Oral History of Jay Last

Interviewed by:
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Craig Addison: Jay, could you start off by talking about where you were brought up and your education experience?

Jay Last: Sure, I was born in Western Pennsylvania and went to school there in a small steel mill town. My father worked in the steel mill there and I was born in 1929 -- the week the stock market crashed -- and so in my first decade steel was a pretty tough industry to be involved with from my father's point-of-view. So my first 10 years were the Depression and after that there was five years of war so by the time I was 15 I realized I had seen nothing but depressions and wars. I got a good high school education in this small town and then went to the University of Rochester and got a Bachelor's degree in optics and had a very heavy physics training there also which gave me the background, then, to go on to MIT and get a doctorate in solid state physics. Solid state physics was a relatively new field then. All of the technical developments from the 1930s and the things happening in the war just had this vast amount of physical phenomenon that were available for use in various commercial products and improving whatever we were doing. So my timing was just perfect. I got an education in solid state physics…so I knew the background of the transistor field.

So then I was approached by [William] Shockley when I was finishing my degree. For my doctoral thesis I was working with a very complicated Beckman Instruments spectrophotometer which didn't work too well, so the Beckman people knew me and wanted me to come to work for them. I said, "The last thing I would ever want to do was have anything more to do with that spectrophotometer." [Laughs] But that was just the time that Shockley had worked out an agreement with Arnold Beckman and Beckman said, "You ought to go talk to Jay Last," so Shockley came up to MIT one day and we started talking and I realized that while transistors were not the field of my main choice, I found Shockley a very interesting and intriguing person. The other job I would have considered, of course, was Bell Labs. They wanted me to work there again in the same field of transistors but I made the decision to join Shockley.

Addison: And you still have the offer letter that Shockley wrote to you.

Last: This is the letter. I'll just read the first paragraph. This was when Shockley was still in Southern California at the Beckman headquarters. This was November of 1955. He'd hired then two people. I was the third one he was considering hiring. He said, "You have passed our tests with flying colors and I hope you'll wish to join my project at the starting salary of $675 a month. We would like you to start as soon as you can after completing the work necessary to obtain your degree."

So that was the start of it. I still had about four months work to do at that time for my thesis and at that time Shockley hired a lot of other people. To his disappointment he was not able to hire any of the key staff people at Bell Labs. I was told by the Bell Labs people who said, "You don't know what you are getting into working with Shockley." But I thought, well, California is where I want to live and whatever happens, it's going to be an interesting time so I joined Shockley then.

Addison: The employment letter talks about tests. What tests did you have to do?

Last: It fit both Shockley's interests and Beckman's to give a series of psychological tests about…are you qualified to do this? The sort of test [that asks] "Would you rather be the motorman or the conductor on a streetcar?" That kind of test. I went through all those psychological tests.

Addison: What were you actually doing at Shockley Labs in the first six or seven months?

Last: We were just setting up a laboratory, which started out to be a laboratory rather than a production facility, unfortunately, for the long-term…but just developing the semiconductor technology and building equipment. Shockley made two key decisions. One was that we were going to work with silicon and [that] the fabrication technology was going to be diffusion and those were the key decisions that carried on to this day. Shockley maintained good relations with the top brass at Bell Labs so we could see the Bell Labs reports on occasion and so we were up with all the technology. We had access to what Bell's thinking was on these things. I was never involved in the diffusion but that was a key thing we were working on then. We were working on crystal growers, all these things. I was working on testing some of the four layer diodes. Shockley's bad decision was to try to make [four layer diodes]…a lot more complicated device than the transistor. He wanted to invent something new which we realized was not the wisest choice to make.

Addison: So did you have much chance to use your optics knowledge at that time?

Last: At that time no. I never used it in a really deep technical sense. At Shockley, no, I never did that. My main focus was on the solid state physics that I had learned. I had never seen a transistor at that time and didn't know much about them so I was busy trying to learn how transistors worked, as was the whole group. We'd have little study sessions trying to learn what are the key things we should be focusing on. I wrote a paper with Shockley on some aspects of energy levels.

Addison: Were there any particular recollections or demonstrations of Shockley's brilliance that stood out to you?

Last: Just that every day, every time you talked to him, you could just see this. When I first met him I had some stumbling blocks in my thesis which was an area he wasn't terribly familiar with. But I started discussing it with him and he just immediately came up with a very good discussion of what I should be doing. I was just very impressed with him. I was then and I always have been. This guy was extremely bright. He paid a big price for that in that he was not terribly socially adept and didn't understand what motivated people very well.

Addison: People have said that because he was bright, in the scientific sense, that he wasn't a good businessman and that he made some bad decisions there, i.e., the four layer diode.

Last: Well, he had no business sense at all which was not surprising. There was no reason he should have but he got himself in a situation where he was going to need that stuff, so relationships deteriorated with Beckman and Shockley and that deteriorated our relationship so individually most of us made the decision we were going to leave. And the story has been told so many times that we realized maybe

there was some way the group of us -- there was a group of seven of us then -- could get a job together and keep doing what we knew we could do [which] was make a transistor, rather than go our separate ways. We would try to find a company to hire us and the Hayden Stone people with Art Rock came out and said, “You should start your own company,” which was just completely foreign to us and it was foreign to the venture capital world. There wasn’t any venture capital really at that time. But anyhow, we worked out an arrangement which led to us leaving and starting Fairchild and with some persuasion we persuaded Bob Noyce to join the group finally after we had got things fairly well set up. So the eight of us went off and started Fairchild.

Addison: Looking back, what did you learn from Shockley during that brief period you worked for him?

Last: Well, I gained an understanding of transistors and we learned the basic technology we were going to use. When we left, there were still huge areas of things that hadn’t been done -- how you put devices in packages and put leads on them and test them and make reliable, reproducible devices. I don’t think at that place [Shockley Labs] they ever made two devices that were the same.

Gene Kleiner’s father had had some relationship with a Wall Street firm with some business he was running. So Gene just wrote a letter to these people and Art Rock was a junior associate there at the time and he had the wit not to throw our letter in the wastepaper basket and he and his boss, Bud Coyle, came out and talked to us. We decided at that time just to start our own company which was a really exciting, unknown thing for us to do. I was the youngest in the group then. I was 27 and the oldest was probably Gene Kleiner who was probably 32, so we were just a young bunch of guys. The agreement was that Hayden Stone would try and find a backer for us and we went down and listed about 20 or 30 companies that would be potential supporters of us to have our own enterprise and all 30 turned us down. The ones that got close, the lawyers would get involved and stopped the deal. And finally Art Rock and Bud [Coyle] got a hold of Sherman Fairchild who was intrigued with this and that turned out to be obviously the deal that worked.

Addison: Now, of course, the term “the traitorous Eight” has come about but according to Emmy Shockley, she said her husband never used that term. Do you know where that came from?

Last: This was some newspaper guy way after the fact. It was at least 10 or 15 years [later] before I had ever heard the term and it just caught on. People seemed to like that.

Addison: When you were leaving at the time you weren’t called anything in particular?

Last: No, I don’t know what Shockley called us behind our backs but it was a great shock to him that we did leave but we knew what we wanted to do which was make transistors.

Addison: Can you talk about the first few weeks at Fairchild. What were you focused on…just getting a building and getting it set up?

Last: An awful lot of things that we had never had any experience with we had to do. We had to get a building. We had to figure out who was going to do what. The interesting thing, as I look back on it, is the group we had. There were eight of us. We all had different skills but among the group we had all the necessary skills and it was a completely cooperative effort. We had no real boss. We had weekly meetings where we decided what we were going to do next. Bob Noyce and I were involved with a step-and-repeat camera. At the time I did use my optics [knowledge]. Jean Hoerni was involved with diffusion and he had a great deep, physical insight into a lot of things about the physics of semiconductors. Gordon [Moore] also was involved with diffusion. He made a great contribution…he was the only one that knew how to blow glass so he was making all the jungles for the diffusion and he also was involved with metal evaporation. Sheldon Roberts just went off and got us right into the silicon crystal business. Vic Grinich was the one that really knew what transistors were and what they were used for and he set up all the testing facilities. Julie Blank was in charge of the facilities and also making equipment. Gene Kleiner was a magnificent equipment manufacturer, great machinist. He just loved that. He was good at that. And Gene also started taking over some of the administrative tasks. It's looked on as a group of eight but we did get some other key people and that's where the story is not quite accurate. The contributions of the people [outside] of the eight of us never got really recognized very well. Dave Allison, in particular, was a key person involved with the diffusions.

Addison: I imagine that having worked together at Shockley and making the mistakes then, you were a pretty well oiled machine by the time you were at Fairchild and could really get things done a lot more efficiently.

Last: Oh, it was a complete change. Shockley was a micromanager and kept us isolated from each other. He had secret projects with some of us that the others didn't know about, but here we were working with a group [having] this Monday morning meeting where we would get together every week and figure where we were at. It took a long time to get the facility put together. We started about the first of October [1957] and we had to get power in the building and had to make all the equipment we needed, all the furnaces. About the only thing really we could buy were microscopes. Everything else we had to make ourselves. We were focused on getting into the transistor business and an interesting thing was transistors up to that point had been made individually by various alloying techniques and this was the first time that transistor manufacture was a batch process. The wafers were miniscule by today's standards but there were still a lot of transistors on them. They were probably, I think, three quarters of an inch wafers… that was the biggest we could handle.

It was remarkable to me, when I look back on it. We went into an empty building without power and had to build all of the equipment and had to develop all the supporting technology. We had to make crystals. We had to learn how to cut crystals, lap them. That was an area that I could use some of my optics background…on making crystals. We had to build the diffusion furnaces. We had to learn how to make controllable, reproducible diffusions. We had to develop all the technology for putting metal interconnections on them. We had to figure out how to put them in packages, how to put leads on the package, and how to test them, and how to build a device that was going to be a high reliability device and so we did all these things. And I look back on it and I was just amazed to realize that 10 months after we went into this empty building we had a commercial product which we announced at Wescon, which showed the way that we were working and cooperating…each one of us depending on the rest of the

group to do their part. They depended on me to do my part and everybody else to do theirs. We all did it. We worked together really without too much of an overall leader telling us what to do. The problems we had to solve were obvious and we just solved whatever had to be done.

Addison: Jay, could you talk in a little more detail about the work you did in the optics area? You said you and Bob Noyce worked on that in the step-and-repeat camera and then also I believe you did some work on photo resists?

Last: Oh yes. I was working on that. The optics was not a question of making our own optics. We were just buying lenses and I knew enough optics…we wanted to get a matched set for step-and-repeat cameras so Bob [Noyce] and I went to a camera store and I picked out an appropriate set of lenses that were matched. And we decided to use photo resist in order to delineate the areas…Bell Labs had made some efforts there and thought this was just impossible to work with so they never pursued it although they had tried it. But we said we just have to do it and Bob and I worked with Kodak and they gave us the best resists they had at the time and we gradually had a working relationship with them that resists kept steadily improving. The problem was not putting the resist on. The problem was getting the resist off without destroying the under layers. There were a lot of technical problems and technical setbacks there but, as I said, we just said we are going to use this and we have to make it work and we did. That was true throughout. Everybody else was solving their own problems.

We had to find a metal solution for making a good contacts and Gordon [Moore] tells the story of working with aluminum which he said was Bob Noyce's thought and I was joking with Gordon about that and I said, "I just think you were doing it alphabetically," and Gordon said, "Yeah, that may be but I left out Argon." He had the wit not to do that. [Laughs]

Addison: Could you talk about the lead up to the planar transistor, how that came about?

Last: The first device we made was an NPN…we could make contacts to it and it was a lot easier to make. We didn't get into some of the horrible problems of boron diffusion. Jean Hoerni's bailiwick was working on the boron diffusion. Jean had been a theoretical physicist and had done work with crystallography but he turned into a pretty good experimentalist working with diffusion. I mean, he had just a "charge full-steam-ahead and try it" [attitude]. When he wanted to find out the limits on boron diffusion, he just kept doing it until it blew up and behind one of the diffusion furnaces there…it was a concrete wall and every once in a while the furnace would blow up and the whole works would come shooting out against the wall so you could see a little hole in the wall where Jean's tubes had blown out.

Something that's hard to explain is that it looks like…and this happens the whole way across technology…it looks like it's enormous insights that lead to a new invention but this is so much based on past inventions and looking at what is practical to make rather than the key technical thing.

When Bo Lojek wrote his book [History of Semiconductor Engineering], he asked me to write a little testimonial on the back and this was a quotation that I had written for Bo for his book. "You and I agree that while the world loves a hero, semiconductor progress depended on the efforts and ideas of a large number of people and that moving forward depended on contributions going back a few decades in some

cases. Also, as is the case with most inventions, a number of people with access to the same pool of common knowledge were working independently at the same time to put it altogether and to make the necessary extensions to the existing technology and who realized that the time was right for society to accept the new concepts." That says that nearly all technical progress is a group effort and always has been and that was certainly true at Fairchild and [there were] a lot of unsung heroes involved in all of these things.

Addison: I've also read that Autonetics, the Minuteman contractor, was a key force in getting to the planar transistor. Could you talk about that?

Last: It was key. The transistors were very expensive, difficult to use…completely different design concepts than were needed with tube design and the use for transistors was completely military. The military needed small devices that could be used for airborne computers and they also had temperature constraints which meant that they had to use silicon rather than germanium and we were at the right place at the right time. We could make the transistors that were needed and so Autonetics came on for the Minuteman program which was a major project and they had very high reliability requirements, obviously, and we had separate production lines there and had sort of almost a division of Autonetics at one point for some of the things we were doing. And then we got into a problem with little metal particles bouncing around inside the package that were shorting out the devices. Finally we realized what that was but that was just the time that Jean made his first planar transistor.

From Jean's widow I've gotten some source documents to figure out what was going on and what Jean was thinking about. We started [the company] in October. In December [1957] he had a long notebook entry discussing the planar transistor so he had the idea of it but the technology wasn't ready and we were completely focused on making our first devices. He [Hoerni] was trying to make a PNP transistor whereas a group lead by Gordon was making an NPN but after a year and a half…let's see, it would be early '59, Jean went back and started thinking about the planar transistor again which was going to involve a fourth mask to delineate the base area and I made that mask for him. Jean wrote up a patent application for this and showed it to Bob Noyce and Bob, after seeing this planar thing getting ready to come along, wrote down his ideas for an integrated circuit and I have that documented to the day. Jean had his idea, he talked to Bob and Bob a week later wrote down his integrated circuit thoughts.

With all of these things it wasn't, as I said earlier, an enormous leap forward in imagination. You sit down for a few minutes and you could visualize these things. The key thing is what can we make? Every day we could come up with a dozen new great ideas of things we could do but the question was 1), could we make them and 2), would the world buy them? So we were focused a lot more than a lot of the venture capital firms are today that think the world is going to pay them for being bright and having a bright idea. We learned quickly in those days the world doesn't work that way.

Addison: I've read that you jury rigged the fourth mask for the planar transistor and that you also witnessed the first demonstration. Could you talk about that?

Last: Well, I just made the mask. We just made an outrigger for our three-step camera. It wasn't a big problem to do it. The tolerances in those days were…we were talking a thousandth of an inch or something. Now you are putting half the world inside of what was our tolerances in those days. These

were just minor things and Jean [Hoerni] made the transistor in a couple weeks. Talking to Gordon Moore, Gordon said there had been some work and some jury-rigged work done on planar thoughts earlier. That's something I don't remember or know much about but the first one that was a real planar device was the one Jean made. Jean worked by himself pretty much and did it all himself and just showed us an accomplished fact and we were just startled to see the improvement in the device. The classical thinking was you had to take the oxide off because all the impurities would collect at the interface and Jean felt the opposite that it might be protection if we just left it on there.

Bell Labs had been down that road obviously before and then they didn't pursue it to any extent. Michael Riordan wrote an article a couple years ago about why Bell didn't do all this stuff first because they had all the basic technology, all the basic ideas but their focus was on building devices, mainly non-military, and building devices that were going to have widespread use in the telephone system. So a lot of great ideas just never got pursued there, even with all the stuff they were doing. Our focus was on making devices that worked and Jean's planar device came just at the time when we were really getting in trouble with the flying particles and we realized that we finally had gotten the yield up to a reasonable level on our mesa devices. The mesa technology we had developed pretty well.

To step back a second, one of the things I worked on is how you define the mesa area. You had to put little dots and I figured a scheme where you could make an array of little tiny wax dots that would line up with the transistor base which could be used to etch the pattern. I had strange chemicals and all kinds of wax to work with but that was just an example of the sort of thing that we had to develop to make the first transistors. That technology would be replaced by the planar technology that in the long run would make it a lot easier to produce devices…but on the short term the yields on the early planar devices was very low. Again, it was one of these things you had to do and so we did it. And, as you mentioned, Autonetics got involved in that. I forget the exact timing but the planar just took over the world.

Addison: And the planar transistor was demonstrated on March 4, 1959, is that correct?

Last: I've been around that with Michael Riordan [co-author of Crystal Fire]. I think it was the next week, not that it changes history that much but we had hired Ed Baldwin to be our general manager and he left with some of the people to start a competing company and the week after that was when Jean demonstrated the planar so Ed should have stuck around another week. He's going into business to make a device that we were rapidly going to outmode. But the planar worked and we had complementary NPN and PNP devices which was a great source of income. Other people had a lot of trouble making the PNPs and we could make this as a matched pair which was useful for all kinds of circuit applications.

Addison: I'm just curious. Where did the planar name come from?

Last: I don't know. It wouldn't surprise me if it was Tom Bay or somebody in the sales department but we came out with brochures on it rather quickly and announced it as a product. It took about a year to get it in production but it was a tough year to develop these into high yield processes. This question of yield is a tricky one. When you are working with a 3 or 4 percent yield, you just have mountains of unusable stuff and then your yield goes to 30 or 40 percent and all of a sudden you've got more devices than you know what to do with [laughs]. So developing this whole thing of production engineering and making

reproducible devices was a big project and we had a lot of very good technical people who were working on that aspect of it.

Addison: So the planar process quickly put a lot of other companies out of business, like Rheem [Ed Baldwin's company] and Philco. They had mesa lines and suddenly they are obsolete.

JL: The interesting thing to me in that regard is that when there was a radically new technology, a new company came along and used it. Transitron and a few other companies were very strong in germanium transistors but didn't make the transition to silicon. The companies that were making devices by alloying went out of business and they never caught up. It still surprises me why RCA and Philco weren't the big shots in the new technology but it's just the way the world works. If you can start with a clean slate, you could focus on what you could do. You don't sit around and tell war stories about the old ways that you used to do stuff and you can see that Fairchild had the MOS technology but it took Bob and Gordon to go start Intel to focus on MOS. MOS technology in those early days was really a tough thing to deal with. The unknown problems were with surface states on the devices. And here you are trying to make a device that was based on those surface states and I remember saying at the time…it was in the early Teledyne days, we were talking about MOS and I said, "If they use MOS devices on an airplane, I am going to take a bus the rest of my life." [Laughs] That was my feeling and the feeling of a lot of other people then.

Addison: Jay, could you tell me when you first heard about TI's integrated circuit and sort of what impact that had at Fairchild?

JL: This was early in '59 that TI started talking about that and TI had a terrible reputation for getting patents and suing the hell out of everybody else so our first thought of this was we have to show the flag too. TI…the first things they were talking about were extremely elementary devices and calling them an integrated circuit was a stretch of the imagination. Really, it was individual devices -- just a transistor and a resistor essentially -- on a piece of germanium but it was something they were talking about. So I remember at Wescon in '59, it would be August of '59, Bob said, "Hey, we have to show the flag here," and he and I talked and I made a little device with four individual transistors in it and resistors from a pencil but at least it showed we were in that area. And at the time Bob and I discussed this I was at loose ends. I had done my part on making the first transistors and was looking ahead for new devices. I did some work on a parametric amplifier diode for a while which looked like it was going to be a good device but I was ready to do [work on integrated circuits] and was given the mandate to start a group to do this and so I went out and hired a group of people and started in.

The main problem we saw was we knew how to make planar devices but the problem was electrically isolating them. It turned later into big patent wars on this stuff and it's interesting that the three key things you need [for an IC] were three separate patents by three separate people. Kilby [at TI] got the patent for putting various devices on one piece of material. Fairchild got the patent for interconnecting devices on the surface of the wafer from the planar device and Kurt Lehovec at Sprague got the patent for the diffused electrical isolation to isolate the devices. The isolation was the key problem we faced. The technology was not ready to do a diffused isolation. This would involve diffusing boron the whole way

through the wafer which was going to be something like an 18-hour diffusion. We were with difficulty able to do a 15-minute diffusion with boron before the furnaces started sagging and getting soft so it was out of the question technically to do that.

The way the first devices were made was by taking the device, turning it, fastening it on to a plate with the operating side down, etch the whole way through the device until you came to the oxide on the back, which is only going to be a few wavelengths thick, and then fill it with some kind of a filler. So we actually developed a technique for making those devices and it involved a lot of technology. For example, how do you see the front from the back? So we developed infrared alignment devices…silicon was transparent in the infrared and we could see what was on the other side. I mean, these devices never would be reliable. As I look back on it, there's no way but we did demonstrate the point that we could make integrated circuits this way. So we were proceeding down that line mainly with the efforts of Isy Haas and Lionel Kattner and some ideas on improving boron diffusion that had come from the pre-production engineering of some other materials. We said, "It's worth a whack" and we went ahead and did these diffusions and the first devices came out.

The first device we made with the back fill technology was made about May 1960 so we had devices coming along and made the first one with the diffused isolation in probably November, something like that. But as late as November Gordon [Moore], who was head of R&D…I have a memo that he wrote and it said, "We are going to have to make a decision; are we going to use the diffused isolation or the back and fill isolation?" It still was an open question then. But the integrated circuit was not a big deal. Now it looks like we should all have been walking around in hushed tones and saying "My God, we are going to change the world." It wasn't that way at all. It was just another more or less research curiosity at the time.

First of all, the Bell Labs people went through [the same challenges]…and there was a famous thing that [Mervin] Kelly [of Bell Labs] said, which was "the tyranny of numbers." When you try to make a lot of devices together, if you have a yield even as high as 50 percent, if you have a dozen devices on there, your yield goes to zero. He was wrong on that. We started demonstrating that…if we start making these arrays, what's going to happen? We went through and said first of all yield is defining a device that meets a lot of criteria. The device we have on this integrated circuit only has to meet one criterion. It has to be matched. That's the one thing the integrated circuit did. The devices are automatically matched because they are made together and had to be matched. Isy Haas took reject devices and started mocking up integrated circuits and they worked…and we also realized that yield was not a random thing. There would be blotches of good areas and bad areas on a device and all we had to do was find a bunch of good areas, so we said the tyranny of numbers just doesn't apply here. There's going to be a low yield but we are going to get good devices and we started proving…that yes indeed we can make integrated circuits. There was no difference in our first problems of making our first transistor. The yields were horrible and you just by brute force figure out why are the yields so low and gradually clean up the process. We weren't terribly clean in those days. We realized that we were going to have to do a better job than we had done. Bob Noyce was a heavy smoker and he'd come around the lab smoking all the time.

So we went ahead and by the end of the year Bob Norman worked on the DCTL ideas which involved transistors and resistors, both of which we can make easily. So then we ended up with an IC and then we made the first one that had four transistors and quickly made the whole family. And I left Fairchild shortly after that, and Lionel Kattner over the next six months got the whole family into production so by the end of '61 it was an established Fairchild product. The only problem we faced was the world couldn't have

cared less about the integrated circuit at that time. Transistors were specified by circuit designers who put them all under their own circuits and the last thing they wanted was somebody to sell them the complete circuit to put them out of business which was the big reason that the sales department was not keen about it. Also, it was a lot more expensive way to do things. So the only use for integrated circuits was military applications where small size was the key [requirement] and it took several years before the first inkling that this could potentially be a cheaper way of doing it. And Gordon Moore told me that when he came up with what's now called "Moore's Law", he said "this was just strictly a sales tool. I was just trying to point out to people that we're greatly increasing our technology and our ability to do these things and this is going to be a cheaper way of doing it." But it took a long time.

Addison: Jay, could you talk about the key people who were involved with the Fairchild IC, besides yourself?

JL: The key people were Lionel Kattner who had come from TI and was the key diffusion person involved with this and he and I laid out the first circuits together so he was my key person. Jim Nall was involved with improving the step-and-repeat camera processes and working on this infrared device for the line up. Sam Fok was involved when we were making the isolation by mechanical means. He was involved with finding good waxes and methods of making a device that way. Art Enquall was involved with work on improving the photo resist processes. And I'm drawing a blank on a few of the other names. This was my group that was working on actually fabricating the devices. I mentioned Isy Haas. Isy was an electrical engineer and was involved in looking at the device parameters and in addition got involved in the diffusion, so he and Lionel together and independently were working on the diffusions that were necessary to do this. There was a whole parallel group under Vic Grinich which was device application…which was Bob Norman and Don Farina and a big group of people there. My group was building them and they were testing them and seeing how they would work and what needed to be done.

Addison: Talking about the equipment you used, did you buy any of that from outside or everything was built inside?

JL: The diffusion furnace part of it was the key item…Art Lasch was involved at Fairchild making furnaces for us and he went off with our blessing and started his own company, Electroglas, getting into the diffusion equipment business. We could, of course, buy other sorts of equipment [such as] metal evaporators. Test equipment was another whole area where we had to build the equipment and we got so good at that that Fairchild set up a separate test equipment division.

I remember…we needed stereo microscopes for a production line and I went to Bausch and Lomb looking at the ideal microscope for us and I said, "We are going to need a few dozen of these," and they said, "We only make six of them a year." So that was the state of the technology then. We needed all sorts of things setting up a facility…backing up a bit. We were starting to work with some pretty nasty chemicals -- hydrofluoric acid and things like that, and trichloroethylene. Some of these were pretty nasty customers and we had no knowledge of that and how bad these things can be and what do you do with the waste products? We were going from things that the chemical companies were used to selling just a tiny little bottle of and we wanted a car load lot of it. So we had an awful lot of stuff to do to learn how to handle these really nasty things…and had them on a production line with people who didn't really

appreciate how bad this stuff could be so we had to put in some pretty severe work rules that people resented.

So the whole way along [there was] the development of all kinds of new technology. And in general it was just scaling up what existed instead of one little thing. We want hundreds of thousands of them. Charlie Sporck developed [the ability] to make reproducible things and here the learning curve really worked in your favor…that these things started at a low yield. The yield would increase. I know the first order that Fairchild took from Detroit was an order for a vast number of transistors at a fraction of the cost that it took us to make them and Charlie said, "We will be making large numbers. The costs will come down," which proved to be the case.

Addison: Why don't we move on to your departure from Fairchild. Could you talk about the events that led to that and what your thinking was?

JL: My thinking there was we had made the first integrated circuit. For reasons that are pretty clear to me now…this really didn't fit into the Fairchild sales programs. Fairchild was building a very successful company making transistors and diodes. Planar diodes were really a great business for Fairchild and that was, again, Jean Hoerni's thinking. So obviously you should be focused on what you are good at and here the integrated circuit was a side thing…(1) you couldn't make it very well and (2) nobody wanted it except for specific military programs. It turned out the thing that made the integrated circuit take off once again was a second Minuteman program based on integrated circuits instead of the transistor. That happened several years down the road.

But the character of Fairchild had changed. When we started it was eight of us together. We each owned 10 percent of the company or some number roughly like that. We were all equals working together as a team. As the company got big and more stratified…first of all Fairchild [Camera and Instrument] exercised their option to buy the company from us. That happened way before we ever thought it would. I mean, it was just a couple of years and so I realized, as did a number of other people, the company was getting stratified and I was an employee in a big company and so the group spirit was going away. Bob Noyce ended up running the place. Gordon was running the R&D and they were doing good jobs at that but it was not the way it had been. When Fairchild owned it…some of the Fairchild management in the east who were running the company obviously could do what they wanted to do with it. So I was missing the excitement that I had when we started.

I also felt that integrated circuits were going to be a major thing and whether they were or not I wanted to work on them. I wanted to work with somebody that really wanted integrated circuits rather than in the Fairchild case [where] it was going to be a distraction and would not be popular with the marketing people. So I met Henry Singleton who was starting Teledyne and he wanted to build a company based on integrated circuits for advanced military systems, so this was just what I was looking for. Jean Hoerni and I were very close friends. We were mountain climbers together and Jean, more than I was, was feeling the sense that he wasn't part of a group any more and so we met Singleton and decided to go into business. And Sheldon Roberts and Gene Kleiner were both feeling disaffected the same way that I was and Jean was, so Sheldon joined us. Kleiner wanted to go off and do his own thing but he came in for the first six months or so and helped set up all our business practices and things like that, so here was half

the original group left to start this and I could see here that I was in an environment where integrated circuits were going to be an essential part of the company's growth.

Together with optics engineer Bob Lewis we made a step-and-repeat camera, an optics set up that was just order of magnitude better than what Fairchild had so we could make extremely tight tolerance devices and make very sophisticated devices with our step-and-repeat cameras. The big thing we missed out on was epitaxy that was coming along. We just never got into that at the right time.

Addison: So as you say, four of the original founders left…I guess Bob Noyce and Gordon must have not been happy.

JL: They weren't happy about it. It didn't help the morale in the company to see us all leave. We were reasonably well liked there. But I kept good relations with Fairchild…it would have been suicide to compete directly head-on with Fairchild. Signetics learned to their horror later on that competing with this big gorilla was a disaster. So what we did…our original mandate was to make very sophisticated devices that could be used for the Teledyne Systems Company to make very sophisticated military equipment. Henry Singleton had come from running a big division at Litton where there were inertial guidance systems and all these aspects. So here I could work with the systems guys and we made a lot of very sophisticated products. Unfortunately, this stuff was all classified and the records just don't exist. And also when the space programs came along, Teledyne was very heavy in all aspects of that. We had a number of things on the first moon shot we made. We [Amelco] had the doppler device that told you how close you were to the moon's surface and all sorts of stuff.

Addison: Just backing up a bit, the name Amelco, is there any particular story behind that?

JL: Yes. Singleton and George Kozmetsky started in business. They wanted to build a big conglomerate and I asked Henry was he trying to build another Litton? He said, "Hell no. I'm going to build another GE." So that was his thinking…our division was the only inside technical thing that they were developing. Everything else was by acquisition and one of the companies they bought was sort of a run down job shop in L.A. called Amelco that was making job shop military things. They had a big tax loss and Kozmetsky said, "You name your company Amelco and then we'll be able to use these various tax [write offs]…" If I was picking a name, then Amelco probably would not have been the one I would have picked but we went ahead on that basis.

Addison: What role did Arthur Rock play in this when you left and set up the company?

JL: Art was at that time on the board of directors of Teledyne and he had come to me as early as August of that year. And he said, "The next time you are in L.A. you ought to go talk to Singleton. He's quite an impressive guy." And I never did so it was just before Christmas [1960] when the Hayden Stone people, I think it was either Art or Bud Coyle, called me and said, "Hey, Henry Singleton's at the other end of the line down there waiting for your call. At least call him." So I called him and Jean Hoerni and I went down

there New Year's Eve and started talking to him and we very quickly said, "This fits our plans. We've got somebody that really likes the sort of things we want to do." So we joined and Henry wanted to put it in L.A. and I said, "No way. There's the infrastructure in Silicon Valley," or what is now called Silicon Valley. It's so important that that's non-negotiable. We have to do it in the Bay Area. He said OK, so we started out.

The problem with Teledyne, it was under financed. Henry was working at the limit buying these companies…he was helping as much as he could but we were always under financial strain. I remember one day I was having trouble meeting payrolls and I just got on the plane and flew down to Henry and said, "Look, I need $100,000 right away. I've just had it." And he turned to Betty, his secretary, and mumbled something and he came back and said, "Here's a check for $60,000, not $100,000. I'm giving you $60,000 because that's all the money there is in this whole goddamn company." [Laughs] So that was the shoestring we were doing it on and that came later on to haunt us because we didn't have the resources to build the mass of low cost production lines, not that that was my temperament anyhow, but we also had the role then of supplying devices for the systems and also being self-supporting by making products. Jean was very fond of field effect devices and we had a good business there so we had both internal and external sales…which were sometimes a little hard to see which one was going to get the priority.

Addison: I've read that because of this financial situation you went and bought equipment from outside, for example, diffusion furnaces from Electroglas? You would have preferred to build your own?

JL: Oh, no. That was always the way the whole way through. If you can buy it, buy it. I built the step-and-repeat [camera] because there was no commercial supplier for anything like that. I had a lens system that was on a bed 20 feet long with the lens about four feet in diameter. I found somebody to build this lens track for us. I said, "What are your qualifications?" And the guy said, "I developed equipment to put asparagus in a can. If you can do that, you can do anything." [Laughs] And it proved to be right. But then anything you can…you buy. Life is too short. And diffusion technology was moving pretty fast…and as the years passed, it got very specialized and sophisticated and a lot of the big [equipment] companies developed out of that. Lead bonding equipment and all that sort of stuff was a real pain to try to build. You could start buying this stuff. And companies like Tektronix with specialized oscilloscopes, you could buy all that stuff.

Addison: You talked earlier about not wanting to compete head-on with Fairchild because that would be suicide, but when Fairchild dramatically cut the cost of the IC, I know that had a pretty bad impact on Signetics, but how did that affect you [at Amelco]?

JL: Didn't affect us at all. The products we were making…our external market was not something that was competing. I mean, Signetics and Fairchild were just head-to-head on a circuit that was a lot more useable than the DCTL we were making. I was always intrigued with linear circuits rather than digital and one big step forward we made at Amelco was making very sophisticated operational amplifiers. That was a business that Fairchild got into a little later and that was one place where we did meet head on. But with that digital technology there was an awful lot of very specialized things we were building for various space and military programs and we were building in small quantities which is no way to run a business in the long run…it's more supported research rather than mass production.

Another thing we did at Amelco was develop a way of taking bits and pieces, little circuit pieces and building arrays, getting a lot of stuff packed in a small volume. We developed a lot of technology for that which was of great interest for military systems and it turned out to be…long term this division is still in existence 50 years later cranking this stuff out and it's now focused mainly on medical equipment. So we did a lot of things connected with very sophisticated packaging. I remember building a little EKG device for the astronauts to wear in a centrifuge…we had to build an EKG with a transmitter on it and that's an anecdote that I laugh at when I think back on it. We were just outside the FM band to transmit this and we pulled it down into the FM band so we could test it…we were picking up a country and western music station and this was a Sunday afternoon I remember. The first song that came out over this thing when we turned it on was "Nobody Knows the Troubles I've Seen." So I still laugh when I think of that. So we were building a lot of device arrays.

At Fairchild we never took any military contracts. Amelco was just the other way around so I made that choice. I remember at Fairchild some of the military people coming and saying, "Why don't you ever want to take our contracts?" And I said, "We need the freedom and flexibility to develop our own products that we are willing to pay for." And I looked at Pacific Semiconductors…that was the company that really scared me as far as the technology they had. They were supported by military contracts making very specific transistors and I thought in a big system there is going to be one of their transistors and there's going to be 50,000 of ours and which one do you work on? So at Fairchild we were successful in a hurry, especially with the PNP transistors. We didn't have competition and we could charge a lot for them so we had a lot of money floating around. We had the luxury, for example, of supporting the integrated circuit program at the time I was doing it. So finances in those early days were not the problem. That [problem] developed later on when Fairchild got into both managerial problems and problems of competition.

Addison: Probably just to finish the story, how and why did you end up leaving Amelco?

JL: Jean left after a couple of years. We were both vice presidents of Teledyne so we could do pretty much what we wanted but Jean was having some difficulties with Kozmetsky. After a couple of years he wanted to leave, and not on terribly good terms, and start something else. That was just his nature. So we got Jim Battey in as general manager and I was running the company from the technical point-of-view…Teledyne was growing very rapidly during this period by acquisition. When we started it was just Amelco and one other little division. When I left there were about 150 divisions. I took an interest in looking at how this whole thing was developing and with my physics background could pretty quickly understand what these people were doing in most cases and got intrigued with this big assembly of companies that was developing and started writing to each of the managers of the companies and trying to make some sense out of where this was going. George Roberts, who came in as president of Teledyne, was intrigued with the way I was approaching this and said, "Why don't you come down to L.A. and be a vice president for technology and just do that full time?" which I did…I was there a total of 12 years I think. By then I was in my mid-40s and I said, "Life is just too comfortable for me here now. I can do what I want to do. I have a plane that flies me around. I'm too young not to have any more challenges. I'm on good terms with everybody here. I like them. They like me. This is the time to quit and go off and do something else with my life." So I just left and for the next year I thought that was about the dumbest thing anybody ever did. [Laughs] The shock of no longer having a plane to fly you around and not having a [company] credit card…this happens to a lot of people who change careers but that's something I did and after I settled down, I focused on other things of interest in the rest of my life.

Those first years and looking back at how compressed things were…making the first transistor in under a year and turning into the big technical company in the business so quickly within a year or two. We weren't volume leaders but we were the technical leaders. And we had one big advantage then. Every good engineer in the world wanted to work for us so hiring people was no problem. We were hiring at an enormous rate and outran our space requirements. We had the one building on Charleston Road, another building behind it and the one across the street. Ed Baldwin, when he came in, went to the Fairchild management and said, "Look, you have to build a big building fast." We had not sold anything at that point and that gave us the momentum and the Fairchild management went along and built this building and I was hiring engineers.

I spent every evening it seemed going to San Francisco taking [prospective employees] out to fancy restaurants. There was never any problem persuading engineers to join us. It was a problem of their family and resettling their family so the problems that arose were along that line and I remember hiring some very top level guy and he came to work and I took him into the annex in the back and pointed to a desk and said, "You are sharing this desk with five other people. This is your desk drawer." [Laughs] That's the way we were expanding in those days. We were just at the right time for making a product that the world needed and we had the right technology and what technology we didn't have we developed, so we were able to move the transistor world along quite a bit.

Gordon [Moore] and I have speculated and given some talks on what would have happened if the group of us hadn't started Fairchild. How fast would things have moved? The fact that, as I mentioned earlier, this was a universal thing…there were a lot of people working on a lot of stuff. It would have happened. I'm not positive that it would have happened in the Silicon Valley. It may have been centered more around Texas or somewhere on the East Coast. But when Fairchild got started, it proved to be a pretty tough competitor.

END OF INTERVIEW

