Oral History of Fairchild Micromosaic and Micromatrix Programs

Panelists:
James M. Downey
Robert Schreiner
James S. Koford
Robert W. Ulrickson
C. Hugh Mays
Robert Walker

Moderated by:
Douglas Fairbairn

Recorded: June 10, 2013
Mountain View, California

CHM Reference number: X6770.2013

Fairbairn: All right. We're here at the Computer History Museum. It is June 10, 2013, and we have six members of the team from Fairchild in the mid to late 1960s involved in two very important programs, Micromosaic and Micromatrix programs, which were the first, if not one of the first, custom integrated circuit programs, and we're going to be discussing those programs, understanding why they came together, what their major contributions were, and what the effect was on the industry going forward. So, welcome to each one of you. We're going to start with an opportunity for each of the panelists to talk a little bit about their own background and how they came to be involved in this program at Fairchild Semiconductor in 1966-67 timeframe. So, I'm going to start on the left-hand side with Bob Ulrickson. Bob, could you give us a little bit of your background and how you became involved in this program?

Ulrickson: Sure. I was a Lockheed scholar at MIT, so when I graduated in 1959, and went through Coast Guard OCS for six months-- I showed up at Lockheed, Missiles and Space Division in Sunnyvale, and was designing aerospace telemetry systems there. A couple of guys in my group were Jim Kubinec and Tony Holbrook. After I'd been there for five years and got a master's degree, Jim Kubinec quit, and went over to Fairchild. Then I quit and was going to follow him. About then Tony Holbrook walked in my office and quit, saying he was going to Philco Western Development Labs. So I called Kubinec and Kubinec got him a job at Fairchild instead. So from there he ended up in his careeras president of AMD at one time. So I showed up at Fairchild, working for John Hulme, heading a systems engineering group, which was a brand-new thing to Fairchild. Fortunately, I had a couple--

Fairbairn: What year was that when you joined Fairchild?

A: That was 1966 in about June. John Nichols and Clive Ghest were already there, and they had already proposed a set of MSI devices, which ultimately became the standard of the industry for TTL. But before we could get those products really off the ground and into production, suddenly I found myself working for Schreiner at R&D. And I found out that-- well, early on we knew that after MSI there would be large-scale integrated circuits, over and above medium-scale. The concept that had been invented by the guys at R&D was Micromatrix, which was a bipolar array, and Micromosaic, which was an MOS array-- an array of gates, if you will, or an array of cells, some of which were larger than gates.

Fairbairn: Why don't we just hold you there and move on to Jim Downey. What does your background--

Downey: One second. We're on hold. Okay? Go ahead? So I graduated from University of Santa Clara with a bachelor's in electrical engineering, same year Jack did-- Jack Balletto-- 1962. Went on to Arizona and got a master's degree in 1964. Considered doing a PhD, but I was getting ready to get married and-- anyway. Came back to Silicon Valley. In those days GE was in the computer business, and in fact was the leader, I guess, at least technology wise-- they had the first solid state computer-- and they had a peripheral equipment lab in Sunnyvale run by, when I was hired, Bob Schreiner. When I got there, Bill

Davidow-- and I won't get into the machinations between those two. <laughs> Anyway, so that was fun for a few years. GE, I would say to be kind, so badly mismanaged their computer business that they sold out to Honeywell by late '65, early '66. Bob Schreiner had some connections with Bob Seeds and others at Fairchild, and so there was a path for several of us to go to Fairchild, and I ended up at Fairchild R&D in Bob Seeds' department, which was looking for these future things. The initial project-- you know, it was a funny thing. Seeds had a vision at that time that they were-- he was so certain that we were going to be able to-- Fairchild was going to be able to make LSI, with large numbers of gates, that the thing that he was most concerned about was how were we going to test them. And so right away Bob Schreiner hired a guy named Harold Vitale, also from GE, and they built the first LSI tester named 8000A, and I did some interface circuitry work on that. And then I got off into actually working in the integrated circuits. And I can remember the day Bob Schreiner said to me, "Would you like to go to bipolar or would you like to go to MOS?" Well, I was taking Andy Grove's course, device physics course, at R&D, which was kind of mandatory if you wanted to go anyplace. And it was a good course. It was probably the best college-level course I ever took. And so I said, "Well, this MOS stuff sounds pretty good. I think I'll go that way," not really knowing why. And so I got into the MOS. One last point and then I'll pass it on. The origin-- before we had gotten there in '65, or maybe even earlier, Bob Seeds and Les Vadasz had come up with this concept of prediffused arrays, both for bipolar and for MOS. And those were called Micromatrix. There was no Micromosaic at that time. And I have some stuff here for the Micromosaic part of MOS, and I have some stuff for the Micromosaic. But the Micromatrix part, being prediffused, also depended on a two-layer metal process which didn't exist. And when they could actually make one that functioned, they were so unstable that it was just all-- nobody had invented gettering yet, so the devices were unstable. Anyway, Micromatrix never made it. The origin was Seeds and Vadasz, and we were trying to implement it. And the story goes on from there, and I'll drop it there.

Fairbairn: So just to clarify, at this point the Micromatrix was a bipolar technology and--

Schreiner: TTL gates.

Fairbairn: And TTL gates, and Micromosaic was an MOS technology.

Downey: **[**Micromosaic] was an array of 80 MOS gates to be interconnected with the first layer of metal, and then interconnected-- intraconnected with the first layer of metal, and then interconnected with the second layer of metal. And it was a pipe dream.

Schreiner: Okay, a little background first. I graduated from Brooklyn Polytechnic Institute as a BSEE with a major in electronics. And my first real job out of school was with General Electric when they were just starting out their computer business.

Fairbairn: And when was that? What year was that?

Schreiner: I joined General Electric in 1955, and I think I was employee-- in that department-- employee number 10 or 12 or something-- just a handful of guys. We were going to go build this big computer for Bank of America, which was called ERMA. And the whole thing started on the SRI campus and we finally ended up with a lab over in Palo Alto, and most of the people transferred down to Phoenix where the production factory was and left a handful of guys behind, and our charter was to establish a laboratory to look at advanced technologies, which we did for quite a while. And it was a good time; I enjoyed it very much. But then finally the day came where General Electric wanted to close the laboratory, and my boss came to me and said, "Well, you're going to Oklahoma City.” And I looked at him and said, "You got to be kidding.” He says, "If you don't go to Oklahoma City, you're going to get fired.” I said, "I'll make it easy for you. I just quit.” Gave him my badge and walked out. <chuckling> So, right away got job offers from a couple of companies. I got one from HP and I got two from Fairchild, two different job offers from Fairchild. And I was kind of fascinated with Fairchild because we will still designing computer circuits with discrete components, but Fairchild came up with the best transistors that I had ever seen, way faster than the germanium that we were using. And these guys were just a few blocks away. And so--

Fairbairn: So you had been designing computer stuff--

Schreiner: I didn't have any background.

Fairbairn: You had been designing transistorized--

Schreiner: Yeah, I designed quite a few of the circuits that went into the ERMA processor, but I was designing with discrete components. I made flip-flops, I made one-shots, I did a whole bunch of analog circuits, tape-read circuits-- if something didn't work-- and almost all the peripherals we bought didn't work-- then I would have to go find out what was the matter with them and find some electronic way to fix it. And that was really my job at Fairchild, and I finally had my own little group doing advanced work-- Jim Downey was part of that. And when the Oklahoma City issue came up, I left GE and it-- the Valley was full of jobs. It wasn't like, "Oh, what am I going to do now?” I mean, it was just-- "Who am I going to work for?" was the real question.

Fairbairn: So you left GE and Fairchild--

Schreiner: And I got hired by Fairchild and Gordon Moore himself explained what it was he wanted me to do. Gordon was already making these projections that every two years everything would quadruple and prices would go down by a factor of ten, and they were making-- they could make a couple of gates on a chip. And he was looking out saying, "Someday we're going to make a thousand on a chip.” "How are we going to do that?” If you cut a rubylith with a thousand chips on it, it'd fill that wall. And the chances for there to be no mistakes in a rubylith is zero. I mean, the chances of there being a mistake is 100 percent. You could not cut a rubylith the size of that wall without making a mistake someplace. So that whole technology was out of place. And we started-- and Seeds was, by the way, the leader in looking at: What do we have to do to make this technology real so we can sell something? And you sit down, you start thinking about all the problems, and certainly mask-making was one of them. Artwork was another one. And there weren't testers capable of testing an LSI device at all, from anybody. And so you start making a list of all these things that have to get fixed somehow. And the reason I was hired is that Gordon was convinced that somehow or another computers were going to have to be used to do all these things. And supposedly I'm a computer expert because I came from General Electric computer department. So he said, "Well, just-- that's all I can do to describe the job. Just sit down and think about it and tell us what we have to do."

Fairbairn: So they fully understood all the problems that they were going to face in creating these chips.

Schreiner: Yeah. Well, we actually made a list and started working on these problems.

Downey: I think "fully understood" is an overstatement.

<laughter>

Schreiner: What's that?

Fairbairn: They had some clue as to what some of the roadblocks might be.

<crosstalk>

Schreiner: Well, it was pretty easy to identify what the problems were, and then what we really did was break the problem up, and different guys worked on different parts of the problem. And if you asked me who created the idea for the predesigned cells for MOS and who figured out how to do the TTL gate array, I really can't tell you, because people got together at meetings, and all of the sudden there was an idea on the table. And I can't remember whose it was-- a lot of it came from all these guys, but not all of it. And all of the sudden we said that we think this is the way to go. And so we had to write up a little proposal and go to Gordon and say, "Here's what we want to do." And generally, at that point in time, Fairchild was making so much money you could have anything you wanted to. And I went to talk to Gordon-- and this is a real incident that happened-- talked to him about the problems, and I said, "You know, you're right, we're going to have to find out how to employ computers to do this. This is beyond the capability of a human being." So he says, "Well, what do you want?" I said, "Well, I want to start working on a tester, and I don't exactly know how to go about it, but I know it needs a computer. So I want to buy a computer, commercial computer." He says, "Well, what do you want?" I said, "I want a PDP8, and I got specs here for the machine," and it had all of 4K of memory-- wow.

<laughter>

Schreiner: I wanted it with a teletype and punched paper tape and a card reader. And he says, "Okay, go get it.” So I went down to the purchasing manager at Fairchild R&D and I walked in and I said, "Here's what I want. I want a PDP8 from DEC, and I want a punched paper tape, and I want blah, blah, blah.” And he says, "You got any kind of paperwork?” And I said, "No.” He says, "Well, how am I supposed to do this?” I said, "Gordon just told me to come in and tell you what I want.” And he says, "Oh, okay.” Thirty days later a truck backed up and we had a PDP8.

<laughter>

Schreiner: And we started putting it together, and we used it as a prototype. And we found out what worked and what didn't work, and it actually did some testing on all the engineering stuff that was going on in R&D, including some complex functions, and we used the tester to test it. The thing was never documented as a production machine. I knew it was just a feasibility model. We built two, because it was the only thing that could test an LSI function at Fairchild. The next thing you know, customers were asking us if they could buy one too. And we ended up-- we had instrumentation, actually made like a dozen of them. No documentation, no maintenance documents, nothing. You want to buy it? You can have one for, whatever it was, 150 thousand dollars, but you're not getting any paperwork, and if it breaks don't call us, because we don't know how to fix it. And I'll be damned if we sold about ten of those machines. But then I sat down and wrote-- I said, "Now I know what features that machine doesn't have that it needs," and the biggest one was memory control. We needed a big, big memory. And we wrote a specification for what I called the 8000B, which became the Century tester, which was, at the time, the only real successful LSI tester. And that's the only thing that I could take any credit for, because I didn't want anyone bugging me. I sat down in my office and I wrote a 350-page spec for the 8000B and I didn't want anybody to critique it. I said, "This is what we're going to do, and this is what we're going to build, and I don't want anybody to come in here and say, 'Yeah, but you shouldn't use a disk; you should use some other--' I don't want to hear it. This is what I want.” And it was a very successful tester. And all the other things that came up that were part of that whole concept, including FAIRSIM and all the CAD software, they were-- I didn't make much of a contribution. I sat in the meetings and if there was an argument with three guys about we should either do this, this or this, I finally had to say, "Number two is the one that appeals to me. Let's go with number two.” That was sort of the limit of my contribution.

Fairbairn: So were you responsible for the whole micro--

Schreiner: Yeah, the whole thing.

Fairbairn: The whole thing.

Schreiner: Yeah, the whole thing.

Fairbairn: So we'll come back to that in a minute. Rob Walker.

Walker: Hi, I'm Rob Walker. I was born across the Bay from here-- we're in Palo Alto now. I was born over in Hayward. And I was really-- in high school, I was the smartest kid in my high school-- San Lorenzo High School-- and I really thought, "I'm it. I'm wonderful." And then I went to University of California--

Fairbairn: I'm glad we have all these other people here.

Walker: I went to University of California at Berkeley, and I realized I was average at best, and all these really smart guys, and I wanted to do electrical engineering because it was the only major that did not require a foreign language. And since I'd flunked out of high school Spanish, I figured this wasn't going to be-- that was not my forte. And so I took electrical engineering. But that was really hard, and there's all these dbs and-- I mean, it's really complex. But then I discovered there was something called "digital." And digital-- everything's a one or a zero, and it's so easy it's trivial. In fact, it's taught in grammar school now. So that was my-- that's what I specialized in.

Fairbairn: So how did you get from Berkeley to Fairchild?

Walker: Via-- I knew I wanted to go to a place where the top guys had the same degree as I did. I started out at Lawrence Livermore as an electrical engineer, and what we turned out to be-- the top guys were all PhD physicists, and we were their techs. And they would say, "Go build this," and we had almost no say in anything. So I wanted to go to a place where the top guy was an electric engineer, or at least an engineer. And I went-- from Lawrence Radiation Labs, I went to Philco Ford in Palo Alto, which got me partway there, but the top guys were back on the East Coast, and they were making all the decisions. The beauty of Fairchild was that it was run by people that you could actually talk to and have an impact on. So I went to Fairchild, in digital, and what I really liked was the ability to put a whole subsystem on a chip. And that was so exciting to me, so that was my specialty.

Fairbairn: Did you come to Fairchild to work on this program that we're talking about, or did you get involved with something before that?

Walker: No. Bob Ulrickson hired me as sort of a digital systems guy, because I had experience in that.

Fairbairn: Great. So, Jim Koford.

Koford: Well, I had a little bit different background. I was born and raised in Cheyenne, Wyoming. And one of the things that Cheyenne had was--

M1: That's no bull.

<laughter>

Koford: Yeah, that's no bull. It's more buffalo. And one of the things that Cheyenne had was a mechanical telephone office, and my uncle worked for the telephone company, and he used to take me down there. And I was totally fascinated because mechanical telephone offices have step-by-step switches, and they all make noise. And this thing was a sea of clicks and buzzes. And so I got very interested in how that all worked and what it was and everything. And so then we found-- a couple of us found that you could buy old, broken-down pinball machines for about 25 bucks, and you'd open up the back of a pinball machine, and here were all these relays and stepping switches and everything in there. So we started building stuff out of that, that kind of thing, when we were in junior high. And the-- so kind of like Rob, I got fascinated with it, and then I went to Stanford, and by then we were doing amateur radio and all the kinds of things that kids did when they wanted to get into that stuff seriously. And studied electrical engineering, kind of made the same decision-- <chuckles>-- Rob did, although at Stanford you had to take a foreign language.

<laughter>

Koford: So I parlez-vous'd Francais a little bit. And then I stayed there and got a PhD. And one of my classmates in that period was Hugh here, so we knew each other since the early '60s. And the professor that we both worked for had managed to buy a small IBM computer. And there was a third member of our team-- there were actually two important members of our team, vis-à-vis what later happened. One was Hugh Mays, whom you'll hear his story in a moment, and the other one was a guy named Ed Jones, and then the third one-- who later made huge contributions to LSI and Fairchild with place-and-route tools. And then another individual was a gentleman from IBM whom some of you may know, named Paul Lowe, who ultimately ran the General Systems division at IBM. But at Stanford, he was just a graduate student who was totally pro-IBM, of course. And so he talked me into going to IBM and joining Hugh-- I'll let Hugh tell the rest of that story-- and we did that for a while. And then my mom began to have some serious vision problems, so I kind of thought I had to come back out here. By the way, at IBM I did something a few years ago, but it was pretty equivalent to your project at Xerox PARC, Doug, where we used a graphical display with a light pen to lay out SLT modules. So I had had some experience at CAD there at IBM, and we gave a paper on that in San Francisco, in I guess it was '65, and this gentleman was in the audience. And the next thing you know, we started getting some calls from Fairchild. So then I joined Fairchild, and you know-- <chuckles>-- compared with today, Silicon Valley in those days was a peaceable kingdom ruled by two benevolent kings, Bob Noyce and Gordon Moore. <laughs> Now people in marketing would say, "You got to be kidding, Koford," but anyway, that's the way it seemed to me.

<laughs> And so they had come to Stanford a lot and talked to us, and they were very approachable. And so by the time I got to IBM even, much less when I came back to Fairchild, I knew something about how chips were designed and made at that time, and I came to Fairchild determined to work on that problem. Let's just leave it at that.

Fairbairn: So you came to work on the program that we're talking about here?

Koford: Yeah, I came to work on the problem that Bob Seeds was posing: How do you design these things with computers? And I can talk more about that later.

Fairbairn: Hugh?

Mays: Hi, I'm Hugh Mays, and I was raised in Taft and Maricopa, California, and when I graduated high school I thought maybe I would go to work as a roustabout in the oil fields. I was very good at math and science in high school, so I got steered into engineering and that's how I did it. I got a bachelor's at Berkeley in '54, and went to work-- it's interesting, I didn't know Rob had gone Civil Service too-- I went out to China Lake, and then from China Lake-- my boss there got me admitted to Stanford on a probationary basis. I had a 2.6 GPA from Berkeley. Aced my first quarter there with all A's at Stanford and went on to get a doctorate at Stanford.

Fairbairn: And you met these guys.

Mays: Yeah, and met Jim and Ed and--

M2: Paul Lowe.

Mays: And Paul Lowe. And so when I graduated, I taught a year at Stanford and then John Linvill and I had a disagreement on how much of a new contract I was going to get. And by the time he came around to my way of thinking, I had already taken a job with IBM in Fishkill, New York, and had a computer-aided design group there. Jim was not part of that group. And we didn't accomplish a lot in that group, but apparently some headhunter had heard about me, that Bob Seeds had hired, and I got out here to Fairchild that way, in '66. And so we started trying to figure out how to use a computer to design things.

Fairbairn: Fabulous. So Bob Schreiner-- there's lots of Bobs and Robs here--

Walker: That literally was true. I was over at Fairchild R&D, and there were, I think, seven Roberts. And I was known as Bob in those days, and so you'd hear "Bob" and everybody-- so that's when I switched over to Rob, because it was-- the only way I could be identified.

Schreiner: You couldn't swing a dead cat without hitting a bob up in R&D.

<laughter>

Fairbairn: So Bob Schreiner, so the ideas for Micromatrix and Micromosaic, which one came first? What was the--

Downey: Micromatrix.

Schreiner: Micromatrix was the first one, because, believe it or not, I used to have a fair number of conversations with Gordon Moore, because he was head of R&D. And he was just kind of interested in, "Keep me posted on where are the problems, how are you doing," and he actually wasn't a big booster of MOS. He thought the technology was too slow and it was not going to be a technology for computer-related people. It was going to be a bipolar world, not an MOS world. He was wrong-- really wrong. But that's how he felt about it. He wanted to do both.

Fairbairn: This is '65, '66 timeframe?

Schreiner: Because he wanted to protect everything. But he really thought we should focus on bipolar because it was going to be the dominant computer technology. And we started that one first. And it was the least complicated because it was a fixed array of 96--?

Walker: No, 32.

Ulrickson: Thirty-two first, 96 later.

Downey: The bipolar was 32 gates and the MOS was 80 gates, both Micromosaic.

Schreiner: It was a fixed array of gates, and you could hook 'em up any way you wanted to with two-layer metal. So it was not a really complicated concept. And it didn't introduce that many challenging testing problems, so it was the easiest one to do. And we actually built circuits (that we shipped to customers) using rubyliths. And I can remember Bob Nevala coming in, and as a stunt, we turned around a customer circuit design and shipped parts in two days. Only did that once because it was heroic-- it was really tough to do. But we did turn the design around-- somebody sends us a schematic diagram, we laid it out, and he connected it, got the masks made, made the parts, and the parts worked.

Fairbairn: So the--

Schreiner: And I can-- I want to finish that story because this is kind of funny. Back in those days, most of the guys who worked in fab and with <inaudible> wore white smocks. That was the custom de rigueur. And Bob Nevala was the guy who headed up the TTL array activity-- Micromatrix was his brainchild. And he came in, I think-- he came into my office and it was like the second time we were going to try one of these stunts where we would make some circuits in a couple of days and ship them, and let the whole world know that we really had this fast turnaround capability. And he's sitting in my office leaning on my desk like this. And I said, "You got that rubylith all done?" He said, "Yeah, we just finished checking it out." And I looked at him, I said, "What's that red dot on your elbow?"

<laughter>

Schreiner: He had leaned on the rubylith and picked up an interconnect dot, which guaranteed that chip would not work, and it was already in mask-making. And I said, "Bob, I think you got a problem there."

<laughter>

Schreiner: And sure enough they went out and pulled the artwork and checked it; there was a dot missing. So rubyliths were really seeing the end of their day as a technology.

Fairbairn: They survived for quite a while longer after that though.

Schreiner: Oh sure they did. That's a real true-- that really happened just that way.

Fairbairn: So, but when the program started off, the customers were at best used to buying MSI components, right?

Schreiner: MSI, yeah.

Fairbairn: And so did you have trouble introducing them to concepts that they could actually design their own chip? And who were you selling to?

Schreiner: No, there were people that were interested in fast turnaround abilities to make something-- not too complicated. It was 100 gates maximum. People were interested in it. And the problem that we had was we had a lot of trouble getting the two-metal process to work. So our yields were not good at all. But Micromatrix never made any money.

Fairbairn: So yeah, what was the state of manufacturing? You had a hard time manufacturing these, the Micromatrix products, or is this any of the bipolar products or just the--?

Schreiner: No, that was the end of it for us, when we finally realized that there weren't that many people interested in 96 TTL gates on a single chip, but the MOS thing looked really, really promising, at least for consumer products. We were doing P-channel [MOS], wasn't it?

Downey: Well yeah, it was-- the original effort in Micromosaic we documented in a handbook-- Rob Walker was a big part of this-- in November of 1966. And this was a prediffused array of 80 gates, and you customized it on the first layer of metal; you intraconnected the cells to make AND gates and OR gates, whatever. And then you interconnected them on the second layer of metal. And the way we would test these things, we had built up PC cards that had two layers of metal on it. That two-layer metal process worked [on PC boards].

<laughter>

Downey: The two-layer metal-- so we were would populate this thing with kit parts, 80 kit parts, customize them by these two layers of interconnect, and the thing would work. We were able to make functions with this. Trying to integrate that was a different problem. The two-layer metal process was difficult at best for bipolar but it was nonexistent for MOS because the second layer of metal caused the introduction of ions into the field oxides and they were just grossly unstable. And gettering had not yet been invented, or figured out yet, so the devices never worked. I ultimately got so frustrated with this thing I went to Schreiner and to Vadasz-- it was kind of a split responsibility in those days because Vadasz and Seeds had started this Micromatrix concept, and it just wasn't flying for MOS. So I said, "Can we do something different like make preconceived cells and somehow photocompose them?” And there had been a NASA paper I think, and maybe something at Philco-Ford at the time, where the concept was explored, but nobody had reduced it to practice. And so Bob Schreiner, I think with Vadasz's acquiescence or maybe encouragement-- I don't know-- said, "Go ahead and try it.” The original effort in Micromatrix-- I'm sorry, Micromosaic, because this was going to be a composition rather than a prediffused matrix, so it was a mosaic of functions put together. And the original effort was a thin oxide metal gate technology, which is a departure from what was going on in the technology at that time in MOS. MOS was a thick field oxide technology which had horrendous steps and therefore difficulty in manufacturing. The thin oxide process required antimony channel stops in the field, and it was a difficult thing to design and density suffered grossly because of it. Anyway, so that was-- I'll stop there because that's-- the transition in MOS from Micromosaic-- sorry, Micromatrix, to Micromosaic.

Ulrickson: I wanted to say one thing about the death of Micromatrix, because it died for several reasons, one of which was what Schreiner said earlier: You couldn't build them bigger than about 100 gates, because we just couldn't make bipolar chips that big and get a decent yield. But also we had a power density problem. They would burn a lot of power, and the chips would burn up if you tried to go over about 100 gates. Plus the MSI devices, the standard products, were starting to take off about then, and they were about the same complexity as what we could do on a Micromatrix array. And when they took off and became standard in the industry, that was the death knell of Micromatrix.

Fairbairn: I see. So this actually came about before the-- this program was initiated before the MSI products really were established and had taken off.

Ulrickson: They just started in 1967.

Fairbairn: So I wanted to clarify exactly what the technologies were that we're talking about here. Maybe either Jim or Bob Ulrickson can talk about-- what are the linewidths were talking about I guess on both-- in the MOS technology that you were looking at.

Ulrickson: I don't know linewidths.

Fairbairn: Jim?

Downey: We were talking microns, units of microns, or linewidths, and separation-- and coming down. We had gotten past mils, or tenths of mils, but it was pretty coarse.

Fairbairn: And what about the wafer sizes?

Downey: Wafer sizes were 2-inch.

Fairbairn: Two-inch?

Downey: Two-inch. We had a-- maybe they were smaller at the Fairchild-- R&D had a lab right across the office that Walker and I sat in, and you could go in there and-- if you knew what you were doing and you could wangle it-- you could write up a process sheet and get stuff built. It was kind of neat. But they were not very high-density. I mean, they weren't high-density from a linewidth point of view, packing density point of view.

Fairbairn: So we talked about sort of the physical side of things. Let's switch over to the design automation side of things. Just to let you choose between Hugh and Jim, what challenge was presented to you when you joined and came under this program? What problem were you trying to solve? What were the major things you had to develop to enable this program to exist?

Koford: I always have to sort of preface this with my stint at IBM, where I got an old graphics display and we-- I designed an interface to the small computer I was familiar with-- IBM, of course-- and so I built my own system in a sense. And then we used that to demonstrate at IBM-- it was just a demonstrate system that you could actually lay out patterns for either printed circuits or chips. And at Stanford we had used a Calcomp plotter, which essentially is a drum plotter that is capable of X and Y motion. So I designed a rotating knife to put on that-- it was my first patent-- and of course wrote the software for it. And so you could actually cut rubylith with this thing, automatically. But you still had to peel it. <chuckles> That reminds me of a funny comment we were discussing at Fairchild once-- bits-- of course computer people always talk about bits. And one of the gals who worked in the-- <laughs>-- in the peeling department said, "Oh, I know what bits are. See those things on the floor, those little square things? Those are bits." And I said, "Well, if you say so." <laughs> And so anyway, you had a bit on your sleeve. <laughs> A chip on your shoulder and a bit on your sleeve. So anyway, I had pretty much come to the conclusion that there wasn't anything you really needed to design integrated circuits that couldn't come out of a computer. And so when Hugh hired me at Fairchild, I was struggling-- and I'd only been there for a couple of weeks-- how do we get a correct image of the design into the computer? That was a big problem, because if you entered the design incorrectly you could have all the wonderful automation in the world but you'd build the wrong thing. And so it was really important to solve that human interface problem, because designed don't come out of computers, they come out of people. And so Hugh probably did one of the most important gestures in my career. He-- this Hugh-- he threw a paper on my desk one day by a guy named Ulrickson at North American Aviation describing an algorithm for logic simulation.

Fairbairn: Not this Ulrickson.

Koford: No, no. Yeah, Ulrich actually was his name. So no, it's not that Ulrickson.

Ulrickson: Wasn't me.

Koford: So I devoured this thing in all of 30 minutes, and I said, "Hey, there's the solution." All we got to do is design a simulator that can be used as a test bench-- there's testing again-- and the computer becomes a partner to the engineer. And once the engineer has exercised his design on the computer and finds it satisfactory, and he signs off on it, not only do we hopefully have a correct design, but we also have a correct computer image of it.

Walker: And the test program.

Koford: And the test program ultimately came out of this. So to me it seemed like it solved a huge problem. And so I said, "Well, I don't want them to fund a big project. This thing might not totally work." Because in my enthusiasm I sometimes would tend to overlook a few little details, like the computer wasn't fast enough to do more than one design at a time. So I said, "I got to write one of these things myself." And, <chuckles>, being enthusiastically naïve, I set out to do just that. And so I wrote the thing at Fairchild R&D, and Rob Walker here was coming in and he was beginning to notice what we were doing, and we used to talk about it a lot. And so I had to design the input language, which I did through the help of IBM macros, and I had to design a test bench language, which I called the Simulation Control Language. And so you had to have two languages associated with this thing. You described the network in one language, and then you exercised it-- you set up pulses and clocks and all the things that you do-- with another language. And in order to really debug it, I put conditional statements in where the variables could not only be things in the language but they could also be symbols in the logic. So you could say "If such-and-such is equal to one, do this." And Rob has always liked that feature. And then I also made the output-- remember, all we had were punch cards and line printers in those days. Graphics hadn't really yet--

Fairbairn: Was this on an IBM system you were developing?

Koford: Yeah, yeah. But then I realized that an IBM line printer is essentially an infinite sheet of paper. So by printing out ones and zeros vertically, you could actually show the behavior of the logic in time.

Fairbairn: Get the traces of the signals.

Koford: Yeah. And I put a lot of printer controls in the SCL so that if you knew it worked in a big section of the logic, you could just shut off printing during there and pick it up again where you were interested. So I won't go into any more details, but then we documented it and Rob named it FAIRSIM, and we used it extensively, for us anyway, in that period as the front-end. And then my colleague, Ed Jones, that Hugh also hired into Fairchild, started working on layout, and essentially once you got the simulation correct then you could just go through the system essentially fully automatically. And then graphical photo plotters came out. We had a guy named Maurice O'Shea who introduced those, so now suddenly we didn't have to peel rubylith anymore; it was all fully automated. And the testing-- thanks to Harold Vitale and company-- was automated. So we had, by the early '70s at Fairchild, a fully automatic instantiation system for actually both Micromosaic and Micromatrix. And of course the brilliant idea that somebody had to prediffuse wafers, so all we were really doing was putting metal on them, made it practical in a fab in a production sense to do all of this. And there was only one other thing that I'll mention and then I'll get off the stage here. Getting-- there is no group more skeptical of anything new than a bunch of experienced engineers. And I always remember a quote from Machiavelli-- maybe it's not a good reference-- but he says, "He who would bring up something new suffers great danger," because you make the people who are doing the stuff-- and you haven't gotten enough running so they don't really trust it. So it took us a while to get people to accept using punch cards and printouts to design logic systems. But I knew I'd sort of won, because usually when people would come up to me during that period they'd say, "Your program did this," as if it wasn't them, it was "your program." And then finally one day-- and I can't remember who it was, whether it was Rich Derickson or-- somebody came up and was talking about the simulator, and he said, "I did this." And I thought, "You know, I think I'm going to get there." <chuckles>

Fairbairn: So there were all these pieces that had to come together to make this an ultimate system in terms of testing and CAD and manufacturing and so forth. Let's just go back to the Micromatrix, the bipolar technology. When you first started doing the very first circuits there, did you have testing in place, or design automation in place, or were the first ones done by hand? How did you actually roll out this program, and did it all come together at once? Who can speak to this?

Downey: He can speak for bipolar, but I can tell you for MOS. When we were still in the prediffused Micromatrix version, before giving up on that approach, we would take the logic design and convert them to gates. These arrays had 80 prediffused three-input gates, undefined, because they weren't interconnected. It could be an AND gate, it could be an OR gate. You could connect them together and make flip-flops or whatever. And so people would-- we would take the logic design and track that onto this 80-gate array.

Fairbairn: So the customer would give you a paper logic design?

Downey: Right.

Fairbairn: And then you would--

Downey: Manually--

Fairbairn: Manually transfer that to the array.

Downey: Right. Right. Now remember, this is in '66. This is before the CAD had gotten going.

Fairbairn: So the program was operational, or you were trying to make chips, before the CAD came along, and before the testing capability came along, right?

Downey: That's right.

Fairbairn: But then you had trouble with the manufacturing.

Downey: Oh, big time. Yeah.

Fairbairn: So did you-- who was the first customer? You delivered some parts, right? I mean, there was some--

Downey: I don't remember ever delivering a Micromatrix.

M3: Yeah, we delivered Micromatrix. They worked.

Downey: Wait, MOS?

M3: No, Micromatrix.

Downey: Micromatrix. Well, there was two Micromatrix. There was a bipolar Micromatrix and an MOS Micromatrix, early on.

Schreiner: Oh, I don't think we ever shipped any MOS Micromatrix.

Downey: No, we did not.

Fairbairn: But the bipolar Micromatrix--

Downey: Seeds and Vadasz had named that FMGA, and to this day-- I think it's Fairchild Metal Gate version A, because by the time we got to the-- just one more-- time we got to the composed Micromosaic, it was FMGC. So it was our third try.

Ulrickson: On the Micromatrix bipolar side, one of the first products we produced as an example of how it would work was on this 96-gate array, the 4700.

Schreiner: Yeah.

Ulrickson: The 4711 was a 4-bit arithmetic logic unit which we wanted to build as an optimized standard product, and eventually did, but we tested it by-- and we also tested the 4700 itself-- by building that function on it. We defined that manually; we didn't have CAD to do that, except for maybe the wire routing. The cell placement and wire routing algorithms would minimize the mean squared wire length or something like that. But that worked fine as a bread-boarding tool, but we couldn't sell them in high volume as you would with a normal standard product because the chips were too big, so they had to be optimized. And the 4-bit ALU eventually became the MSI 9341 or the 74181, as TI named it, and it was a very high-selling, high-volume product. It was the basis for the Data General Nova computer.

Fairbairn: Right. So you started dealing with customers with paper input and manual design of the parts. When was the-- and it sounds like you did get some automatic place-and-route working for the Micromatrix, for the bipolar technology. Jim, was that the first one that--

Koford: Yeah, I think it was, although we shifted over to MOS, as I remember, fairly soon because--

Mays: Early on.

Koford: Because Gordon Moore wasn't totally wrong about bipolar, in the sense that big computers of that era were bipolar. But with the big computer came a big air conditioning system, and in later years a big rotary motor generator set to power these things. And so it was clear that power was a huge problem with that technology, and of course we all knew the physics of CMOS and MOS, especially CMOS, which was really later. And so it was probably the right thing to do to begin to focus on MOS, because that's why it ultimately won. And the amount of power and cooling that you had to-- I mean, IBM used to have a piston sitting on the chips and running water over them to cool those big things. And DEC too, Amdahl, IBM, DEC-- they built those big mainframes in that era out of bipolar. So I think it was a shrewd move, but it took the industry a while to, as probably Jim mentioned, to get on top of really making really double-layer MOS. Because you need at least two layers for routing.

Downey: And the two layers came from silicon gate technology. The original Micromosaic MOS composition of cells was a thin oxide metal gate, as I mentioned earlier, with the antimony field stops. Lousy packing density. A guy named Federico Faggin, among other things, was really the leader, if not the primary inventor of the silicon gate technology, also at R&D, concurrent with what we were doing. So we decided, in Schreiner's group, to do a second version of the Micromosaic in MOS in silicon gate, and that allowed you to have what we called two and a half layers of interconnect. The half layer was very short intracell diffusion interconnects. You were doing every layer so it didn't matter if you used diffusion interconnect-- and then a layer of silicon, and then a layer of metal on top. So that gave us two and a half layers. Silicon interconnects were pretty conductive, so we didn't suffer a big speed penalty with that.

Ulrickson: Mentioning Federico Faggin, that brings me back to a speech he gave once, where he compared all of the circuit technologies that could be used to build large blocks of logic. And his conclusion was CMOS was the only way to go, the only way you could get the power density and the physical density to do the job right. But it took a long time for Fairchild and other companies to be able to produce that in the factory. The process wasn't there, even though the logic form seemed like it was the obvious choice.

Downey: Even the MOS-- either P-channel MOS, which the early efforts were, or later N-channel, which was another unipolar type technology-- but they both had a resistive load that-- and so there was a continuous current or power dissipation. And that was becoming a limitation, as integration got higher, even in the MOS technology. Nothing like bipolar, but it was still a limitation. The answer to that was CMOS, because there the load would shut off and there was not a continuous current.

Ulrickson: And now everything is CMOS. The big advantage of it on a circuit is all you have to do is charge and discharge some capacitors-- that's what slows everything down on a chip-- and in CMOS, you had hardly any current involved in charging and discharging the capacitors. So on the chip, the delays were much lower and everything ran much faster.

Fairbairn: So the bipolar Micromatrix program, you delivered some number of parts to a very few customers, it sounds like, and you then switched over to MOS technology. So you started-- this program formally kicked off with management approval in '67. When did you first ship the bipolar Micromatrix and when did you sort of stop and decide that wasn't the path to go? Roughly a timeframe, anybody?

Schreiner: We were all marketing people.

<laughter>

Koford: Well Rob, you would--

Walker: I don't remember.

Koford: I was so deep in my CAD stuff at that time. <chuckles> I don't remember the exact year.

Fairbairn: But it was '68 or '69 by--

Ulrickson: '67, '68, I think.

Fairbairn: So it didn't survive very long.

Ulrickson: I forget when Bob Nevala passed away, but he was the bipolar guy. Nothing much happened after he died.

Fairbairn: So you switched to MOS, and that's what you focused-- Jim and Hugh-- that's what you focused the design automation effort on, is that right?

Mays: Yeah.

Koford: Well, by the-- we moved out of R&D. I wanted to get a little closer to the real product world and the real fabs-- we both did-- and we also couldn't put a really big production computer in R&D. We had a smaller one, but that was when we got a computer that was big enough so that we could actually have a design service and the engineers could all-- it was a big time-sharing machine. The engineers could all get on that, and ultimately we even had terminals and we were able to throw away punch cards. But by the time we got down there, I think we were in MOS.

Mays: Yeah, it was MOS <inaudible> down there.

Fairbairn: In what year?

Koford: I would say roughly '69 or '70, somewhere around in there.

Fairbairn: When did you have sort of what you view as a full design automation system working with place-and-route and logic simulation?

Koford: Probably after that, but in that period. I mean, that was--

Fairbairn: In the 1970 timeframe?

Koford: Because that's where we got those big Xynetics plotters. Remember those things? And that was still the rubylith era. But we had a great big flatbed plotter with four knives. It was kind of like my invention except you didn't rotate one knife; you had four different ones that were pointed in different directions. And of course the software could compensate for the offsets and everything. And so that was-- we had two of those machines, and they were pretty much busy all the time. So Rob, we did several hundred circuits, and I suspect some of those circuits are still in use.

Mays: I don't remember us ever fully-- I left in '73, and I don't think we'd fully automated placement by then at all. It was still manual. There was still a large group doing manual design.

Koford: Yeah, that may not have-- you may be right. I think that happened--

Mays: Yeah, I think it was later.

Koford: I think that happened later, but I was gone-- I left some time in '73 too. But we had enough automation to have a production system, and we had enough automation to deliver parts that worked.

Fairbairn: Did you have trouble-- logic simulation was a new concept at the time-- did you have trouble getting your customers to use the logic simulation?

Koford: By then we were getting better at that, and that had pretty well established itself. Because I had a lot of people-- whenever there'd be a problem with a program of some sort-- and there were problems with that program-- I'd get a lot of calls. And so I knew people were using it.

Fairbairn: And had the density of these MOS Micromosaic things grown? What was the technology that you were in in '70, '71, '72?

Downey: By that time it was silicon gate exclusively.

Fairbairn: So, much higher density?

Downey: We passed through the metal gate very quickly because it wasn't dense enough, the thin oxide metal gates. I'll give you a quick story about mask-making. When we went from the prediffused array, Micromatrix, to the composed Micromosaic, we had to create every mask in the process. Fortunately the processes were pretty simple then, relative to today. So Vadasz found a-- you won't believe this-- but when they compose the wrapping for frozen peas, it's multicolor. How do they put that together? They take a layer of green and a layer of yellow and a layer of red and whatever, and they superimpose it. And there was a machine in a factory over in Emeryville called the Misomex. So we went over there with our rubyliths of cells and we'd put them on and step out the flip-flops and then come back and step out the gates and step out whatever, whatever, and that was the diffusion layer. And we'd do it again for the contact layer, and the metal layer, and whatever.

Fairbairn: Using printing equipment?

Downey: Using printing equipment. And then we'd get the final thing and we'd shrink it down. That didn't last too long, I can tell you, because that was a really tedious process. But it proved the concept of composition, and then we learned how to do it photolithographically.

Koford: Well, that was Maurice O'Shea's contribution, because he brought that-- I guess it was a Gerber machine that could automate the mask-making.

Downey: PerkinElmer, I think.

Koford: Well, whoever the manufacturer was, it was quite an advance, because it kind of took human error out of that part of the process. The interesting thing too was that-- Rob has always maintained-- this Rob-- that we did both gate array and standard cell in that period. And what you just described we would call standard cell today, although it was still viewed as kind of a mosaic, matrix-like product.

Walker: You know, one thing that we haven't talked about is what these things were used for, and I got a little story on that.

Fairbairn: Yeah, I was going to get to that. So please, go ahead.

Walker: I got-- <chuckles>-- I got contacted around 1970-- no, 1990, I guess-- by a fellow from Sandia, and he said, "I'm going to be in Silicon Valley. Can I stop by and see you?" And so he stopped by my home and he said-- we talked about the long-term reliability of our MOS Micromosaic. And I said, "Well, it depends on temperature." And he said, "Well, this is room temperature, controlled environment." We went through all the aspects and he finally admitted that this was a timing device for nuclear weapons. <chuckles> And so our little chips were stuck in with the uranium and plutonium and all of that. And--

Fairbairn: He wanted to know how long it was going to last.

Downey: I didn't do it. <chuckles>

Koford: I knew that there was some stuff like that going on. I wanted to stay away from it-- as far away from it as I could. But recently I asked somebody at DoD did they-- how had they managed to replace chips that were designed in that era. And he gave what might be sort of a scary answer, <chuckles>. He said, "Oh, we just bought a lot of them at the time." Well, what is the shelf life of that stuff?

Fairbairn: So, I did want to get to who were the customers. This was not bipolar now, so the computer people were still using bipolar, right? And TTL was in full swing by then. What were the applications, besides nuclear warheads, that these products were--

Downey: Well, early on we had trouble figuring out-- getting people to-- we had a few customers who would stick their neck out. But Rob designed a standard function called an up-down counter. You remember that one?

Walker: Yes.

Downey: And that's 1967, and that was one of the first Micromosaic products that we made. I don't think it sold much, but it was--

Fairbairn: What book do you have there?

Downey: This is a PerkinElmer State of the Art Photolitho-- *Photographic History of the Integrated Circuit*.

Fairbairn: Oh, so it's about-- it's pictures of chips.

Downey: Yeah. A few pages later comes the 4004.

Walker: Speaking of books, if people are interested in this history that we're talking about, they can go to Google Books, and ask for *Silicon Destiny*, and you can read it right there on your screen, and this is the early history of custom circuits and Micromatrix.

Fairbairn: Good, thank you. And that's a book that you authored some time ago.

Walker: *Silicon Destiny*. Right.

Fairbairn: But you sold several hundred of these, is that right? I mean, several hundred different designs.

Schreiner: Well, to answer your question, one of the early customers was Burroughs, and Burroughs built a bottom, entry-level computer completely out of Micromosaic chips. I don't remember how many parts <inaudible>. Quite a few.

Ulrickson: Quite a few.

Schreiner: Twenty or thirty different part types, all Micromosaic.

Hadley: Xerox was using them too.

Schreiner: Who?

Hadley: Xerox.

Schreiner: Xerox. Yes, Xerox was another customer. Right. By the way, there's a marketing person here, so.

<laughter>

Schreiner: She can probably answer most questions.

Fairbairn: That's Geri Hadley speaking from the sidelines.

Koford: The one thing that was interesting is even when we put LSI together-- and now that would have been 1980, '81-- the first products of LSI were going to be bipolar, if I'm not mistaken.

Walker: No, we actually hired a bipolar guy, and an MOS guy.

Koford: Yeah. Yeah.

Walker: And so from the beginning it was two tracks.

Schreiner: Most of the guys that worked for us were bipolar.

Walker: And then bipolar dropped out. And CMOS took over.

Koford: Which had developed a great deal by then, took over it.

Fairbairn: When did all the pieces come together? I mean, was there a time when you could say, "Boy, somebody can develop the logic simulation. We can do at least the routing, if not all the placement, and there's a test program afterwards.” Did that all come together at once in this program?

Walker: Well, we said that from the beginning we didn't have it, but we--

Fairbairn: Yeah, I'm trying to sort out between the--

Koford: But you know, from your point of view, Doug, you would almost be a better source of information on this than I am. We were of course tracking what was going on at Berkeley, and the universities had gotten very interested in this stuff, especially Berkeley. And so of course Berkeley was the home of HSPICE, which became a totally essential tool. But also there was a lot of R&D done in Berkeley on place-and-route. And as you remember, a technique known as simulated annealing was developed which was I think a pretty big development in physical layout. And of course logic synthesis also was developed in Berkeley at that time. And these are all standards now in EDA, so the system is really pretty automated. But there were changes going on in those final years that we were at Fairchild that were to have a huge-- as you know-- have a huge impact-- there was the work of Carver Mead also-- would have a huge impact in later years.

Fairbairn: But I was trying to understand-- I mean, it sounded like you folks on the design automation side left in '73, and this program essentially kicked off in '66, '67, and the Micromatrix program sort of kicked off but died a quick death because of power and other constraints. You then switched to a metal MOS technology but then very quickly to a silicon gate MOS technology.

Downey: Right. P-channel.

Fairbairn: And that was really the workhorse for this program for I guess several years. Is that right?

Downey: Right. That's right.

Fairbairn: And over that period of time, you developed more and more automation in that sort of flow. Can you talk about what was-- you talked about being able to turn a circuit design in two days with heroic effort. What was the normal time for somebody to-- for you to take a design which somebody had maybe signed off on-- did you have sign off on logic simulation, and then to actually create a chip for them? What was that--?

Walker: The process actually starts with training. The customers have to do their own simulation because only they know what they want to do. So that means that you have to train them, and that typically was a week-long period to train them how to use a simulator, and then they could simulate the proposed product, and then they would sign off. And the deal was if we build it and it acts the same way as the simulation that you've signed off on, then pay us. Whether it works in your final system or not, we have no control over that.

Fairbairn: So that was the process that you at some point instituted as part of this Micromosaic activity. Is that right?

Walker: Yes.

Fairbairn: But early on, it was done by hand and no simulation. When did you-- were you able to do a simulation sign-off in this process, Jim, or--?

Koford: That was before I left. One of the things that we actually did pretty well considering we were a little bit feeling our way is we put a fair amount of discipline into the process. And it was essentially then repeated later in LSI [LSI Logic] and worked very successfully. What Rob just described was pretty fundamental, because you couldn't end up with finger-pointing in these things.

Fairbairn: But the LSI, that was ten years later.

Koford: I believe that this happened at Fairchild, before I left.

Ulrickson: It did. It was 1969. I remember that's when we moved from R&D to Mountain View, set up the whole CAD system down there, and we had what we called CAD tours. I must have given 150 CAD tours to customers, describing how we start with the training, go into the logic simulation, the cell placement and wire routing, the test algorithms, and then the cutting of rubylith, and eventually the PerkinElmer reticle generator that eliminated the rubyliths. And we'd tell them all about this every time they'd come in. Several of us were duty CAD--

Walker: We had windows into the computer room, and we had a series of posters which explained the various steps of taking this thing through. So customers would get the tour.

Koford: And we had goodies that were kind of fun to look at. We had that great big computer with spinning tapes and all that sort of thing.

Ulrickson: IBM 360/67.

Mays: Big.

Koford: And then we also had these great big XY plotters that were cutting rubylith. <chuckles>

Fairbairn: So Bob, it sounds-- go ahead.

Downey: From my point of view as sort of a user of the automated effort that took place and evolved-- first came the FAIRSIM, and the simulations became pretty good, and customers would accept them and sign off on them. And then the test--

Fairbairn: In the '69, '70 timeframe?

Downey: Yeah, when were down on Ellis Street, so that would have been '68, '69, '70-- I mean, it evolved in those times. And then the next was the test generation, and we had one of these old 8000A that was sufficient for our needs, and we could get a test program from the automation guys and make it work pretty quickly.

Koford: Yeah, and that tester was in our same computer room, so they could see that.

Walker: Well, the tester was designed for us. It later became a standard product and the only thing that actually made any money I think on this-- in this whole story.

M4: That's right.

Walker: But it was designed for our Micromosaic product.

Downey: I think the toughest nut to crack from a computer-aided point of view was the cell placement and particularly the interconnect. Correct me if you guys think that's not correct.

Mays: Those were the big problems.

Koford: Yeah. They required algorithm development that we didn't totally have at that time. Universities are useful. <chuckles>

Walker: From the beginning they were interactive, so that we could always complete the routing by hand, and we would do that. I remember a trip to Bell Labs, and they were showing off their standard cell, and they had no interactivity, so if the automatic wiring program didn't complete, they would just make the chip bigger and run it again. And the idea of having somebody going in and moving things around by hand, it never occurred to them to do that.

Koford: Well, one of the things that Ed Jones put in that early software was checking. Because remember, fundamentally we had a correct description of the circuit in the computer. So whatever someone did by hand could be checked before we actually turned it over to mask-making. And Ed did that automatically.

Downey: Yeah, that was good.

Fairbairn: So you had several hundred customers for this program, or what was the number of customers?

Downey: Boy, I don't remember.

Schreiner: I don't think we ever had several hundred customers. Much smaller than that. They were mostly computer-oriented people. The calculator guys were buying chips to--

Fairbairn: Computer and military, it sounds like, were the major customers probably.

Schreiner: We didn't sell a lot of military MOS stuff to the government. We had some problems with something called threshold drift. <chuckles>

Koford: Oops.

<laughter>

Schreiner: It wasn't very popular with the government.

Fairbairn: Hugh Mays, can you say any other comments about the design automation stuff or what you thought were the major developments or problems or issues, or any other things you want to add to that, what Jim's already talked about?

Mays: A lot of my-- I mean, these guys did the technical work. A lot of my contribution was selling the computers to Fairchild and saying, "Hey, we need these computers, these big monsters." At one point--

Fairbairn: These were the biggest computers available at the time, right? Commercially available.

Mays: Right. It was an IBM model 67 is what we had. And at one point it wasn't working right, and so having known Paul Lowe, Jim called him up and said, "Hey, this is not working. Kick these guys in the ass and make it work." Hey, we got it going. So it was-- those networks worked.

Koford: Hugh was great to work for because I remember I didn't have to worry too much about that. <chuckles> I just got what I wanted.

<laughter>

Mays: Yeah, I did a lot of sales stuff of what we needed, convincing people that we needed this.

Fairbairn: So how big a team was doing all this? It's Jim and Ed Jones, and who else?

Mays: Well, we had quite a few.

Ulrickson: Leo Kraft. Ralph Bestock

Mays: About fifteen?

Koford: Yeah, something like that. Remember, we had something called the Last Supper. We all got together for dinner as people were leaving and, I don't know, there were probably ten or so at least at that meeting.

Fairbairn: So did the manufacturing for the silicon gate two-layer process, did that settle down by the--

Downey: It wasn't two-layer. The second layer was the silicon gate <inaudible>.

Fairbairn: So did that process settle down? I mean, you could make these chips reliably in the '71, '72 timeframe?

Downey: Arguably it did. I used to gripe-- <chuckles>-- a little bit--

M5: A lot.

Downey: --about the fact that we could design these things and we couldn't make them. So finally somebody said, "Okay, you go make them." I said, "What?" He said, "You go make them." I said, "I don't know, you do it." And it was pretty bad. And I think we were sorting it out at the time that I left Fairchild by consent, mutual consent. So I went over to AMD and we did the same thing over again, and it was highly successful. So I think that Fairchild was close. Bob Ulrickson was asking me earlier here why were we not successful in manufacturing at Fairchild.

Ulrickson: MOS.

Downey: MOS-- well, linear was even worse. I mean, it was-- there was just chaos at the top. We had a guy come in by the name of Roy Pollack who succeeded Gene Blanchette, and in like 18 months he had 21 organizations-- 21 different organizations reporting to him. It was just chaos.

Walker: Yeah. A clown a month would come in. "Hey, we're going to put this on a business basis."

Schreiner: Yeah, right.

Walker: And it was always 18 months later the guy was gone and another clown would come in.

Fairbairn: Were these people coming from outside the industry and just not--

Walker: Outside of Fairchild.

Downey: Pollack came from RCA, didn't he?

Ulrickson: He did, then he went back, lost another business.

Walker: Yeah, RCA, where he destroyed-- he went back and destroyed their consumer business.

Koford: He did those capacitive video disks, didn't he?

Walker: Yes.

Koford: With that needle.

Walker: Yes, he did.

Koford: Never really worked.

Fairbairn: So, Bob Schreiner, you were running these programs. What was happening at the business level? I mean, was this considered a success? Were you always struggling? What role did this play in Fairchild, and what were the pressures one way or another to continue or shut it down, or whatever?

Schreiner: <sighs> Well, there were-- it actually wasn't a very easy job because I was supposed to be like looking over all this technology, and it was a tremendous breadth of technology. So it was really tough to stay on top of all the problems and who was working on them, and at the same time try to do any kind of rational marketing planning, which I was also supposed to be doing. And I don't know, I have a vague feeling that this was another case of snatching defeat from the jaws of victory because we basically had all the bits-- and nobody else had it. We were the only company that had all these pieces, that worked to some degree. And to answer your earlier question, it didn't come together all at one time. But when they designed a particular package, like a simulator or a cell placement package, there was a way for a human engineer to interface and say, "Nah, the computer says do this; I want to do it this way." He could actually move cells around and make the machine-- again, start with, "Cell A goes here. Now do the rest of it." And that happened with the simulator; it happened with the test program generator, where if the machine didn't quite do a complete job testing, a smart test program engineer could jump in and add things to it. So it wasn't like everything started working at the same time and it all came together. It came together in little bits and pieces. It was my job to watch it.

Koford: And you know what's interesting, my current job, we just put together a CAD flow. And even the current CAD tools have things called "keep-outs" and "lockdowns" and various commands where you can do just what Bob's been describing; you can tweak it by hand. And the computer tries to do the other stuff for you, which is where people make mistakes. But fundamentally human judgment I don't think is going to go away in a lot of these problems.

Fairbairn: Well, I can certainly understand, having been involved in what became known as the ASIC business 10 or 15 years after the activity you're describing here, is that it required a huge amount of technology across the board. You had to have the best design automation; you had to have rapid turnaround fabrication; you had to have the latest technology in fabrication; you had to deal with packaging issues; you had to deal with testing issues, and those sorts of things.

Schreiner: All those.

Fairbairn: So what I'm hearing is that you were-- it sounds like you were sort of leading-edge technology. The standard product people were not using the technology that you were using, right? I mean, is that a true statement?

Walker: That's true.

Downey: Pretty true.

Koford: They began to use it in later years, but in that period I think-- right.

Fairbairn: But you were sort of plowing the ground in design automation in physical layout, in layout generation for-- mask generation-- testing-- I mean, you were the ones that drove the development of the testers, right?

Walker: Right.

Schreiner: Yes.

Fairbairn: That then became critical tools in standard product design.

Schreiner: <inaudible> standard, yeah.

Fairbairn: So you were plowing the ground in all of these technology areas for standard products, whether it was applied to this-- whether this program, from a silicon point of view was successful or not, these technologies became fundamental for all the later silicon development down the road.

Koford: That's certainly true. And the other thing is you never got a lot of credit for this stuff, because basically--

Schreiner: Yeah, that's the part that really hurts.

Koford: It basically worked, and if it had been some sort of a disaster where we were walking around like gurus who were the only people who could fix it, it wouldn't have-- but it basically did work, and we delivered circuits that worked. And that was, "Oh, big deal. If you can deliver circuits that work, it must be easy."

Walker: But you're right-- we wrote it out of our résumés, because it was a job-killer, you know?

<laughter>

Walker: "I worked on Micromosaic." So we went into-- all of us went into other forms of profession.

Koford: Yeah. Rob's absolutely right. Absolutely right. I went out and played with data communications for five years.

Fairbairn: So was this the last--

Downey: Let me just say one quick-- when I went to AMD-- I was recruited to go to AMD-- Sanders, maybe the first day, thumps me on the chest, he says, "We're. Not. Making. Custom. Circuits. You got it?"

<laughter>

Ulrickson: But the guys that stood on their own shoulders I think were Koford and Jones, who developed all this CAD package in the first place. Ten years later they were the same guys who went to LSI Logic under Corrigan, and perfected the technology. But by that time the densities of the chips were such that you could put 10 thousand gates on a chip. And Rob was there, and these guys stood on their own shoulders and made the whole thing very successful ten years later.

Walker: Yes, we founded LSI Logic to be in the custom business, and I knew I wanted Jim Koford. And he had a great job at Boeing, and he showed some interest, and actually talked to the Boeing people and they said, "We have to have you. We will put a facility in Silicon Valley if you want, just so you can stay with Boeing. You can have any equipment you want, any computers." And so I told Jim, "It's our legacy to finish this." And he bought it.

Koford: Well, I've never forget--

Walker: And it was.

Koford: I'll never forget that day when Rob-- when the phone rang, in October, in the afternoon--

Fairbairn: October what year?

Koford: That would have been '80, wouldn't it Rob?

Walker: Yes, '80.

Koford: Yeah. And so Rob had kept contact with Jonesy, who was also at Boeing at the time-- Ed Jones, and me-- and Jonesy was always complaining. So he probably was more gettable than I was at the time. And Rob said, "Are you sitting down.” <chuckles> I said, "Yeah.” And he said, "Guess what? I've decided to join Wilf Corrigan in a new ASIC venture.” And I said, "Huh?” <chuckles> Because Wilf was not viewed as a friend of Micromosaic. Most semiconductor guys weren't friends of Micromosaic and Micromatrix. And I said-- <chuckles>-- "What is going on?"

Schreiner: I would like to make a point about that though. Back in those days, the gorilla in the business was TI. They were by far the biggest company and had the best technology, and blah, blah, blah. And they had a competing with Micromosaic that they called Discretionary Wiring. Very simply, they would put a whole bunch of gates on a rather large chip, and they would probe the individual gates to make sure they all worked, and if some of the gates didn't work, they would route the wires differently. So they had to make a custom mask for every single circuit. And we looked at that and said, "Well, those guys must be crazy. I mean, that's never going to work.” And that was the only guy that was in the running. So we looked around and said, "Hey man, we got the world by the tail here. All we got to do is pull a little harder and we're going to be the biggest semiconductor company in the United States.” It didn't happen.

Fairbairn: Let's talk about the wind-down of this program. How did it come to an end?

Schreiner: Corrigan pulled the plug. <chuckles>

Fairbairn: When?

Schreiner: I wasn't there when it happened, so you'd have to ask one of these other guys.

Koford: After I left.

Fairbairn: Was this--

Schreiner: The story I told about buying a PDP8 at R&D was repeated. The same thing happened. After we got done with a feasibility model of a tester, I knew we had to have a big tester, because these guys were on board. Now they needed a big machine. And again, I walked into Gordon's office and said, "Okay, guess what? I'm back again."

Fairbairn: Same question, bigger machine.

Schreiner: "This time I want an IBM 360." And he says, "An IBM 360?" I said, "Yeah, because the CAD stuff, I mean, the PDP is a little Mickey Mouse machine." So he said, "Have you got a list of what you want?" Yeah, I had a big list because I had been talking to these guys. He said again, "Go see the purchasing manager." And then the very same thing happened. I walked in and said, "Here's the stuff I want." Now we're talking about millions of dollars' worth of equipment-- capital equipment. I didn't have a piece of paper one. And he said, "Who's authorizing this?" I said, "If you really want to know, pick up the phone and call Gordon." And he said, "Oh, not that again."

<laughter>

Schreiner: And placed the orders. I never filled out a return on investment analysis; I never decided how much the machine should cost per month. But it was a big machine and the monthly rental was a big number. And at some-- and when Fairchild began losing money at a good clip and Corrigan took over, he shut the whole thing down.

Fairbairn: And what year was that? When did he--

Ulrickson: That was '69, '70.

Downey: Oh, no.

Ulrickson: It was after Hogan's Heroes came in.

Koford: Yeah, it was well after that.

Fairbairn: You said it was still going in '73 when you left.

<crosstalk>

Koford: It was after I left.

Schreiner: Well, <inaudible> in '68, and they didn't shut this whole thing down till '71 or '72 or something like that.

Ulrickson: First Noyce and Moore left, which prompted Hogan's Heroes to come in. They came in in '68, and we were already in Mountain View making stuff. And then--

Downey: Remember, Blanchette survived for quite a while.

Ulrickson: And we had management problems. Blanchette took over the MOS group. And it stopped working somewhere along there. We weren't able to make MOS in the factory.

Downey: I got to contradict you. That part's true, the last statement. But after-- Hogan was made general manager of everything by-- sorry-- Corrigan was made the general manager of virtually everything in operations by Hogan, and he and Blanchette reported to him with this custom logic stuff, including all the electronic EDA and what have you. And then he got fired by Corrigan.

Fairbairn: Who did? Blanchette?

Downey: Blanchette. And Corrigan hired Pollack. So it went on for another couple years after that.

Fairbairn: Because you said it was still going in '73 when you left, right?

Koford: Yeah. Well, I kept contact. When I went to the East Coast to work on the internet-- the Arpanet, actually-- I didn't want to sell my house out here, so I rented it to a guy who you guys probably know, because he did a lot of work on testing, Bill Jensen [ph?], who worked in my group and did test gen and some of the testing interfaces. Well anyway, Bill rented my house, so I had kind of a built-in contact with what was going on. And I remember hearing when I was on the East Coast, which would have been in like '74, that layoffs were coming and that Fairchild was getting pretty scary to work for. And so that must have all happened in '74 and '75, somewhere around in there.

Fairbairn: So Rob, when did you leave Fairchild?

Walker: I forget.

Fairbairn: Was this the last program you worked on at Fairchild?

Ulrickson: No. Rob had a second life at Fairchild after the MOS thing failed. He came to work in marketing for me as a product planning manager for digital circuits.

Fairbairn: Bob Schreiner, when did you leave this program? And did you stay at Fairchild for a while in this?

Schreiner: Yeah, I was down at systems-- what we called systems technology-- mostly to make sure the 8000B <inaudible> testing got finished, and that it worked. And I think we shipped about two machines, and I was basically summarily yanked out and said, "You're going to back to Mountain View." I said, "Well, okay. Doing what?" "Product marketing manager." I said, "I got to tell you, I don't know diddly-squat about marketing. That's not my bag." But anyway, "You're going to be the product marketing manager." That only lasted maybe a year, so it would have been '71-- '70 or '71.

Ulrickson: Does Conference Room H come to mind?

Schreiner: What?

Ulrickson: Conference Room H. That's the place where they moved managers to before they died.

Schreiner: Oh yeah, yeah. Right toward the end--

Ulrickson: You ended up in Conference Room H.

Schreiner: Conference Room H.

Ulrickson: Yes.

Koford: I remember when Rob once when down to systems technology, Bob. He said, "You know, you can see the curvature of the earth in that building." It was big.

<laughter>

Fairbairn: So Jim, what about you? Well, finish up with-- so you came back and then you left Fairchild when?

Schreiner: Are you asking Jim or me?

Fairbairn: No, I'm asking you, Bob Schreiner.

Schreiner: I believe it was either '70 or '71.

Fairbairn: Oh, okay, you left earlier on.

Downey: I left in December of '92.

Fairbairn: Seventy.

Downey: I'm sorry, '72. And joined AMD directly.

Fairbairn: And Bob Ulrickson, you were--

Ulrickson: I left in March of '73 after running the digital marketing department for a couple years.

Fairbairn: When did you leave this program?

Ulrickson: Four years before that, in '69.

Fairbairn: So when it was still on its sort of ascension, you had gotten it started and so forth. Hugh?

Mays: Yeah, I wanted to say one more thing about the CAD. These guys that we had in that department pushed the computer technology so hard, we ran out of gas with computers. And I think the reason that CAD didn't get very far was until the computers were big enough to handle the kind of technology these guys were developing, and in '67 it ran out of gas. It worked the way it was advertised, but we were running out-- they couldn't do things. There wasn't the capacity.

Koford: Hugh makes a good point that there's a corollary to, and that is those machines were expensive. They cost millions of dollars a month to rent, and the power and everything. So they ran out of gas at the same time as they were getting more expensive. And it wasn't until the outgrowth of this technology produced cheap computer chips that were very small-- everybody knows that the smaller a computer chip gets the faster it goes-- that people could really afford this. And I think that's a good point because that was really a factor in these things.

Fairbairn: So between '66 when the idea was first conceived, and early seventies, '72, '73, when things were wound down, you created silicon technologies, testing technologies on software and hardware as well as the-- silicon testing, CAD, and the whole design automation flow. And then it sort of died under its own weight. It was not cost-effective at the time. You had manufacturing issues unrelated to any of your own contributions or issues.

Ulrickson: Not to mention the Micromosaic technology itself that Jim was very active in, or made happen, actually.

Fairbairn: Sort of the whole design technology and how you put it together.

Downey: The cells, and the cell family.

Fairbairn: The cell family and so forth.

Downey: The cell family would have still been a manual plug-along without the electronic design automation that was coming in. And Hugh's right-- I think we just outgrew the computers. They just couldn't handle it.

Fairbairn: And that whole technology sort of went into hibernation, if you will, for ten years, and then was reborn when LSI Logic, the LSI Technology and a number of other companies resurfaced to take advantage of computer technology--

Schreiner: And the people. And the people.

Fairbairn: And the same people came back.

Schreiner: That's right.

Koford: Well, the thing also that we did at LSI which I'm kind of proud of, is we got very close to the new breed of computer companies, like Sun Microsystems. We not only supplied them with chips and they built our machines, but we also were big customers of theirs, because these things were very cost-effective. And the company that occupied this originally, Silicon Graphics, we got serial number 002 of that machine. So we now had tools that we could afford that could do this stuff, and that only continued to get better.

Fairbairn: Right. But even then, as I remember, the technology used for custom and what became known as ASIC was essentially leading-edge technology for the silicon industry, that the standard product people were later in adopting the automated design flows and testing methodologies and so forth that was developed even in the early '80s.

Koford: And you guys had the ALTO workstation, which I think was another leading machine of that ilk at that time-- graphical and good performance.

Fairbairn: Yeah, certainly a Xerox <inaudible>.

Koford: So we just rode that wave. We helped it along. <chuckles>

Fairbairn: So let's just-- maybe this is a good time to wrap up, and I'll just ask each one of you to-- I tried to summarize my view of things, but. We can start with Bob.

Downey: You did very well.

Fairbairn: Thank you. Bob Ulrickson, any other comments, insights, points you wanted to make in terms of this effort and where it led, or the impact that it had, or any other stories you wanted to tell as part of this?

Ulrickson: Well, yes, because in the beginning we couldn't get enough stuff on a chip to make it economically feasible in the marketplace to do a standard product so we went custom. And then the standards took over from another direction in the MSI area. They ate up the smaller Micromatrix. And then the microprocessor came along, and it became the programmable way of eliminating custom circuits, because you could now program in software to use a standard product that was now built in high volume in the semiconductor industry, and everybody could make a lot of money on that. So programmable systems became the way to go in almost all electronic design now. But then the next step came with the LSI Logic, and eventually they were able to put microprocessors on larger chips as the core of that chip and do a lot of the logic around the microprocessor on the same chip. So everything moved in waves, and one of the first waves was Schreiner's outfit at Fairchild R&D.

Fairbairn: Jim?

Downey: Yeah, I agree with what was said. The set of tools that evolved became the industry enablers, in lots of areas. And I guess it was disappointing-- I think we got ahead of the manufacturing technology, and that's just-- that's just a statement of fact.

Ulrickson: We were on the bleeding edge.

Downey: Bleeding is right. I'll say one thing here in conclusion. We did get recognition in the industry. It wasn't all--

Fairbairn: All unappreciated, huh?

Downey: There was a magazine called *Industrial Relations*, and Micromosaic 3401 was one of the 100 best products in-- they recognized-- in 1969. So there was some recognition, although it didn't bring any money with it.

<laughter>

Fairbairn: Bob Schreiner?

Schreiner: Well, I think Ulrickson made a very good summary. Kind of the reason we went off on this path at Fairchild Semiconductor-- I used to spend lots of time talking to Bob Seeds. He was one of the smartest guys at Fairchild R&D, and got very little credit for what happened. I don't know why not. But we used to sit and talk about Moore's projections and say, "You know, when you can put a thousand gates on a single chip, how many kinds of standards products could you possibly come up with?" The answer was hardly anything. What could you do with a thousand chips?

Ulrickson: Until you made it programmable.

Schreiner: Well, wait a minute. And we said, "Moore's probably right, says that someday you can put a whole microprocessor on a chip." And what escaped both of us was the fact that if the microprocessor is cheap enough, it doesn't matter that you don't use the whole thing, you could use it make a door opener, or whatever you want-- they were inexpensive enough. We said, "There's got to be a huge custom circuit business that's going to come about if we can do all these things." And we both agreed, "That's right." And he even gave a paper at Solid States Circuits Conference to that effect. "It's going to be mostly a custom business." He believed it, I believed, Gordon Moore believed it. And we said, "In that case, we better get busy and get all these bits and pieces working.” And it turned out that if we were a little bit smarter we might have foreseen the fact that the microcomputer was going to dominate this industry to a large degree and that a lot of the stuff we were doing really wasn't all that necessary. Could have made money with computer chips if we knew how to make them.

Fairbairn: Rob?

Walker: Well, when I first got into the custom business in the seventies, I just thought this was a dream come true. I could-- I'd been designing digital systems for some time, and to be able to put that on a chip was just mind-blowing.

Ulrickson: Engineers loved to have a pen that would write on silicon.

Fairbairn: Jim?

Koford: Well, I completely agree with microprocessors on chips. We had to wait till LSI days to do it. But another colleague of mine who did all our front-end after I got somewhat out of it, but we were both still at LSI-- Doug Boyle and I cornered Wilf Corrigan in Germany, when we knew he couldn't pick up the phone and call his little set of bodyguards, and said, "Wilf, we got to have a microprocessor core. We want it. Will you let us put that together?” And so then we went home and talked-- and so he really didn't have the choice-- <chuckling>-- he had to sort of say yes. And then we went home and talked to Rob about it. Rob liked the idea but he said, "I want to educate you guys. This is no small deal. You better be ready to do this.” I didn't quite know what that meant at the time, <chuckling>, but I later figured it out. And Rob had many years of experience at Intel. And so then Doug went and negotiated both SPARC and MIPS-- microprocessor core licenses. We weren't about to design one at that point in time. And so we got into the microprocessor core business that way, and it turned out to be very successful. And we hired a guy named Brian Halla, who I think had been at Intel, to actually run that division. So it was big enough to finally have a division that did that. But we were-- we think-- I like to say-- I'm not sure Ed Jones would totally agree-- that we invented the embedded microprocessor EDA system. Because I don't know who else was doing it.

Fairbairn: That was at LSI Logic?

Koford: At LSI Logic. So we had a later history of that, of Seeds' vision, that I think was exciting and it was probably the last really innovative thing that I did at LSI Logic.

Fairbairn: Hugh?

Mays: Well, of course I was out of this whole loop in '73, and I always viewed MOS as having chewed me up and spit me out, and it sounds like it did a lot to some of us here.

M6: It was good at that.

Mays: And what I got from today was how much the technology was being pushed in all areas, not just the computer area, and we didn't have a smart enough management that could pull us all together-- we probably needed a manager who was a genius-level technology guy, and also a good manager, to make it all pull together.

Fairbairn: Well, as I think-- and timing is everything. And you were on the right path, but you were running out of computer power, you didn't have the process technology. So you were absolutely on the right path, but the underlying technology and computer power was just not there to support what you had set out to do in a cost-effective way.

Koford: Yeah, we were on the right path but the horse died.

<laughter>

Mays: Sounds like a Wyoming saying.

<laughter>

Fairbairn: Right path, wrong time.

Downey: That does sound like Wyoming.

Koford: It is.

Fairbairn: Well, I think maybe that's a good way to wrap it up. Any other final comments or whatever? Appreciate all of you coming together. I think the synthesis of all of you together really formed a much more complete story than I had been able to piece together from things that I had read or heard or whatever, and so I think it was a valuable session, and I appreciate all of your participation.

Koford: Well, thank you Doug. You did a great job.

Downey: Thank you.

Schreiner: Thank you.

Ulrickson: Thank you.

Mays: Thank you.

END OF INTERVIEW

