Oral History of Sam Harrell

Interviewed by:
Craig Addison

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Craig Addison: Thank you very much, Sam for joining us.

Sam Harrell: My pleasure.

Addison: Could we start off with you talking about your early days -- where you grew up, what sort of influences you had, what you wanted to be when you graduated?

SH: Well I grew up in Texas. I grew up on a ranch at Stephenville, Texas and was privileged to be in an outstanding school system which was a very poor school system economically [yet]…over 90 percent of its students graduated from college, which in a rural area is very abnormal. So I was blessed by really good teachers. I had an outstanding teacher in chemistry and in physics in high school. And that got me turned from an agricultural interest toward chemistry. And then I went to Texas Tech University in Lubbock, Texas, and then to the University of Cincinnati in Ohio where I got a doctorate degree in chemistry. And I went directly from there in 1963 to Texas Instruments in Dallas where the timing was great because it was at the birth of the commercialization of the integrated circuit. Up until that time the integrated circuit had primarily been a military market. The majority of the dollars were from the military applications and space applications. So what happened was, at Texas Instruments at least, we began to look for volume commercial applications and they succeeded in doing that. And I got involved very quickly in how to make these things at a high yield. And at that time the definition of “high yield” was 5 percent. Typical yields at the beginning of devices were one-tenth of 1 percent, or maybe a big success was six-tenths of 1 percent. So we had to totally change the technology in order to begin building them at yields of the order of 30 percent or so, which got us to a set of economics that could allow commercialization.

Addison: So you joined TI in ‘63 and that was, as you said, when the IC was being ramped up. Was there a lot of excitement about this new technology and how it would change the world or at that stage they didn’t really realize the impact that it would have?

Harrell: I think TI, particularly Pat Haggerty and Jack Kilby, had visions that it would change the electronic world. They really did believe it would become very pervasive. And they felt that probably for 30 or 40 years that it could grow at a faster rate than the GNP would grow. And so it was a great opportunity for TI. TI at that time was a seismic exploration company. And TI had a world view at that time because of the seismic exploration. And so they looked at the integrated circuit business as a world business. And the tough job would be to get the ability to produce them at a cost that would be competitive with other ways of doing those jobs in the commercial world, which were largely mechanical at that time. Calculators were mechanical. They might have motors that drove mechanical things but they were basically mechanical. And a lot of the TV tuners were mechanical. So it was a feeling that this could be revolutionary. I don’t think they had any concept that it would be the size as a percent of the GNP it is today, but they certainly had an idea that it was going to be big.

Addison: Now at the same time that you guys were ramping up, Fairchild over in Silicon Valley, was doing the same thing. Were you aware of what Fairchild was doing and was that kind of a competitive situation?

Harrell: We were aware definitely of IBM, Fairchild, Motorola and National. But in those days major customers would not adopt an IC unless you had a second source. And so you ended up choosing one of these competitors as a second source in order to get something adopted. And there was a lot of cross collaboration. There might be intense competition in most of the product line but then there would be a portion in which you were cooperating. And one of the ways that that showed up was also in equipment and materials because most of the equipment and materials were internally developed and internally produced. But if you were going to have someone as a second source you had to have compatible materials. You had to have at least mostly compatible equipment, and especially test equipment.

Addison: In the equipment and materials area -- that was all developed in-house -- can you talk a little bit about how you acquired that technology or how you grew that technology at TI?

Harrell: Well, in order to get production yields up and costs down we had to work on replacing the science of the R&D phase and getting a production worthy set of science and engineering implementations. So to do that we had to study the fundamentals and figure out other ways of doing it. In most cases that might be built internally. But in some cases we would find machine shops or specialists outside to build our design. We had some cooperative programs, for example, with IBM. They were a very big customer and so we would compare notes on how to perform certain tasks, for example lithography, printing equipment and so on. And then they would build theirs. We would build ours. And sometimes we would look at each other's product and improve the ideas. At the same time Fairchild was doing the same and National was doing the same. And I don't mean to imply there weren't other companies in the business. There were. But these were the primary movers at that time. And what began to occur over time was driven a lot by the change in wafer size, which was a productivity change. Now today we talk about the difficulty of 300 millimeter wafers. At that time we were talking about going from three-quarters of an inch to an inch and then from an inch to an inch and a quarter and then an inch and quarter to an inch and a half. What those required were changes in equipment. At the time you changed the wafer size, you ended up changing maybe 80 percent of the parts in a machine. And that's when all your best ideas got put in. Instead of incremental improvement, they were more, stronger productivity improvements and technical capability improvements. And from time to time those transitions were extraordinarily difficult. What you thought would be an easy uniformity problem turned out to be extraordinarily difficult uniformity problem. And it might seem trivial compared to the degree of control that we have today. But there was a lot less detailed understanding at that point as to what caused the defects and the degree of equipment precision required. So at that time a piece of equipment that cost $10,000 to $15,000 was extraordinarily expensive. Today the spare parts cost that.

We changed lithography. We changed the test methodology. We changed the diffusion, later on implementing ion implantation. And a lot of difficulty in the metallization schemes to get to a robust metallization technology. So what happened in going from the two inch conversion to the three inch conversion, all of the companies began to rely on outside suppliers. As some of Fairchild's internal equipment engineering people were able to raise venture capital and formed companies in the Silicon Valley area, some of the TI shops were allowed to sell beyond TI. And step by step there began to be an infrastructure outside. I was on Texas Instrument's Capital Committee in the late 1960s when the idea came up of cooperating across equipment segments and material segments particularly relating to standards. And the thing that was a catalyst was that IBM, for example, used a notch to define the scribe lines within the silicon scribe and break planes, and TI used a plane that was ground off on the side

instead of a notch, so the pieces of equipment that had to handle the wafers were not common. The handling side was not common. So as the desire came to make the handling more automatic and not be handled by people…then there became a need to standardize, if not on one standard, at least a family of standards so that the guys building the equipment and particularly the wafer carriers and so on, could standardize.

So the motivation I think from the point of view of the semiconductor equipment and materials people was heavily driven toward having some kind of venues to help themselves. The motivation from the IC manufacturers for whom I worked was to try to be able to make the development of these pieces of equipment more efficient [as well as develop] standards activities. And these things kind of came together. First I think there was a lot of dissatisfaction by the treatment given in the WEMA shows and other venues at that time, which were electronic but didn't give much [attention] to test and manufacturing people in the semiconductor equipment industry. I know as a member of the TI Capital Committee we had a debate about whether we wanted to foster this idea or whether we wanted to keep our ideas to ourselves and not cooperate. And we talked to our brethren at IBM and we made the decision to cooperate. So Howard Moss, who was one of the very early directors of SEMI, made the decision that we would cooperate. And so we did. We were there at the very first [SEMICON] show and we were there in the first standards committees. And our motivation in the standards committee was that we were frustrated with the National Bureau of Standards' slowness. Their procedures were so cumbersome and their round robins took so long that we wanted a place where, if we agreed on standards, we'd just start using them.

I think from the equipment and materials side, they wanted a place where they could get some customers to a show and not be half of one percent of a show but be able to really have access to the customers. And so I think there was synergy. There weren't the same objectives but there was enough synergy [so] that what became SEMI came into play. And the first show was in the Hall of Flowers at the Fairgrounds in San Mateo [California]. And I remember it wasn't full of semiconductor equipment or semiconductor materials people. There were insurance booths and all kinds of things to try to fill it up. But it was the beginning and became an incredible force.

Addison: After SEMI was formed in 1970, and you said that TI had made the decision to cooperate, what equipment manufacturing did you want to keep in-house? What did you want to keep and what did you want to purchase from outside at that stage?

Harrell: In any company there are people of differing views. And we certainly had those in our company. But we made the people who developed equipment internally have to go through the same capital committee as [those] procuring it. So we had a central point at which had this debate with each and every kind of equipment at each generation of investment. But I think there were groups within TI that for the next 20 years continued to make equipment. And they might still. I don't know. But there are always engineers who feel that their idea is better. It's unique. They ought to get credit for it. They ought to get to do it. And then there are managers who say, "Where do we want to make our investments?" But the decisions mainly got made because you were going to have to share the data anyway with your second sources in order to choose the wafers that would be used, to choose whether the curves were identified by notches or flats, what kind of carriers would you have. All these kinds of things were deals you had to work [out] with your second sources. And especially test equipment.

So you ended up sharing it with maybe a third of the community anyway. So it wasn't that hard a thing. And what happened [with] the materials…there were booms and busts in the '60s and '70s and '80s and '90s and there still are today. Well as the boom comes, you can't make enough. Whatever investment you've made in your internal silicon capability can't make enough. Now you've got to go buy from somebody to have enough wafers. So you'll have to have the quality you need. And you end up sharing. So as the commercial community of suppliers began to work with more companies, they started getting good quality input and they started developing and outrunning the internal people.

Addison: During the late '60s and early '70s, the industry started moving offshore for the assembly and test. What sort of impact did that have at TI?

Harrell: The offshore movement began because of taxation policies and protectionism policies of different parts of the world. So we found that we had to go to different locations in order to be European to Europeans and Asian to Asians and so on. And we found that our costs were far less. But TI's management was very adverse to that as a permanent trend. So they wanted to get more of the offshore capability back domestically at least for the domestic market. So that generated a lot of effort at automation and a lot of automation programs were funded explicitly…so that the end product could be made in the U.S. for at least the North American market. And my observation is during my tenure, which was through 1973, that every advance we made in automation we ended up shipping to the offshore sites. So their advantage in cost of labor and cost of logistics and support and taxation just got added to the advantage of the automation so it never got changed. And eventually in the early '70s we began to put more and more facilities offshore. We had facilities in England and France, Germany, Italy, Japan, Taiwan and virtually everywhere there was an end market there was manufacturing eventually.

Addison: Fairchild and National went to Hong Kong and Asia in general to beat the automation at TI by using low cost labor. What was TI's response to that?

Harrell: There wasn't a TI. There were several TIs. And each of the TI's followed its own approach. There was an automation program which was extensive -- really extensive. There was a big one at IBM. There was a big one at Texas Instruments. But at the same time there were others within the company who were using more conventional technology and trying to use other means of getting the yields, the costs and benefits to compete with National and Fairchild specifically. And they found ways of doing it. In fact one of my big revelations when I moved in 1973 to Computervision and got involved with the Cobilt operation of Computervision, now I could go see how these other people did things. And they were very different. You go to each company and they were using different tradeoffs. But they all had the same goal line. They knew what cost per bit or what cost per function they had to meet in order to be successful with a customer. And they all did it in different ways but they all got here. And if you didn't get there you wouldn't survive. So it was quite interesting -- the innovation.

And then about the same time, I spent quite a bit of time in Japan. Now I had spent time in Japan already with Texas Instruments in the early '60s or the middle '60s under the integrated circuit patent training activity. And the Japanese took different approaches than the U.S. guys. But they all got to the point where they were competitive. So teams of people in different locations with the same laws of physics balance the economics differently but they were all competitive. Now over time the dominance of the outside equipment suppliers and the availability to all manufacturers of all of that equipment, I think, was

instrumental in raising all the ships and getting a little more, if not uniformity, at least likeness in character of the ways that the processing was done.

Addison: You mentioned Japan. What sort of feeling did you have when you visited Japan during the '60s? Were they going to be a big competitive threat to the U.S., was that evident during that period?

Harrell: In the '60s and even into the early '70s, the Japanese equipment and facilities were inferior. But their attention to detail and their attention to the detail of data was superior. They improved faster. They were not satisfied with less than the best that they could figure out how to do. And so I had many, many…I still have many good friends among the Japanese leadership. And I think they had a superior, unrelenting drive toward improvement. And eventually that paid off for them. Now they also had very low cost of money. When your cost of money in a business that's very capital intensive is near zero, then you have some striking advantages. Every generation you just go do another factory. When there's the better equipment, you just buy it because your cost of money is so low. And in the U.S. at those times the cost of money was very high. And that was a distinct advantage the Japanese had. But overall I think the Japanese just did an excellent engineering job. An excellent engineering job.

Addison: I've heard several stories from different people about equipment being copied or reengineered by Japanese. Did anything like that happen with Texas Instruments?

Harrell: There are many examples of that happening. But in Texas Instruments' case we did a joint venture with Sony as their beginning entree into Japan. And so the equipment was available to them. And so it wasn't that they stole it. It was available to them. They paid royalties under the patent licenses. But the second half of the question is improvement. They were really good at improving equipment. In fact the most important things we did were to get access to all the improvements they made because they made good improvements. They did a really good job.

Addison: Was this in the very early days with Sony before they started building transistor radios? Did TI actually get Sony into the integrated circuit business?

Harrell: No. I hesitate to go into the detail but the Japanese and TI did not agree on the integrated circuit patent technology. And eventually TI won and embargoed technology that was coming from Japan containing those integrated circuit technologies. And it was after that agreement was hammered out that they were free to sell integrated circuit technologies outside Japan. And so they already had the technology. They already knew how to make it. They were making it. They just weren't paying for it. So they agreed to pay for it. We agreed to license them. We agreed to train not just Sony but other Japanese companies. And I was one of the trainers so that's how I first got involved in Japan. But they were very skilled at doing the best with what they had. I don't think our engineers could have taken the starting materials they had and gotten nearly as good a results. They did an awfully good job. And of course with time they got a good set of equipment and a good set of facilities and became very proficient -- very, very proficient.

Addison: Before we move on from TI, Sam, I wanted to ask you about your experience working with Jack Kilby. Can you talk a little bit about that?

Harrell: Well Jack is a giant of a man both physically and intellectually. And he also had a very keen sense of economics. He would tell us at times when integrated circuits were selling for thousands of dollars each that they all had to eventually be made for a dollar. And so he had this vision that to be the pervasive technology it needed to be you had to be able to make them for a dollar. So that drove a lot of what we did. We made road maps. We made technology transition charts and all kinds of things trying to figure out how you were going to make these things for a dollar. The answer is -- you couldn't do it with the ways that we were doing it then. We had to invent new ways in order to make that happen. So Jack was very, very skilled. He was a good electronic engineer in the first place -- very bright. But in addition to that, he had a really sharp business sense as to where integrated circuit technology could be used and what would be necessary to solve to do that. And so I consider myself very fortunate to have been able to work with him during that time. And between a group of maybe four people, we essentially changed the technology package to something that was extendable and is mainly still the path, the fundamental path that integrated circuits are built on. So Kilby is a very capable person. And I think he would be very capable in any technical problem you put him onto. He's just one of those kinds of people who could think through problems in a manner where they were most likely to get solved and get solved practically as well as theoretically.

Addison: So let's move on from TI. You left TI in '73 and went to Computervision. Can you talk about how that came about?

Harrell: At the time I ran the design centers for TI as well as the front end processing technology -- especially lithography. And so I was intrigued by Computervision because it was bringing CAD/CAM out of the universities into commercial life. And so it was the power of CAD that attracted me -- computer aided design. It was very clear to me that without successful computer aided design you would not be able to design circuits at the complexity we needed for them to be. And that's true of printed circuit boards -- true of the integrated circuits themselves. So I thought that was a very attractive and interesting thing to work on. And quite frankly at that time I had reached the level where I was spending all my time being presented to or presenting to somebody else and I wasn't ready to stop working. I was too much of a manager and not enough hands-on and I was not going to be able to stay there and get out of that trap. So I changed. At Computervision I was the chief strategy officer for the corporation and so I did get my hand in the CAD/CAM area somewhat. And probably the biggest contribution I made was strongly encouraging them to concentrate on the mechanical and mapping and architectural areas rather than the electronic areas because the electronic market was just so much smaller than the number of people who needed mechanical CAD in the world. And that fostered a lot of growth. I think we were the highest P/E ratio on the New York Stock Exchange for seven straight years and the highest growth rate, which would not be phenomenal today but it was phenomenal then. So it was a great success story.

But because I had the semiconductor experience I got connected with Ken Levy, who has also been a member of the SEMI board, because Computervision bought a company called Cobilt. Cobilt made mechanical aligners that printed the semiconductor wafer with somewhat superior technology to the standard of the day. And Computervision had a package of automatic alignment which would allow you to align the layers more exactly. So they could put the automatic alignment into these Cobilt aligner packages and create a new paradigm for wafer printing. So that was the attractive feature there. And so I moved to California, as did Ken Levy, and we created new methodologies for the lithographic process.

And we sold hundreds of machines all over the world. It really reigned until the period of the projection printers became dominant.

Addison: Can you talk a little bit about Cobilt -- how the products developed and some of the highlights during your period there?

Harrell: Cobilt was a relatively small company so it was very intense, very active. And we had a strategy which was essentially to outrun the competition to each new node in the technology. So it was a technology in which the existing players would typically run with the design for quite a long time. And they would buy large quantities of parts to get the cost as low as possible and so on. So what we did was concentrate on the printing technology and try to improve it technically to add more automation and to outrun to the next nodes. And we were able to do that successfully. And so it was considered in it's time to be the productivity engine. It would grind out wafers reliably and for the customer who set up the disciplines correctly in the mask making process, the automatic alignment worked well. For those who didn't, it didn't work well. The problems we had were primarily in wafer handling. Wafer handling has always been a tricky thing because there wasn't enough money in the error budget to do the job really, really well. And eventually it had to be because machines got so expensive that you had to solve that problem. But we instituted what was called "soft contact printing" which was very gentle as opposed to very hard, therefore doing less mask damage, therefore having longer mask life and higher yields. And so it was an advantage and was widely used.

We also put together automatic spin bake systems and integrated them with the aligner, which was the first time that was done. And we had automatic inspection systems where the automation was really in the handling of the wafers so that the operators didn't add defects in the process. But it still was a microscope system where the operators looked at the wafers. As you know, Ken Levy later left Computervision and formed KLA, which was based on trying to automate the inspection process which he and his team succeeded in doing.

There was one other product that we made which was kind of revolutionary and that was an automatic prober. And we could probe the wafers after the metallization step was complete and indicate good or bad die. And it was a highly automatic machine. And interestingly enough it didn't do very well in the U.S. except at IBM. It did extraordinarily well at IBM. And did extraordinarily well in Japan. And that was a cultural issue because they could run the testers 24 hours a day and the women could go home and be home at night, which was a cultural necessity at that time. In the U.S. where we didn't have that cultural requirement, people were not as interested in automation. Now they're all automatic. But at that time, that was the first automatic bonder. And it was the first microprocessor driven semiconductor equipment machine.

Addison: Can you talk about what happened to Cobilt?

Harrell: Cobilt's job was to be a cash cow for the CAD CAM business [of Computervision]. The CAD CAM business was growing at a very high rate. And then a decision was made to turn Cobilt into cash. The reason was that there was a set of rumors that some large companies wanted to acquire Computervision. And whether it was smart or foolish the management decided they didn't want to be acquired. They wanted to stay independent so they needed to build a giant cash hoard. And so they set out with

directions to take Cobilt apart and sell the pieces. And so we had a bonder operation in Hong Kong, which we sold. We sold the spin bake equipment line and the prober line to Tokyo Electron, which became the heart of their equipment business. We sold the remaining parts to Applied Materials. So we disbanded it. And then Computervision did continue to grow. However to complete the story, they were caught in the trap of Michael Milken because they did have a giant cash hoard. They had a huge number of buildings around the world all paid for and they did not realize that people could come in and take them over, distribute the cash to the people who gave them the money to take it over and then leave them hanging in debt to compete. It was a tragedy. But everybody involved learned a lesson, which is, you better have good poison pill things to make it hard to do that. But that's what happened to Computervision.

Addison: Did the silicon cycles have any impact on that decision because business got so bad during the down times? Did they think, "We just want to sell off this business"? Was that part of the reason?

Harrell: If that was a factor, it was a 10 percent factor, not a 90 percent factor. Certainly the business was cyclical and remains cyclical. But the main reason was that the growth opportunities and the threats were there on the CAD CAM side, which at that time was maybe $250 million a quarter in sales. It was big business, particularly in that time frame. It was a very big business. They had shown that you could make gigantic profits and gigantic growth rates in that business. And so that leads to people who covet what you've built. But the danger didn't come from where they expected. They prepared for an onslaught from big companies coming into the market and the onslaught came from Wall Street rapists. It was totally different.

Addison: What was the feeling within the semiconductor equipment industry at that time? There was great potential or it was in the doldrums?

Harrell: I think it was actually very positive. Applied Materials had made the big conversion by bringing out the 8100 family. And there was an emergence of projection printing in the lithography segment. There was a lot of automation in the bonding area. So I think there was an excellent perception of the roadmap and the direction being taken. If there was anything at all, it was perhaps a fear from the VLSI program in Japan that the Japanese government was helping companies gather positions to be an equipment business. And competitors were being birthed for other than only economic reasons. Certainly there were a lot of debates about that in the community at that time.

Addison: So Cobilt was sold off and I presume you were out of a job, so what did you do next?

Harrell: Well, I formed a small company, called Micronix, which had some specialists in x-ray source technology. And we had two primary product lines. One product line was an x-ray source for breast cancer detection. And it would allow the detection, about six months earlier, of breast cancer because it would detect smaller spot sizes and it would allow far lower dosage. So you've got earlier detection and lower doses. And so that was a very successful product line. Eventually we sold that product line. And the other was x-ray lithography. X-ray lithography was not successful and it was not successful because you couldn't make good enough masks to get high yield with it. The printing side of the thing was successful but the mask technology was not. Optical lithography improved way beyond what the physicists had said in earlier times. And so the necessity of going to x-ray lithography to solve the problems was significantly diminished. So the risk to the customer was more easily accomplished by staying with the extension of

the optical technology, which is what happened. You got the institute of the stepper, which allowed the mass technology for optical technology to be solved by a four to one reduction instead of one to one. So that got easier. And that was the work horse of the industry for a number of years. And so we closed it. We closed it I think about 1986.

Addison: The x-ray lithography, where did that technology come from when you started the company?

Harrell: There was a program at Hewlett Packard. There was a program at Bell Labs. And there was a program at IBM. We tried to learn from what had been reported from these other programs. But we set out and developed machinery ourselves. And that worked. The alignment technology was quite good. The printing technology was quite good. But the mask technology was not good enough. And therefore we essentially filled the market for all the R&D machines there was a market for. And it couldn't make the turn to production technology without solving the mask problem.

Addison: Were there many other x-ray lithography start-ups during that time?

Harrell: There were. HP turned theirs off toward the end of this period. IBM continued theirs for a time, mainly working around synchrotron approaches. And then there was a start-up called Hampshire Engineering late in that period. And they ran into the same problem but burned through some venture capital on the way. The technology is just like the lithography options we heard about today. There are a lot of options. But you'd better make sure you can build a mask first. The lesson of Micronix is, make sure you can solve the mask problem first.

Addison: Was that a real personal disappointment for you? How did it affect you personally?

Harrell: Of course it's a personal disappointment. You go out and gather money and a bunch of it is your own money. And then you gather a team and the team works hard and worked hard for several years. And you have a number of successes but you can't make the production turn happen. It's a disappointment. But it wasn't hard to come to the decision that it isn't working therefore you've got to stop. We had supporters who would have put more money behind it if we had thought we could solve that problem. But in that time we could not.

Addison: Now we're up to the late 1990s period. So let's just back up a little bit and talk about your involvement with SEMI, becoming a member of the board of directors and eventually serving a term as SEMI Chairman. How did you get involved with SEMI in the first place?

Harrell: I began my interaction with SEMI through the standards activities, first at TI and then later with Cobilt. And then I was asked to join the board and to take as a project the implementation of the technical programs. At that time there were some programs but they were mainly what I'll call "oral commercials". And the board wanted to change that. They wanted to create technical programs that would be real symposia and would have some academic standard standing and would be perceived as a place that real technologists would want to come and interact. And hopefully do that in concert in some cases with shows. And it would cause a higher level of technical customer people to come to shows. And so the logic was very good and so we set out to do that and we did it. We set up the symposium around the

SEMICON shows and then symposia that were outside the shows, and [we held] the biggest one which was the technical symposium in Japan.

Then the next thing that we did was the decision to set up the trade partner's conference. And Ken Levy in particular took a leadership role in that. And that was very successful. There the purpose was not to bring in the high level technical people but to bring in the business people for interaction. The belief all along is if you get really good people face to face you'll get more problems solved. You break through patterns that will be good for the industry. And so I think the trade partner's conference was great. We had some trouble learning how to get the right quality of [Japanese] translation, in Hawaii in particular. And one year we had hired what we thought were good translators and they were not able to handle the technical jargon of our industry. And so a couple of the Japanese members stepped in and did the translation. They politely threw out the translators and they did the translation and rescued the conference.

Addison: Was Shigeo Takayama [of Hakuto] one of the guys who took over the translation?

Harrell: Yes, he was one of the guys who helped with that. But there were also a couple of customers. But the trade partner's conference was a good thing. And in the midst of all this during my time on the [SEMI] board of directors and the time I was chairman, there were two giant issues. One giant issue was whether we were going to be cooperative or competitive internationally in the shows. And there were independent parties trying to set up competitive shows in Japan and in Europe. And so we went to the customers at the executive level and were able to get agreement that we would have cooperative shows – that we would not have our show and your show. We managed to keep a cooperative spirit within the SEMI community at that time. I think the second really big issue was what I'll call the internationalization issue. Would we have international members? Would we treat international members like equal members? That kind of thing. And I know some of those most violently against international memberships sold their companies to international companies within the next two years. It was really funny. But I had had a lot of experience in Japan. We had other directors who had good success in relationships as well as business in Japan, in particular, and in Europe. And so we were able to guide ourselves through this process and come to a point where SEMI was an international organization. That was very important, I think, and very pivotal. The other issue that was a derivative issue of that was that in the U.S. there was a movement toward, through the SIA [Semiconductor Industry Association], toward the establishment of a consortium for manufacturing technology. And that later became known as SEMATECH. But in its earliest time they recognized that if you don't include the equipment and materials industry, you can't get the changes needed to be competitive. And so there was the beginning of this issue of, now that we've decided to be international, can we be connected to this consortium that the SIA is putting together? There was a lot of good heated discussion about that too. And in the end the decision was, if we're going to be an international organization then we have to have our members who want to be a part of this consortium…join a separate organization. And so SEMI birthed a separate organization …I was physically there and we made one very bad decision on the name. The name was SEMI-SEMATECH. And I think it took a really long time to get that name changed…because it caused confusion. But in any case the decision made by the board was that we were international, we were cooperative, we would remain cooperative. All [SEMI] members are members. All members really are equal and eventually we got international members on the board and now that's an old story. But at the time it was a very contentious decision to reach. And as a result of those decisions the decision was that SEMI-SEMATECH had to be separate and distinct -- totally separate membership, separate structure, separate management.

Everything. Then after we reached all those decisions then they came to me and said, “Now would you go run that?” And so I was very deeply committed to SEMI. Very deeply. That was the hard decision. It wasn’t a hard decision to close Micronix but that was a hard decision because you had to choose between these paths. But when this was being formed, Charlie Sporck [from National Semiconductor] stuck his long finger in my face and said, “If we form this thing, would you be willing to come and spend at least two years of your life trying to make it work?” And I said, “Yes. I would.” And so the reason I said yes was that a year and a half before I had told Charlie yes and I felt that I was committed. And I went home and looked in the mirror and asked myself if I was committed. And so I did. It ended up being six years, about half of which was with SEMI-SEMATECH and the other half was as the chief strategy officer of SEMATECH itself.

That was an interesting thing because I spent a lot of time with my Japanese friends. Essentially we decided that all the things that were big advantages to the Japanese were things that were a result of choices we made because of our culture and we could change them if we wanted to. They weren’t written in law. They weren’t written in stone in some form and unchangeable. They were just our habits. And if we wanted to get ourselves closer with our customers we could do that. And so we did.

Addison: I also believe you were involved with the formation of SEMATECH itself before SEMI-SEMATECH. So can you talk about how that came about?

Harrell: Yes. The U.S. was losing its position internationally in manufacturing technology and in particular, in yields. Yields and productivity. Not in the design side but in the manufacturing side. So there began to be studies in the SIA with the SRC [Semiconductor Research Corporation] and other bodies… were there things we could do to accelerate positive change? And involved with this was a group within the SRC, a working group of which I was a member. And so we reached some conclusions and recommendations out of that group and went to key members of the SIA board -- people like Bob Noyce and Gordon Moore, Charlie Sporck and others. And they decided to not only adopt those recommendations but to raise them up a notch to a higher level of funding level and a higher level of intensity of manpower applied and so on to make it a bigger deal. And it took some assurance that we would have support in Washington for it. Not only financial support but in particular support out of Congress to make it clear under the law that the competitors could work together on pre-competitive cooperation. So then lawyers had to fight about what those words mean. But it was a pre-competitive cooperation thing where everybody could go home and use the technology as they choose. Everybody had access to all the information but it was a pre-competitive cooperation agreement. And Congress passed the law. Then Ronald Reagan signed it. And so now those of us who were involved had to make decisions as to whether we wanted to be involved because for the people involved, it was a question of; would you step out of your career path and go do this for a while? Let’s say you’re a TI employee or an IBM employee, it’s very unlikely that it enhances your career path because you’re out of the stream of whatever the normal promotion paths would be for an extended period of time.

The interesting thing was that when it was established there was a waiting list of hundreds of people who wanted in. It was not a problem. The people side which was the biggest fear -- would people do that? -- was not a problem. And I have been in a number of start-ups and it was the most intense start-up I ever saw. People were there at 9:00 at night. They were working. They were motivated. They wanted this thing to fly. They had never been able to work with their competitors before. They had never had this

environment before and it was a lot of motivation. There were obviously challenges too because you have in that case, 13 companies, 13 cultures thrown together, each one knowing a set of rules from their company and norms and so on of behavior. Just simple things like office size or much less complex things like, which projects do you work on? And so it was an interesting experience. It rounded me out a lot because it was an experience where you have -- think of it this way -- you have 600 people working for you and none of them report to you. All of them can get in their car and drive home. You can't fire them. So it was a consensus management kind of challenge that nobody in that environment had had before. And so we had to kind of create it on the fly. It was very interesting. Very dynamic. And it went through several phases. And in any case I stayed for six years. And it was one of the most challenging and rewarding parts of my life. It really was. And I think in retrospect I think it made some difference in the U.S. competitive position. And it increased the cadence of the industry road map substantially. It went from a four year cadence to a three year cadence to a two year cadence to an 18 month cadence. And that was set by that environment and all the things were done with it and what everybody did in responding to it. By everybody I mean Korean companies, European companies, Japanese companies, as well as American companies had to step up and run at a different cadence. And so I think overall it was good for the whole industry.

Addison: Can you talk a little bit about the difference between SEMATECH and SEMI-SEMATECH. For example, were you physically in the same building? How did each group operate?

Harrell: That's something around which there is not a good understanding. An individual from Texas Instruments was an assignee to SEMATECH. And the employees of SEMI-SEMATECH were assignees to SEMATECH in the same manner. So while they did ombudsman tasks for their membership they were assignees to SEMATECH. So if you were assigned in a lithography program, you worked in the lithography program. But you also were responsible to make sure that the lithography companies who were members got the information they needed. They got access, whether it's technical meetings or other kinds of opportunities to get together with customers and so on. But we were assignees. I was an assignee reporting to Bob Noyce who was the CEO [of SEMATECH]. And I was on Bob Noyce' staff and was in any and every staff meeting that we had. But I was an assignee from the SEMI-SEMATECH membership, which were companies by free will that just joined and paid the dues. So everybody in the building was an assignee except those that were employees. There were a few hundred employees but they were mostly in administrative, or let's say, like purchasing kind of things or legal. Most of the employees were not in the technical mainstream. Most of the technical mainstream were assignees.

Addison: Earlier you talked about working with Jack Kilby. Can you talk about Bob Noyce -- what sort of person he was to work for and as an individual?

Harrell: I loved Bob Noyce. He was a friend for a long time before SEMATECH was ever formed and I was one of those working hard to try to get him to come to SEMATECH and be the CEO. He was at least half retired from Intel at that point. And so he finally relented and decided to do it. Noyce was, I think, the only renaissance-man I've known in my lifetime. He's a brilliant technologist, but you can have an engaging discussion on any subject on the planet and he had thought about it. He had an opinion about it. He was ready to listen to your opinion about it. He was a very open person. So he was an enjoyable person to have as a friend and to have as a colleague. Many people say Bob Noyce was not an outstanding manager and in the classical Harvard Business School sense, that may be right. But what he

could do better than anybody I've ever known is he could work on a problem in a team as a team member and not dominate the team. And if the team got stuck, he could get up and be the leader, get them unstuck and then sit down again and be a team member and not have that leadership through that period cause people to tilt his way. Now that's a unique skill. I've never seen it as well done by anybody else. I hope I can do it but he did it best. So he could work in a team and he could work in a team if it was confrontational. He could work in a team that was not confrontational. But he knew how to work on the issues and make a climate in the team where you worked on the problem. He also was very good at having this clash of 13 cultures [at SEMATECH] come to a conclusion and then everybody had to follow it. So you could fight all you wanted in a room but when you finished it was time to get up and go do it. And if you were battling the decision afterward he would send you back to your company. And he did. He sent them home.

Addison: So he could be tough when he wanted to.

Harrell: Yes. And he'd just get them out of there.

Addison: Do you have any anecdotes or funny stories about Bob Noyce?

Harrell: There are many. At one time we had a problem at SEMATECH of low yields. We had trouble getting our own fab up to standard. Even though we had good equipment, we had good facility, we just didn't have the right discipline and so on. So he made a tape, a videotape, being the Clint Eastwood Rowdy Yates character from Rawhide with a bull whip and he'd crack that whip and say, "Raw yield." It was funny. But what it did was get everybody's attention on the problem -- that we were going to solve this problem. But he did it with humor. He had great humor. He had the ability to kind of grab people's attention in an unconventional way and have them say, "OK. We're going to get together and solve this."

Addison: So he was actually in a video saying this?

Harrell: Yes. Right. We had monthly meetings and so it was shown in the monthly meeting. So he's in there in his cowboy outfit and cracking his whip and so on. And it was very funny. But it also got the point. It was effective. Noyce was a very good man. I enjoyed him very much. It was a great regret when he died and a loss to my family because we were friends with him. And of course SEMATECH had to go on and make changes, which we did. Because nobody else could come in and command the respect and so there were changes that were made. But we went through it.

Addison: Did Bob Noyce ever talk to you about living in Austin? Did he like it? Was that something that he was happy to do?

Harrell: [He] had a ranch at Half Moon Bay [California]. So if you want to know where he really wanted to be at any moment in time it was at that ranch in Half Moon Bay. But they [Noyce and his wife, Ann Bowers] had a home in Silicon Valley and then they had a home here [in Austin]. I think the way that he thought about it was that this was his commitment. It wasn't whether this was fun or whether it was interesting or whatever. It was a commitment. He had made a commitment. It was a solemn, sacred commit. It had his energy. Here's a guy who could have worked 10 percent of the time and flown around and climbed mountains or whatever but once he made a commitment, he was very, very committed. He

was very involved here [in Austin] in the American Institute of Learning which took dropout young adults and gave them a chance to…rebuild their lives. So there were always multiple sides to Bob Noyce. He not only was a renaissance man, he was a very… I'll put it this way; he wasn't willing for the world to be built without him. He was at home in Washington. During that particular time he assigned me the task of being in the halls of Congress one week a month, influencing those technology committees, helping educate them. Not to raise money for SEMATECH. That was the easy part. But to help them understand what we needed to be successful as a country. And then he was there typically for one or two days a month.

Addison: What do you think Bob Noyce would think about the industry today in America, with it having moved offshore? Do you think he would be really concerned about that or consider it just part of the global flow of competitive industry?

Harrell: Well, let me talk about two people because the chairman of the board [of SEMATECH] was the head of Motorola [Bob Galvin]. And so we had Noyce and the Motorola view. We had these two juxtapositions. Bob Galvin took the position that technology was going to be mobile. It was becoming reproducible enough where it could be reproduced anyway. Therefore the technology was going to move to around the world. And then eventually the standard of living of different societies was going to rise. And so you'd better be investing. And of course [Galvin's] company was investing in China big time. Way before it was popular at all -- in fact when it was distinctly unpopular. And so I think Noyce felt like it was important to keep the leading edge technology and essentially the scientific seed corn growing here [in the U.S.] But that if we were foolish enough to not fund our institutions…that it was going to be taken by others and we deserve what we would get. And if you look at today, China and India are both graduating more science graduates than we are. So I think Noyce would look at that and he would say, "It isn't their fault. It's our fault. We need to take care of our young people so that we are fostering that seed corn for our prosperity tomorrow." I think that's what he would say. And I'm pretty sure I'm right.

Addison: Maybe for the last few minutes, let's talk about post-SEMATECH. What happened after SEMATECH in your personal career, Sam?

Harrell: I made the decision that since I had extended from two years to six years that that was enough, and just told everybody I was going to retire and go take care of my ranches and our meat business and retire from that. So I did. But I got a call from Ken Levy of KLA Tencor and he met me for breakfast one morning. And I thought he was going to talk about an investment or something. But then he asked me to come and work on KLA's future and the directions and business development issues and so on. So I agreed to do that. And I'm really surprised I did in retrospect because it involved commuting between Austin and Silicon Valley a lot. In the end it was a very rewarding time. It was very challenging. They had 18 divisions and so you've got all these things to keep your finger on. I think we grew the company from $400 million a year to over $2 billion. The biggest was the merger of KLA and Tencor [in 1997] which made sense to me… It didn't make sense in terms of the people issue because they had tried to merge once before and had a real falling out over it. And so I said, "Look. Let's look at this from a customer's point of view and what you can do by having more of the data origin points for controlling the factory yield and parametric control." And so slowly the group came around to it. And so we ended up doing the deal. At that time it was the largest semiconductor equipment deal that had been done. And the Wall Street guys said it was just too big. You just can't get it done. But we got it done. And then of course the next

challenge is integration -- putting this stuff together and making the choices and what programs to keep and what programs to stop and so on. But that was a great time. First of all, I really like working with Ken Levy. I worked with him before in the Cobilt period. A person of great integrity and I just enjoyed working with him. And then later, as he pulled back more into the chairmanship, continued to work. But also I'm not in any way regretful of deciding then to retire because it's been a great thing. I get to spend more time with my family. For 41 years I averaged 200,000 air miles a year. And it's enough. I'm now able to just go periodically. I try to sign up only for things I can say no to. And so I'm helping a small company in Dallas working in the medical side, taking nanotechnology and thermal control and applying it to wound therapy. And so making what I think is a contribution there, helping a bunch of young people to get that into the market place. And there are now several hundred machines in the field. And then I have our ranches and meat business. And then my wife and I now are going to seminary classes. We're taking Old Testament in the seminary and that's been interesting. We're not ministers, we're just people but it's really fun to be with 30 and 35 year old young people who are zealots, who really want to go out and change the world for the better and are doing the hard work to prepare to do that. And that's been fun. So that's where I am today. I enjoy it and I'm happy and look forward to whatever happens. I'm on a couple of boards. I'm on the board at Texas A&M and on the Development Board at Tarleton State University. Those give me an opportunity to work on scholarships, and trying to teach people who handle endowments to think in terms that if they could get the costs down a little bit you could fund another 100 scholarships. And think about returns in terms of who you're helping. Somebody gave this money to help kids and we ought to look at how to invest it. Anyway, so I'm having a good time.

Addison: That's a good place to stop. Thank you very much, Sam. It's been really interesting.

Harrell: Thanks for the opportunity.

END OF INTERVIEW

