughter] There was a company coming in every couple weeks or every month. A very active acquisition program. A lot of them didn't make technical sense. But as I said, the PE multiplier effect made good business sense. I realized after this, Henry was playing just a very complex chess game with himself, just figuring out what we were going to do with this company and how he was going to build it, and in 1972 he stopped acquisitions dead. Never made another acquisition, and by then had insurance companies who had big pools of money and worked on consolidation of companies and running them as businesses rather than building them. Then finally the whole thing was dismantled.

BROCK: That seemed to happen soon after his active participation.

LAST: Yes. That may have been part of his grand plan all along.

BROCK: To have it dismantled?

LAST: Yes, build it and get it into better shape than it was in, and make some reasonable divisions and sell them out. I mean, I look at the annual reports of companies like Unitrin, which is the most active, the most money-producing thing, and the other Teledyne companies, and the family still has massive holdings of these stocks in all these bits and pieces.

BROCK: That's interesting. So why did you decide to leave in the 1974 time frame?

LAST: Well, with the acquisition program stopping, you know, it is virtually impossible to make a technical transfer from one division to another. "Not invented here." People won't work on other people's ideas, and they're resentful. There just wasn't that much new excitement and I could see I was getting bored. I was in my fairly early forties, forty-four or something like that, so I said I have a lot of other things I want to do with my life, and I'm in a position where I'm not mad at anybody, nobody's mad at me. This is the time to make a graceful exit and get on with my life, which I did.

I could see the company turning into being run more by the bureaucratic mind that was necessary. People were jockeying for power, and all of the entrepreneurs left. I mean, Joe Smead left, Tech Wilson moved to Europe, a couple other people left, and the people brought up from the financial side stuck around and got in positions of power. I could just see that I would lead an extremely comfortable life that would get progressively more boring. So I just left.

Then after that, for about a year I thought, "Now, that was the dumbest thing I ever did. Here I had a nice comfortable life. Now I only have a credit card, and instead of having a plane flying me around, I have to stand in this damned line." [laughter] But then it settled down and I settled into my life the way it is now, where I got interested in publishing books and more active art collecting, and have been involved with maybe half a dozen little companies that I got started.

BROCK: In a venture—

LAST: It wasn't a typical one. It's where I take a pretty large ownership, like 25 percent or something, and try not to play the statistics of the venture game, where you just throw money at something and see if any of it ever sticks, and if you get one out of five or one out of ten, if it pays off well, that's what you want to do. I take the approach—I've always been critical of that approach, and have said if you make a commitment to be involved with a company, you should make a commitment to the people there to support it as well as you can. So it's been a mixed thing, but these are paying off, these little companies.

BROCK: Technology companies?

LAST: Yes, in a sense. Some are not as technical as others. One I sold was a company that figured a very clever mechanism to fasten expensive stuff like speakers to walls, where it could be rotated in any direction and locked in place. After that, the company—I sold it last year at a very nice return on investment.

BROCK: Any activity though in semiconductors?

LAST: No, and I wasn't inclined to spend any more time on it. I mean, it's a young person's business, and I was getting fortyish, and the contributions were going to come from me at twenty-six rather than—

BROCK: The technical contribution.

LAST: Yes. The world was getting much more complex, and from my point of view, a lot less interesting. I mean, making another ratchet on Moore's Law was not as interesting as making the thing in the first place.

BROCK: I wanted to ask, after you left Teledyne, what relationships have you had with the eight co-founders of Fairchild subsequently? Whom have you kept in touch with?

LAST: I would see the group on an informal basis. It would be an anniversary once in a while. The last one was after Noyce was gone and Jean was gone, we got Hodgson and Art Rock and all that original crew together up in San Francisco. Very cordial. Anytime I've met these guys, it's like visiting a long lost brother. We were always very friendly with each other. They put the Fairchild stuff on a postage stamp. It's that one on that wall there. So Sheldon Roberts and Gene Kleiner and I went up to Maine and commissioned the stamp, so we had just nice, warm relations together. Charlie Sporck started a National museum, we all went down there and spent a very nice day together. That was the last time we were all ever together.

BROCK: How has your relationship been, business and personal, with Arthur Rock in this period?

LAST: It's cordial, but we're at the opposite ends of the state, and when I'm at a board meeting in San Francisco, I'm in and out of town, and he hardly ever comes here anymore after he quit being a director at Teledyne. It's cordial, but we just don't have that many occasions to get together.

When he left the board at Intel, Andy Grove asked me, "Would you write something? We're putting together a book of memories for Art. Would you contribute to that?" Which I did, and said, "Just think, Art, what Silicon Valley would be like if you hadn't been around." Which is true. How different things would have been. A lot of this stuff would have eventually happened, but not the way it did. He sent me back an extremely warm letter, what a dear friend I had been throughout the years.

BROCK: Did you participate in the early Intel investment with Rock?

LAST: Yes, that was a good investment.

BROCK: I'm sure. [laughter] That's something that doesn't get a lot of play, I guess, in the historical writings that have been done to date. I guess the other six Fairchild co-founders all participated in that first round of Intel investment.

LAST: Yes.

BROCK: Could you tell me a little bit about your decision to do that?

LAST: Well, it wasn't even a decision. Art said, "I've never been through something like that in my life. I raised all that money I needed for the company in three hours."

BROCK: Just finding people.

LAST: He said, "If you're interested, there's a hundred thousand dollars you can invest." Which he told all the others. And we all did, and it worked out extremely well.

[END OF TAPE, SIDE 12]

LAST: —money around, figuring out how to allocate it. It was oversubscribed. At a later meeting, Gordon said, "This is something that really makes me feel good, is that we didn't get all that much out of the Fairchild deal, but that gave us a grub stake to go on and invest in other things. Here everybody is participating in what is the big success story, is investing in Intel." We all had the opportunity to make a lot of money in that if you kept your stock.

BROCK: That's interesting. I hadn't thought about it ever in quite that way.

LAST: It was one of the best investments of all time. Nearly all of us sold out. Intel was not a success there for a while, and it looked pretty sad there in the early 1980s. So a lot of people had made a lot of money, but sold out at still a small fraction of what it turned out to be in the

1990s, and some of the dynamic decisions they made in those days were extremely powerful, difficult decisions to make.

BROCK: For example, to get out of memory.

LAST: To get out of memory. God. What a decision.

BROCK: That was a very interesting decision. It would be similar to Fairchild saying, "Let's get out of transistors and just bet it all on integrated circuits."

LAST: Yes, that's right.

BROCK: In a period like that.

LAST: Yes. It was the right decision. It was a pretty agonizing one to make. I'm sure Gordon's gone into that.

BROCK: He has.

LAST: In some detail.

BROCK: It was extremely difficult for them to do. What are your thoughts about—just to stick with that theme for a minute, or about Gordon Moore for a minute, on his contributions at Intel? Do you have a sense of that at all, or an opinion of that at all?

LAST: Nothing really first-hand. He never discussed it very much, and he's fairly modest about this kind of a thing, wouldn't want to discuss it very much. I could see in discussions with Art Rock that Noyce was getting more and more out of things and not following through. His interests had changed, and Gordon, who had always worked in Noyce's shadow all that time, whereas I personally, as I said, I felt Moore had made enormous contributions that were unrecognized at that time. As Gordon rose in the company and gradually turning out to be chairman, I was pleased to see that it worked out. Does that answer your question?

BROCK: Yes, that's great.

LAST: As I said, whenever I saw him, we were cordial about this. I went to one of the annual meetings where he'd been in the ill-fated watch business, and he said, "I just get a stomachache thinking of going into the board meeting and getting beat up on the damned watch thing again." That was the only time I saw him discussing the negative sides of his—less pleasant aspects of running the place there.

He had a good board. Chuck Young at UCLA was sort of behind the scenes. I was on another board with Chuck for a while, and I could see what a powerhouse he would be in that kind of a thing. And the other board members were good. So it was a well-run company. With the financial reverses they suffered when IBM bought out part of the company, those were tough times. They probably would not have succeeded if they hadn't made some of these dynamic decisions, but they did.

BROCK: In actually executing or in making those difficult decisions.

LAST: Yes, and as I said, my early opinion of Moore was that he didn't do this in a way that was going to blow his own horn. He was sort of interested in seeing the result being achieved, and achieved through other people. That's the view—I don't know how accurate it is, but that's the view I hold of him.

BROCK: Some people have described him as being an accomplished sort of judge of technological proposals or as having some sort of a technical judgment that was unusual.

LAST: I think it's extremely high. I've felt that. The work he was doing at Fairchild on getting the MOS started, it took a long time for that to take off, but at one point I was interested in MOS for Fairchild, for a Teledyne project, and went over and discussed it with him; could Fairchild do it. He said, "No, the time isn't right yet. MOS is not a reliable enough thing yet for a big-scale thing like you're talking about." But the results speak for themselves. He picked the right technology with Andy and the other people involved, and while it never took off at Fairchild, it was the foundation of Intel. I've never doubted his ability to make good decisions like that.

BROCK: Did you see Gordon and Betty Moore much in the Fairchild or the Shockley days, or was there sort of a married guy, bachelor guy—

LAST: Not quite that way. Well, I saw Jean and Sheldon. I had dinner with them quite often. I never saw Betty except if it would be some fairly big event where husbands and wives would get together.

BROCK: We've talked about Moore's Law, and we talked a little bit about—well, I guess we talked about it at lunch—this paper that you wrote in 1998, looking, comparing the advent of printing with the advent of the silicon technology, the book with the computer and this dependence of communication or information innovations upon materials technologies (13). So for the printing there's paper, inks, metals.

LAST: Metallurgy was strong.

BROCK: And for the computer technology, the transistor computer technology relies on a vast—a longer list, one might say, of materials technologies. I suppose my question there is to ask you about your reflection on working on making seminal developments in sort of the seminal period of the development of the silicon technology, how strong of a dependence do you think that is on the materials technologies weighted against maybe other factors? Is it a defining feature?

LAST: It was a defining feature, completely. I mean, it was the ability to get pure silicon to start with, was key, and that was pushing materials technologies, as Tanenbaum will tell you, to the limits. Being able to build it, to understand the diffusion process in enough detail to solve these aggravating and non-ending problems with surface contamination, getting into epitaxy and ion implantation techniques, was all strictly a deep understanding of materials. So it's a materials-oriented business and whether you call it chemistry or physics or solid-state physics or industrial engineering or something, it was a tie-in here with all these disciplines that was key. It really is a materials business.

BROCK: Yes, a transformation of materials—

LAST: From one form to another. And all of the side materials that were needed that don't show up in the final product are essential for the manufacture of it.

BROCK: Rinses and—

LAST: Rinses and polishes and the whole thing. I find it very gratifying now to see, when I talk to people running MIT, how they're trying to make interdisciplinary stuff the leading thing at the university, and it's breaking down all these artificial divisions that took place.

BROCK: And to organize it around more problem-centered—

LAST: Problem centers, and there's an awful lot of resistance from people that are professors of something who want to maintain the status quo; and getting rid of that. Especially all these communications laboratories and things. And the area of materials, looking at the broad—this from a lot broader point of view than you do if you're just stirring a bucket of something and passing it on to somebody else to stir it for a while. [laughter]

BROCK: We've talked about this key materials development, sort of problem areas in the semiconductor story. Are there people who really stand out in your mind as people who grappled with or made an advance in these materials areas?

LAST: I don't think about that much. I mean, I know the big chemical companies that turned into very reliable silicon manufacturers and turned into the ability to make progressively larger wafers were key in this. That would be, I think, the key thing. As far as purity of materials and stuff, you could just tell them they needed it purer, and they'd do it.

BROCK: Was that the situation that you often found yourself in with, even going back to working with the photoresists, that you were really telling your suppliers, really defining the problems?

LAST: That we need a better one, or we steadily needed it, and Kodak jumped on that and just kept at it for years making steadily improved photoresists. They got real good. It's not just the resists, but the properties that enable you to get it off when you want to. You can't scrub it. You have to have something that is a compatible complete chemical system that you can get it on, get it off when you want to, and that will stand up under these high temperatures when need be, and stand up under these strange conditions.

BROCK: I guess what I should ask you at this point, is there any aspect of your technical career that I haven't touched on that you really think I should have, an area that we really should explore?

LAST: I don't think so. We got through what I learned in school, how I applied it, and how I used the stuff, the semiconductor things, and how Teledyne, when I had the job of Vice President of Technology, I could be a very quick study on a business that I'd never seen before with my physics background, and get in there and figure out real fast what they were doing and the general makeup of the company. I'm really pleased to have been educated as a physicist.

BROCK: For that analytical bent?

LAST: Not so much for the physics I learned. I haven't used quantum mechanics, I don't think, since I got out of school. But I have indirectly because I'm looking at understanding quantum phenomena. I've used that indirectly. But I never directly solved Schrodenger's equation again or something like that. But the education I got was very broad. But just the basic way of thinking as a physicist has stood me in good stead.

BROCK: How would you describe that? As a way of approaching and defining a problem?

LAST: A way of looking at a lot of things that don't look like they're related terribly well to start with and making some sense out of it. I don't know really how much of that is cause and effect, how much of that was just engrained in me or how much was physics education, but the physics education formalized it a lot. So I'm pleased with my education.

If I'd stayed in optics, I would have had a very disjointed time. I was about the last class that studied classical optics with designing on a desk calculator. You had to work to ten places past the decimal point, and any trig table gives you three places. So for every calculation, you had to calculate the trig function you were going to use to do the next step. It was an extraordinarily ponderous thing and good designers like Kingslake, a lot of that was just intuition with them. They could make very intelligent guesses.

But just as I left MIT, the first computer was starting to be used for this and that just took over opticalization completely. I gave a talk at the commencement at Rochester a couple years ago and pointed that out that the value of a broad education enables you to change. Rather than a narrow education, I would strongly recommend to everybody, especially on an undergraduate level, that they get as broad an education as possible. I still feel that way. I see the young people I'm in a position to give some advice to, to take some of these especially liberal arts courses that can enrich your life forever and give you an appreciation of the world that you're not going to get by being narrow-focused. It enables you, if your interests change throughout life, which they should—

BROCK: You have the flexibility.

LAST: Yes. Arbuckle, that ran the business school at Stanford, put that well. He said, "Man is like a delicate plant. To really thrive, he should be re-potted every four years." It's true. I think this is a good thing for term limits for various offices. I had a good discussion last week with the president of Rochester, who feels his time is up, and we both felt it was the right thing to do. I mean, it's time for somebody else to start doing this and it's time for him to do something else.

BROCK: I did want to ask just a few questions about some aspects of your second careers in this period after you left Teledyne. We talked about your ongoing collecting activities and how they changed, in particular the African Art, and how you began to collect the agricultural labels. Did those collecting activities lead you kind of directly into art history work? Or was that something that—

LAST: I would say yes. Commercial art history work and I could start seeing, like in orange crate labels, art nouveau being replaced by art deco, and replaced by commercial art. These were very dramatic steps; when you look at the labels, you can see this. That interested me to document that. And talking about lithography from a technical angle, and how that was utilized throughout making labels, stippling effects, and the color combinations. That led directly to my present interest on trying to document the whole lithography history.

BROCK: Do you think there's any connection between the lithographic processes that you were deeply into, with the semiconductor industry and your—

LAST: I don't think so. Lithography for the semiconductor was a misnomer. Litho means stone, and that's the last thing we were involved with was standard half-tone lithography or anything. It was the thing we were using by exposing an image and changing it around a bit. No, I don't think so.

BROCK: It was through the agricultural labels.

LAST: Yes, which turned into a very strong interest. Gordon McClelland and I have written about four books about various aspects of the label industry, commercial art, along those lines.

BROCK: Then how did the interest in documenting the history turn into the decision to start your own press?

LAST: Well, I had heard almost universal complaints by people that somebody else editing and publishing their book that they wanted to change it all around or not do it at all, or buy the rights and then scrap the book, and I said I have the resources to just figure out how to do this myself, and I can write the book that I want to write, and get it published and sell it. So I had to learn all the things about getting books published and bound, and paper opacity so you don't see the other side of the sheet, and gradually learned. And then how to sell them, and I've had, I'd say, very good sales, and all these books have either been reprinted or sold out that I've done. I've done about a dozen books now. They just keep selling.

Most book companies are, again, like the venture capital. They're playing for the one big hit and scrap books before their time. I just said, "If it's a good book, if you just wait long enough, you're going to sell them all," which is the case. It makes a lot of sense. I've liked the idea of a book that was the first book on the subject, and I would have been very happy to read it if it existed, but if not, I ended up getting involved enough to write it.

BROCK: Was it through this California commercial art that you became interested in the watercolorists?

LAST: No. That was another interest, and that was Gordon McClelland's interest, my partner, who had been collecting the stuff since he was young and said, "Let's collaborate on this." We interviewed people. The major effort, and the major input on those books was Gordon's. I did my part.

BROCK: How did you meet him?

LAST: He was selling orange crate labels at the flea markets here, and he's a native Californian and started collecting labels when he was twelve years old, and by the time I met him he was in his early twenties, and he was the leader in collecting labels. So we met and hit it off well, and ended up still to this day being very close partners in all the things we're doing. That's been going on for a quarter of a century now. We write books that I'm very proud to have published. They get a good press and people like them.

BROCK: Can you tell me about your involvement or founding, maybe, even, of the Archaeological Conservancy and what that does?

LAST: I'll take a break first.

[PAUSE IN RECORDING]

LAST: It was started by Dr. Steve [Steven A.] LeBlanc and Tony Berlant, an artist whose work hangs in the other room. Steve was involved with archeology in the Mimbres Valley in New Mexico and Tony had been collecting Indian rugs, so they both had a great appreciation of Indian things and were horrified at what was going on with people going in and digging up this stuff, just get a backhoe and go in there and when they saw toe bones fly up; they'd stop and look for pots. It was just sad. And they were both horrified with it.

So they approached me, who had some sense of organization, to get involved with them. So we started a foundation called the Mimbres Foundation. We realized you don't do this by being a nice guy to save the site, but as with the Nature Conservancy you get into some pretty good hassles, and we went to the State of New Mexico and got a law passed in the legislature that made it illegal to do this kind of pot hunting.

At the time I met Mark Michael, who started and has been president of the organization ever since. This has been a couple of decades now. So we succeeded in stopping this Mimbres stuff pretty completely, and then we said that we could use these ideas to turn it into a national organization. But I didn't want to go around with a tin cup and raise money, so the Rockefeller Foundation and the Ford Foundation and a couple others gave us some pretty good-sized chunks of money to do this.

The first thing we did then is get a law through Congress updating the 1909 Antiquities Act which put some teeth into doing stuff on federal land at least. There was no mechanism in this country to stop private use of land, as opposed to most countries in the world.

So we had very lean years. Right after we started, we had this war chest from the Rockefeller brothers, and we started looking around, talking to state archeologists, and it turned out the key eastern site in the eastern United States was the Hopewell site in Ohio, which was a big Indian central point. You find obsidian from Yellowstone there and mica from Tennessee, and shells from the Gulf of Mexico. It was an enormous trade route. And this was going to be subdivided and destroyed. So we took our whole war chest and bought it. So then I was out with a tin cup for a couple years, and the organization gradually strengthened.

Stuart Udall, who had been Secretary of the Interior, called one day, and said, "Hey, I'd like to be involved with you people. Can I help?" And he did. Under his name as being a conservationist, the organization slowly grew and we started active programs to build our membership and, as I said, now we have about twenty-five thousand active members.

I want to keep it small and lean. We have three field offices. Each has a couple people in them, but that's about it. I don't want it to turn into a bureaucratic organization like the Sierra Club or the Nature Conservancy, and especially not where, in the case of the Sierra Club, anybody in the organization feels that they can speak for the organization, and it works at cross purposes. So we've kept it small and we're now acquiring a site a month or something like that. We've acquired about three hundred of them by now.

So I look on that as—the conversation I've had with Gordon is—if we hadn't done this, what would have happened? The time was right. We were there just to give it a push forward quicker and implement it. Gordon said, "You know, it may have happened. I don't think it would have happened this way. It could have taken quite a bit longer." Which I agree with. But it would have happened. But this archeologist stuff, if I hadn't been involved with it, it wouldn't have happened. So that's a very satisfying feeling.

BROCK: So that's the strategy that the organization is taking now, is the direct purchase of these sites?

LAST: Yes. We've always directly purchased them or appeal to somebody's better nature and have them give it to us, and then find some way to find a good final home for it.

[END OF TAPE, SIDE 13]

LAST: —the last board meeting I was at, I just came away with a good feeling and said, "This organization is now not dependent on this board. It has a life of its own," which it does. It's a good feeling. They can build something permanent.

BROCK: We've talked about your involvement with funding and advising companies in this period. I don't think we've talked about your interest in writing on the history of technology, for example, this 1998 article, other writings that you've done.

LAST: I like writing. I don't like doing the final draft, but I like doing the research and thinking it through. This writing on the Gutenberg thing really opened my eyes to a lot of interesting phenomenon, as we had mentioned at lunch, but I think definite correlations you can make about—or observations you can make about widely different technologies as far as their acceptance by society, and that interests me a lot.

I like looking at the broad picture rather than, like most articles in the history-of-technology journals are very narrow and specific, and that doesn't interest me as much as some bigger or broader observation I can make about the whole works. But I find that very interesting, and I'd like to continue my thinking along that line, the line of how technology has changed in my lifetime and the various things that have changed without people really realizing it very much.

I am not as interested now in the technology of the future because I probably won't be here. A lot of these things, a thirty-year crisis problem is not going to be my problem, but

somebody else's. So, looking at the technology I've seen in my lifetime interests me a lot more than the other stuff now. I'll keep puttering around with writing about some of this stuff.

BROCK: That completes my list of questions. That's pretty impressive for our work today, but I was just going to open it for any other reflection or comment that you have at this time.

LAST: What I can say is that the success of today was due to the homework you did in preparing this list. We would be just really going around in circles and we'd have missed a lot of key points. We at least touched on some things, and looking over this list, something else may occur to us, but I think this is a pretty accurate discussion of how I spent my life.

[END OF TAPE, SIDE 14]

[END OF INTERVIEW]

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