Oral History of Gordon Moore

Interviewed by:
Craig Addison

Recorded: January 25, 2008
Mountain View, California

CHM Reference number: X4427.2008

Craig Addison: Well, thanks very much, Gordon. The story of how Shockley recruited you to go to work for him is well told, so let me jump straight into when you were at Shockley Labs, what specifically were you doing in those months?

Gordon Moore: Well, when I got to Shockley Labs, I didn't know anything about semiconductors, really. And because that was very early in the history of the industry, there wasn't an awful lot known when you come right down to it. I was a physical chemist by training. Shockley knew chemists did some good things for him at Bell Labs, so he needed one out here. My job turned out to be to set up some of the diffusion technology and do experiments to figure out how to make diffused silicon devices. It was really a learning experience. What we were doing was different than what had been tried before. We had to repeat some of the Bell Labs experiments and then move on from there. It was really interesting work to do, very exploratory in nature.

Addison: And where did you get the equipment and the materials to do this?

Moore: The equipment and materials generally weren't available. The stuff we bought for equipment was standard laboratory kinds of things -- laboratory furnaces, generally heated by glow bars, because you had to get up to high temperatures, 1200, 1250 degrees centigrade in order to do the silicon processing we wanted. And not many furnaces were capable of operating those temperature ranges. But the standard laboratory equipment that you could buy didn't have flat temperature zones, for example. Typically these were tube furnaces that were big enough to put a small piece of silicon in. Materials were a problem. In fact, one of Shockley's first major projects there was a new way of growing silicon that would avoid the contamination that generally came out of the crucible. That was a big project, although it never ended up quite being functional. Other equipment we could buy standard, bell jar evaporators, for example, which were useful for putting down thin films. But we had to build a lot of it ourselves. I remember building a water system that involved several five-gallon jars of water connected together so you could get distilled water to rinse the wafers with. [It was s case of] building laboratory-scale equipment from what you could buy out of the typical laboratory supply houses.

Addison: I've also read that the gas “jungles” for the diffusion furnace, they were all blown by you? The glass blowing?

Moore: That was one of my jobs. In my education and subsequent work, I'd done a lot of technical glass blowing, making the old gas jungles that let you manipulate gases and purify materials. So I took the same technology and used it for the controls over the diffusion furnaces. Initially quite simple things, and then they became increasingly complicated as we figured more things we wanted to do.

Addison: Now, because you were breaking new ground, I'm sure a lot of mistakes were made. Any stories about things that went drastically wrong?

Moore: We were doing new things and some of us succeeded in doing some pretty dumb things. We had one engineer who sealed some silicon and some arsenic into a quartz capsule and shoved it into the furnace. He forget to look up the vapor pressure of arsenic and the tube exploded and arsenic vapors went all around the laboratory. That was a case of fairly poor judgment. But we had some accidental successes. One problem we were having was making silicon junctions that had what we called hard breakdowns. They really showed the kind of characteristic you wanted in a diode. And I was diffusing gallium into silicon, and controlling the gallium concentration by water vapor and hydrogen to determine how much gallium oxide evaporated. And one time I ran out of water, and the net result was a lot more gallium evaporated It formed puddles on the silicon wafer. The wafer came out just looking terrible. Those were the hardest junctions we ever made. In retrospect, it turned out that the liquid gallium metal gettered the impurities that were in the silicon causing the diodes to be bad in the first place. And those were actually the diodes that were used by Shockley, [Tom] Sah and Noyce in their study on space charge recombination, because they were ones that behaved theoretically the way the diodes should.

Addison: And there was also the story about you melting some expensive material. What was it?

Moore: Well, one of the furnaces that I tried to design after deciding that we needed a long flat zone…I used platinum winding. I ordered a significant amount of platinum wire since the melting point of platinum was above where we had to be. I put double windings on the ends to compensate for the heat losses and actually got a fairly good flat zone in the furnace. Unfortunately, the furnace only lasted for about two weeks before the element burned out. It turns out that while platinum doesn't melt at these temperatures, somehow or other it sublimes. When we took the furnace apart, there were little crystals of platinum away from where the wire had been, and we had to send it off to a recovery company to salvage this several thousand dollars worth of platinum that were in the furnace.

Addison: Did Bill Shockley get involved very much in what you were doing, sort of looking over your shoulder?

Moore: Shockley didn't get involved very much in what I was doing. He was a physicist, I was a chemist, so he didn't think he had to know everything that I presumably was doing. He was useful for broad concepts. The one place he did get involved where we disagreed fairly strongly was when he wanted to change his objective from making a silicon transistor to making a four layer diode. He was going from a general purpose device to one with, at best, very narrow applications, and would have required essentially the same technology.

Addison: From a technical point of view, did that really change the equipment you needed?

Moore: Well, that didn't need to change the equipment much. It probably simplified some things because it only required contacts on the top and the bottom. It didn't require anything to interior layers, but that was mainly a device assembly simplification. The processing was pretty much the same. It was using diffusions and evaporations of metal, that sort of thing.

Addison: Looking back, how much progress do you think you made in the 15 or 18 months that you were there, in terms of perfecting the process? Was it that you made leaps and bounds, or was it slow going?

Moore: Well, I don't think we moved the state of the art ahead very much. Looking back at it, it was really a dirty facility. It was hardly more than a Quonset hut, no air conditioning, no clean room capability at all. The net result was we had a very difficult time making devices with good electrical characteristics. We learned a lot of things not to do, and when we went off and started Fairchild, we could use that knowledge of what not to do to start off in a new direction with a much better idea of where we wanted to go eventually.

Addison: Well, moving on to Fairchild, when I interviewed Jay Last a while back, he said he just thought it was amazing that you got this transistor factory up from an empty factory to a production floor in, like, eight months. Could you talk about how you saw that and your perspective on the first several months at Fairchild, the challenges?

Moore: Well, Fairchild got started, again, with the idea of making a double diffused silicon transistor. We thought we knew the direction we wanted to go. We divided up the various elements that had to be in place among the senior staff there, and each set out to do it. I took on diffusion and metallization, for example. Jay and Bob Noyce took on developing photo lithography. I worked on some of the assembly technology. Sheldon Roberts worried about growing silicon crystals. Essentially, we divided up the job among the people who were used to doing the kind of equipment preparations that were necessary. And we went out, then, to get the equipment we thought would be suitable for what we were tackling. We built furnaces that took advantage of an element that was available from Sweden that was capable of going to these high temperatures and not burning out in a couple of weeks. All of the equipment for the photo lithography had to be developed from scratch. Photo lithography had been used for printed circuit boards, but we wanted to really apply it to production silicon technology, and that required everything new. We had to develop the mask-making technology as well as the techniques for coating wafers with the photo resist material and so forth. So it was an extensive amount of new technology that we were bringing to bare in our first products.

Addison: So you weren't buying outside…the photo lithography was all in-house built?

Moore: The machine we made for making masks was one that was developed internally, initially, using three lenses for 16-mm movie cameras, and it stepped three masks at a time for the three different patterns. And by having them all tied together, any error in one was repeated in the others so the mask would actually align with one another.

Addison: Were there any special challenges in procuring materials for transistor production?

Moore: Getting pure enough chemicals was always a problem. We frankly didn't know how pure we had to get them, so we got the best available and pushed the suppliers to continue to improve the purity. The silicon itself… initially we thought we had to grow our own crystals, but I guess [Dean] Knapic, who had been with us at Shockley, set up a company at that time to grow silicon crystals and supply them commercially. So, while we made our own crystals in the very beginning, as soon as we could buy them on the outside, we abandoned that particular part of the business.

Addison: And still on materials, did you ever work on anything like gallium arsenide during your time at Fairchild?

Moore: Not during that time. Now, later on, after Fairchild was well established in the silicon business, in the R&D lab, we did work with gallium arsenide and looked at other materials. We did enough with gallium arsenide to convince ourselves it wasn't going to replace silicon generally.

Addison: All right. Now, there's also the story of Art Lasch, and I believe that you encouraged him to go off and make the capillaries and then eventually he started his own company.

Moore: Art Lasch was my technician for a good part of the time there. He helped me build the furnaces. And then when we developed the gold ball bonding technology, where a small gold wire was put through a glass capillary that could be used to squish it onto…to make the contacts, we had a problem that the capillaries kept getting plugged. So we had to have a significant supply of these. Art became very good at making these things. So he was encouraged by our production people -- Gene Kleiner in particular, who was in charge of that -- essentially to moonlight and make glass capillaries on the outside and deliver them to us. Well, that business grew, and Art next upgraded the design of the furnaces we'd built at Fairchild and started supplying furnaces also from his company, Electroglas. And that was really the first company I know of that was specifically set up to deliver equipment to the semiconductor industry.

Addison: I guess there were no IP issues back then. His furnace was based on your furnace, but he didn't particularly mind about that?

Moore: It wasn't that much, and the furnaces we designed used commercially available elements. There was nothing that we thought especially patentable. And Art picked it up and improved it. And as so often is the case in the semiconductor industry, it wasn't long before the furnaces being supplied on the outside were better than the ones we were building internally.

Addison: So you started buying from Electroglas eventually and stopped making your own?

Moore: Yes. And other people got into the furnace business also. But that's been repeated over and over again, that a company dedicated to supplying the equipment that has a broad market ends up doing a better job than an in-house equipment supply capability can. So, when we set up Intel, we decided we'd do nothing on equipment internally, we'd work with the vendors, and even if this resulted in technology we developed getting transferred to the rest of the industry, it would be the most effective way for us to continue to grow.

Addison: Well, let's move on to Intel. I'll get on to the supplier relationship later, but first wanted to ask about your very first fab at Intel. What were the challenges in getting that up and running and working?

Moore: At Intel, the challenge of the first fab was just getting it done in a hurry. We set, I believe, it was four goals that we had to accomplish before we could really make devices, and set up a wager between the people who had to do it and the people who were watching to see if it could be done. These were pretty aggressive. It required getting these things done by the end of that first year [1968]. Now, we started really the beginning of August, and we wanted to get them done by the end of December. So, it was really a challenge just to get it done. In fact, the last goal was actually achieved, I believe, on the 31st of December with a little fudging in order to make that happen.

Addison: Do you remember the specific goals?

Moore: One of them was to make a stable MOS device, which requires getting everything purified and the like, and that was the last one that was accomplished, but it was accomplished by putting a barrier layer in rather than by cleaning things up so much that we could do it directly. But they involved the usual things about being able to make good junctions and so forth. They were relatively trivial but things that took time to set up. And the challenge of going from essentially an empty building to being able to accomplish these things in a span of August, September, October, November, December, just five months, was really a challenge. We gave each of the engineers a book of purchase orders -- each of the engineers responsible for a particular area. Not requisitions that had to go through a purchasing department or anything, but the engineer would talk to the salesman for the equipment, handwrite the purchase order and hand it to them as soon as the equipment was specified, just to get everything going in a hurry. It shocked the salesmen quite often. They didn't know what to do with this kind of a purchasing procedure, but it was very effective in a startup.

Addison: As a follow-on to that, I've read in Leslie Berlin's book that Eugene Flath went to the Wescon show and basically was buying stuff off the floor; that was kind of the same thing?

Moore: I'm sure that's the case. The Wescon show came at the right time of year for us to do that. And we needed the equipment pretty badly. I think an evaporator came right off the floor. I don't remember what else, but I know rather than have the company ship the equipment back to their factories, if we could get it shipped to Intel at that time, it helped us get started in a hurry.

Addison: So in building that first fab at Intel, you could get all the equipment off the shelf from outside? Was there anything you had to build?

Moore: I don't remember us really having to build everything. We had to adapt a few things. In particular, we had to adapt an epitaxial reactor to deposit poly crystal and silicon. We tried to do the silicon gate MOS. But the only things we would build would be a few relatively simple jigs and fixtures. We just tried to work with the equipment industry.

Addison: You talked about this a little bit before…companies like IBM and TI built their own equipment, and they were sort of hold-outs; they resisted buying from independent suppliers for a long time because they thought that was their competitive edge. But you were completely the opposite at Intel. What was your thinking in terms of not wanting to have any proprietary in-house equipment?

Moore: The thinking, about our approach at Intel, resulted from some of the problems we'd gotten in at Fairchild, the typical situation being we would build a first generation of equipment that would work. What we learned would be picked up by the equipment vendors, and pretty soon the equipment available on the outside was better than the stuff we did internally. I mentioned earlier where this happened on diffusion furnaces. Probably the strongest example had to do with epitaxial reactors. Again, in the beginning, we had to build our own. There was no equipment industry to supply them. But we built a couple of kluges that worked after a fashion, but their commercial machines turned out to be a lot better than what we were doing internally. So it wasn't long before we had to abandon our internal efforts and adopt what was available on the outside. And we began to see this as a pattern; that you just couldn't maintain state-of-the-art equipment internally because you didn't have the customer base that needed something new all the time to let you keep improving things. You kind of got locked into a generation for a long period of time and would have to make a big improvement, which was a lot harder to do. So, the equipment industry and the semiconductor processing industry really were very complementary and increasingly I think that split has been recognized by everybody.

Addison: Now, in talking about working closely with suppliers, I believe you actually invested in Applied Materials.

Moore: That's right, I did. I was interested at that time in doing some venture capital kind of things. Applied Materials looked like an interesting possibility. I guess I never expected we'd end up being their biggest customer. In fact, when Intel started doing much with Applied Materials, I sold my investment in it. It started to look more like a conflict of interest.

Addison: So your investment wasn't so much to support an equipment company but just a VC type of investment.

Moore: That's right. I was looking at it as a financial investment rather than as something to help us get equipment later down the road.

Addison: And then I also believe you were on the board of MicroMask with Joe Ross?

Moore: That's right, I was on the board of MicroMask for quite a while.

Addison: What was your motivation for that?

Moore: Again, I went on it early. It was an opportunity to get on the board of a company and learn something about how somebody else worked.

Addison: So it wasn't helping to get masks for Intel?

Moore: Well, that was a case where we were buying quite a bit of stuff from MicroMask, and I was interested in make sure that we had a good supply. At that time, Intel thought it could buy its masks on the outside also. We didn't have an internal mask-making operation. As the industry developed and the mask demands became much greater than they were in the beginning, we just had to start doing it in-house. And about the same time Intel set up a significant mask-making operation in-house, MicroMask kind of disappeared. So the timing worked out reasonably well.

Addison: Were there any other suppliers that you worked really closely with in those first few years? Lam or KLA or Tencor or anyone else?

Moore: We worked with a variety of them. We certainly worked with Lam quite a bit. And, you know, my involvement got less and less in the details of these things, so my memory is increasingly fuzzy. But the idea was we'd work with the equipment vendors to get what we needed.

Addison: Now, let's talk about the Japanese equipment vendors. Do you have any recollection of when they appeared on your radar screen and when you started buying from them?

Moore: Well, the place they really appeared was in photo lithography. The big steppers were coming out of Canon and Nikon. There wasn't a comparable piece of equipment in the U.S. And that was such a critical part of the entire process, we got very concerned about where it was coming from. We had a major program, in fact, with a Lichtenstein company to make a stepper. Very sophisticated but also very expensive, and the development went too slowly for them to really make an impact on the market. We ended up buying Japanese equipment because it was the best available, and there wasn't really an alternative source for that. And I guess that's still the case now with lithography equipment.

Addison: Except for ASML in Europe.

Moore: Yeah, okay, the European company's an alternative. The concern, of course, was that the Japanese were going to expand from there and take over the entire equipment industry. And then we got concerned that we wouldn't have the access to it that we had with other suppliers, so that became increasingly our paranoia as the Japanese were making increasing inroads into the whole semiconductor industry.

Addison: I understand that Bob Noyce lobbied in support of the lithography industry and there was a particular sale of a company and he tried to stop that from being sold to Japan. Do you have any recollection of that?

Moore: I know Bob worried about this a good deal, and I'm sure he lobbied to try to keep the U.S. ahead. It was something that he thought was pretty important. To a significant extent, that kind of thing was what drove the industry toward the SEMATECH operation, something where we could do a lot of the equipment work in one place.

Addison: Well, that's the next question…SEMATECH. Some equipment suppliers that I've talked to have said that before SEMATECH, they were frustrated because the device makers wouldn't share their future road maps with them. Therefore, they couldn't design equipment. But after SEMATECH,, that changed. Did you see that wall between device and equipment companies in terms of not sharing road maps and so forth?

Moore: I hope that wasn't the case with Intel. We tried to make sure the equipment vendors were there when we needed the equipment. But, you know, it's a complicated deal. The equipment vendors had to match the schedules of the semiconductor suppliers. I remember giving a talk at a SEMI meeting once, trying to explain this problem generally, that the bus leaves on a particular sort of technology at a particular time, and if they're not in that first bunch of equipment, they lose that whole generation. They can come in six months later with a better machine, but it wouldn't be used by Intel. The processor had already been developed with the equipment that was there. So they had to have equipment ready to match our schedule of new technology or they had to wait typically three years and get on the next load. And this was always a complicating feature because it was a change in the way the industry was operating. We wouldn't always buy a better mousetrap. It would only be on occasions that we could get one qualified for use in the next process.

Addison: I just wanted to move on to the wafer size transitions. IBM funded the 8-inch or 200-mm, and I'm told that Intel pretty much funded the 6-inch transition. Why did you feel that you had to do that?

Moore: Wafer size changes turned out to be pretty tough, but the advantages after you've successfully moved to a larger wafer are pretty great. We were setting up a new plant. That was the first one in Albuquerque, really, first big one. And we thought that 6-inch was the way we ought to go. But it requires debugging an entire generation of equipment to go to the next level. And that was quite expensive and we weren't ready to take it on again at the 8-inch, which was not much later in time. But fortunately, other people did. We moved to the 8-inch and are now barely doing 12-inch. I continually am amazed at how big the wafers have gotten. I don't believe that I was convinced we'd go beyond about 6 inches for a long time.

Addison: So you never considered putting up the money for the 200-mm transition? You wanted somebody else to do that?

Moore: We were not ready to do it. It was probably something at that time where the memory manufacturers would benefit more than we would. We would have done it if nobody else had, but fortunately, somebody else stepped up to do it.

Addison: Another question that I came up with was about the silicon cycles. Did you have a strategy to survive those at Intel?

Moore: The silicon cycles?

Addison: Yeah, the silicon cycles, the up and down.

Moore: The thing you learn in this industry fairly early is it tends to have cycles. We certainly did develop a strategy. The philosophy was: You never get well on the old products. These cycles for the device suppliers were generally price driven, not volume driven. In fact, if you plot the volume of devices, you see very, very few dips and very mild ones. You plot the dollars and you see very wide fluctuations. I know one case for example kind of etched in my mind, where Intel's most profitable product price fell 90 percent in nine months. While the industry's good at decreasing cost, it can't follow that kind of a curve. So, this caused fairly abrupt dislocations, but that price never comes back up. You only get the increased revenue by moving on to the next generation of products. So it's very important that you continue the R&D investment across the bottom of the [cycles]. You'll always have to have the new things coming out the other end. And this is something that tends to be counterintuitive to people used to operating in other industries where you cut your cost, which means often cutting development and one thing or other during the recessionary periods and build them up again during the others. Here you can't do that. You have to keep developing the new stuff. In fact, you even have to accelerate the development of the new stuff across these negative periods.

Addison: Is there any opportunity to work with the equipment suppliers during those down periods?

Moore: There's an opportunity to work with them. The problem is that those are periods when you're typically not putting in new capacity, at least not in any quantity. You're developing new products; you're developing new technology. So, the equipment supplier suffers even worse than the device manufacturer. Their order book often turns negative during that time because people start canceling orders faster than the new ones are coming in. It reflects the problems that the semiconductor device manufacturers have much more strongly on equipment manufacturers. And it could even be worse than that on some of the material suppliers. If you look at something that includes the desire to decrease inventories during these periods, for example, the silicon suppliers may find they don't get any orders at all for a while. It's the nature of this kind of industry where we each depend on somebody further back in the line. The poor guy at the end of the chain gets really whipped during these recessions. You try to do something to make it at least so nobody dies during the period, that the companies are there when you need them to come back, but it's pretty traumatic for everybody.

Addison: Did these cycles exist going back to the Fairchild days, for example? Was it the same thing?

Moore: Yeah, these cycles have existed about as long as the industry has. I remember them in the early '60s. We weren't doing an awful lot of business back in the '50s, but they come. No two of them are exactly alike, but the one characteristic they seem to share is price collapse.

Addison: So, Gordon, did you often visit the SEMICON shows? And if you did, was it useful having all of that under the one roof?

Moore: I didn't often visit them. I did certainly a few times. Again, I was getting farther away from making the decisions on this kind of stuff, so it wasn't so important that I looked at the equipment. Certainly Intel had large gangs of people crawling all over the shows and looking at all the equipment that was coming out. It was very important that we kept track of what the industry was going to supply us with.

Addison: All right. Well, we'll move to the [Computer History] Museum sound bites. Just talking about Moore's Law, how speculative were your early predictions that later became known as Moore’s Law.

Moore: The original paper, which Moore's Law got its name, made a prediction for ten years, that the most complex integrated circuits would go from about 60 components to something like 60 thousand, a thousand-fold increase in complexity. That was a wild extrapolation of very little data. I was just trying to get across the idea that integrated circuits were going to be the route to cheap electronics, something that was not clear at the time. And amazingly enough, that ten doublings in complexity that I predicted turned out to be nine doublings, actually, pretty close, much closer than it had any basis to be. But it got the name Moore's Law, which has stuck to everything that changes exponentially ever since.

Addison: To what extent was it apparent to you that this almost infinite doubling was physically possible? Or put another way, when did you become aware of the durability of the Law?

Moore: The first prediction for 10 years was all I was willing to state. In 1975, I redid it, changed the slope, and again expected a decade or so to be all we were looking at. And in fact, we stayed on that amazingly closely ever since. In fact, if anything, we've done better than my revised prediction in '75. But some day, all exponentials on physical quantities predicted disaster. And we're getting pretty close to molecular dimensions in the devices we're making now, and that's going to become a fundamental limit in how we can continue to shrink things. So, it's going to change after another two or three process generations -- I don't know exactly when.

Addison: Were you surprised by the success or the accuracy of your early predictions?

Moore: I was surprised. There was no reason, really, to believe quantitatively that it was going to be that close. Now we're at the point where people in the industry recognize they have to move that fast or they fall behind. It's a funny industry. The next generation of technology gives you performance improvements, reliability improvements and cost improvements simultaneously. If you fall behind the leading edge on the kind of products that need it, you fall behind on all fronts. So it's very important for participants to stay on that leading edge.

Addison: In that similar vein, how extraordinary do you think semiconductor price performance is compared with other technologies, and is it accidental or a forced outcome as a result of this investment to keep up?

Moore: The price performance improvements applied by the semiconductor industry have driven most of modern electronics. You can look at other places where you get the same kind of thing, for example, disk storage, which is nicely complementary to the semiconductor devices. But over long periods of time, it's hard to see any technology that has remotely given the same kind of cost reduction. The only one that I can point to, perhaps, is printing, where the first Gutenberg press kind of letters must have cost the equivalent of a few dollars a character, and now you get the New York Times on Sunday with lots of characters for a few dollars. But the semiconductor industry has made bigger changes in a few decades than printing has over a few centuries. It's a marvelous technology where the characteristics are driven by the physics of the devices. You know the old statement that if the auto industry had improved at this rate, you'd be getting a million miles a gallon and so forth today. Somebody once pointed out to me from the audience, "But, yeah, the car would only be 2 inches long and half an inch high, not very good for your morning commute."

Addison: All right. Our next topic is the integrated circuit. Again, when I talked to Jay Last, he recalled that most people at Fairchild at the time viewed the IC as a research curiosity. When did it become apparent to you that it was going to be something big?

Moore: His "most people" must address a different population than mine. I don't think we considered it a research curiosity. We considered it a product. And when we did the first integrated circuits and moved them on into engineering and production, I remember assembling a group in the laboratory and saying, "Okay, we've done integrated circuits; now what'll we do next?" We started looking at other physical phenomena and the like. But we still had work going on in integrated circuits. At that time, I don't think I had the vision to see how far this could go, but it was only a couple of years after that that I published the Moore's Law paper. So we were beginning to appreciate that this could be really a major change…particularly the cost, but [also] in the nature of the electronics industry.

Addison: Were there any early applications of the IC that surprised you?

Moore: The early ICs were expensive and could only go in applications where weight or volume was extremely important. These tended to be military, NASA and aerospace applications in general. So, the early applications there didn't surprise me. Now, if you change the question to early applications of the microprocessor, then my answer is completely different. The first microprocessors after the calculator went to a variety of funny applications. The one that stands out in my memory was somebody automated a hen house, taking advantage of the fact it was a computer you could program to do the things you want. Now, I don't know what you do when you automate a hen house, but I remember that that was a peculiar application. In fact, I remember a board meeting where one of the [Intel] board members asked when we were looking at applications of the early microprocessor, "When are you going to get a customer that I've heard of?" The people buying these were startup companies, were obscure little operations. They weren't the Fortune 500 that they sell to today.

Addison: At Fairchild, did you design ICs that would have wide appeal or applicability or were they designed for a very narrow purpose, like defense or NASA?

Moore: No. The integrated circuits we designed at Fairchild initially were general purpose logic circuits we expected people to use to build computers and computer-like systems. Then we started doing linear circuits that were fairly broadly applicable. It was only when we got specifically into a major program like Minuteman-II that the circuits were designed very specifically for a particular application. But that was one program. We were still doing general purpose …circuits with most of our development capability.

Addison: This is a what-if: Had there been better theoretical understanding, could the technology have skipped over vacuum tubes completely and moved directly from the early solid state research of the 1930s to transistors?

Moore: Sure. If vacuum tubes hadn't been invented and the transistor had been, that would be a completely acceptable path for most of the things we want to do. There are still places where vacuum tubes do things that we can't do with solid state. These tend to be high-power, some very high-frequency applications. But otherwise, if electronics had grown up around the transistor rather than initially around the vacuum tube, it probably would have been simpler in a lot of respects. It's just that getting the first solid state device -- it could be an amplifier -- took a lot longer than people expected, took a lot more material science. The actual idea of an MOS transistor was patented in the mid-'20s. You just couldn't make it practically at that time.

Addison: All right. And just one last question, something completely different. Did you have any idols or heroes when you were growing up?

Moore: You know, not especially that I recall. I had a couple of teachers in high school I was quite fond of who I thought were very good and tended to -- particularly my math teacher, who I thought gave me a good start there. I guess I can't really point to anyone in particular that I say was somebody I really wanted to emulate.

Addison: All right. Well, thank you very much, Gordon.

Moore: Okay.

END OF INTERVIEW