Fairchild Model 4000 IC Tester Oral History Panel

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Tom Hines
Harry Sello
Dave Wiesen
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Moderator
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Paul Sakamoto: Hello, my name is Paul Sakamoto. Welcome to our oral history of the Fairchild 4000. Many history projects have focused on the creation of the semiconductor, and the products developed from this technology. The question is almost never asked as to how we know these wonder products actually work as advertised. To help, we have assembled this panel to discuss the first purpose-built Automatic Test Equipment, or ATE, for semiconductor mass production. In the first section, we'll discuss the background and the history of the system, for which we are pleased to have Dr. Harry Sello, a storied pioneer of semiconductor development on our team. In the second section, we'll have the user experience represented by Mr. Wesley Wong, who will join the panel in Harry's place for that portion. To start off today, why don't we start off with Mr. Tom Hines. Why don't you go ahead and introduce yourself. We'll go through our panel in that direction.

Sakamoto: So starting with Mr. Tom Hines, can you please introduce yourself and discuss a little bit of your background with the 4000 and what you're doing today.

Tom Hines: Okay, I'm Tom Hines. Excuse me. I joined Fairchild in 1966 as a Field Service Engineer out of the Los Angeles Sales Service Office, and was ten years servicing testers in the US and Europe. And then I quit Fairchild and started my own company doing the same thing, competing with Fairchild for 20 years. And today, I'm retired.

Sakamoto: Thanks, Tom. Dave?

Dave Wiesen: I'm Dave Wiesen. And I had joined Fairchild in 1969. And started first up here in Sunnyvale; got my training here. Primarily on the 5000s, but I also then carried a bag for 4000s as far as doing just on-the-job training, so to speak. Then I moved from here down to Torrance, California. And supported the LA office. And so I did that for a few years. And then Jim Healy recruited me to come over to Japan to help out with service. I did that for about 13 months. Came back for service here in Sunnyvale again. And moved back over to Japan when Jim had to leave to take over Europe for Fairchild. And so then I was handling apps and service to start, but just migrated into sales. And it was a very, very interesting transition. And then moved back here in 1968, and started in sales. Worked on sales for the Sentries as well as [the] 5000 CEs and some of the other products including Xincom memory testers. Following that I moved on to GenRad. To Eaton first, and then to GenRad. And ended up working with LTX for about ten-and-a-half years. And moved on from there a few other operations. One in the front end, and the other one in packaging. And now I have been my own rep since about 2001/2002.

Sakamoto: All right, thank you.

Wiesen: Thank you.

Harry Sello: Jim?

Jim Healy: My name is Jim Healy. My first encounter with the 4000, I was working at Space Technology Laboratories, Redondo Beach, California, [which] later became TRW Systems. And we bought the second 4000 ever developed by Fairchild, [the] first commercially shipped product. And my job was to learn about it, and to accept it for the company so we could use it in production. Actually, it was incoming inspection. It took about, I would say, six/seven weeks before we actually had it working. During that period of time, I became very close with the service engineers, and I learned they had an expense account. So I made a decision then I wanted to join Fairchild. And eventually I did join Fairchild in the field service capacity. Working on the 4000s. About a year later-- this was like 1966, they sent me to Japan for six months to help the installations of 4000s. Because at that time, Fairchild had licensed supplying their process to Japanese companies, and they were like thinking the old Intel days today, copy exact. So they didn't want to make or have anything different, so they bought the same testers as Fairchild used; the 4000s. And I installed those across Japan at NEC and Fujitsu and many other companies. And actually ended up staying there six years during that period – that was kind of the birth of the semiconductor industry in Japan. It was quite an experience. And there were many, many 4000s. They were the workhorse there. I think they-- I would say they launched the Japanese IC industry, those 4000s. The tester was so popular, that NEC actually copied it verbatim, exactly as it was, [as well as] their subsidiary, a company called Ando. And then we ended up competing with Ando for the Japanese market years later. Now I'm working for Sony. So I guess I'm still part of the Japanese operation.

Sakamoto: There ya' go. Still coming full circle here.

Healy: Yes, sir.

Sakamoto: Harry?

Sello: Well, if anybody has come full circle, I think I can qualify for the largest and most wide-open circle. I started with Fairchild-- best way I can describe it is I was a little slow in getting to Fairchild, because I worked with the "Traitorous Eight," so called at the Shockley Laboratories. And when they left Shockley, I refused to become number nine. I stayed at Shockley for another couple of years. So I joined Fairchild at their request in 1961, when this was the entire group that had started semiconductor. Of course, my main effort was in processing and manufacture. I was not a skilled salesperson as the others around the table. I was not a maintenance man. But I was trying very hard to learn how to use these kinds of testers. The most exciting part that I found was that the gentleman who was one of the eight people who left Shockley and went to work at Fairchild was a co-founder of Fairchild, Dr. Vic Grinich. So I became a close associate of Vic Grinich. And Vic was in charge of all semiconductor test equipment and measurement in the early days of Fairchild. There will be a lot to say about that as we go through some of the history. However, I would like to point out one interesting little fact that has slipped sort of on the side, and only us old gray-haired historians can think of some of these things. But Fairchild was the first company to build an active test equipment company for integrated circuits. And this was prior to the days of building transistors. In 1961, we invented or was invented at Fairchild the family called Micrologic. Micrologic were integrated circuits. And these integrated circuits went over big to customers. There was only one problem. How do you measure them? So Vic Grinich being very astute, put a guy to work, and in 1962 Bill Hafner built an integrated circuit tester-- unknown in history to that point. That group under Grinich then went on to build dozens and dozens of beta testers and transistor testers. And later on, 4000s and the Sentry series. But way back in those days when they had to do something at the beginning, they do have a record of having built the first integrated circuit tester known in the semiconductor industry. And we can talk more about that later.

Sakamoto: Well, thank you very much for your introductions and your little bit of background. And we can go back to Dr. Sello again. Harry, maybe you can give us a little bit more background history on the team that put the 4000 together, and some of the other factors around the organization that allowed that kind of genesis to take place.

Sello: I can point to certain facts, of which probably Jim knows more of the details that emerged from those. But there were a certain series of points that were extremely sensitive. We were making the only devices of that type known to the industry. The so-called planar integrated circuits. Invented by Jean Hoerni. Now these transistors, diodes and integrated circuits were Fairchild's proprietary material. No one else was making them at the time. Anyone else who got into the act used to have to buy a right to use the Fairchild technology. But that wasn't the problem. That's a problem for the marketing guys. These excellent experienced guys around the table with me. But the problem for us internal people was the fact that we were making the devices, brand new at the time, known to no one else, and how do you measure them? How do you measure the leakage current, which was three orders or four orders of magnitude lower than any of the known integrated circuit, or discreet device integrated circuits, and integrated circuits. These were down in the nanoamperes. And we were supposed to make these. And if they didn't-- if they leaked more than nanoamperes, we had to throw them out. But we couldn't even measure them to throw them out! We could do cosmic work. So the start of Fairchild systems under Vic Grinich, who was himself a PhD electrical engineer, was to build all the testers in-house that we needed to use for transistors, for diodes, for integrated circuits, MOS, bi-polar, any kind. But build them in-house, because you couldn't buy them. And the 4000 was one of the first most successful ones that was built because it was the one that was most needed. It was needed long before Sentry was needed. But the 4000 was needed in the early days of the manufacture of the semiconductors. So it stands unique in a startup, with this one little tiny exception that I have to say. There was an integrated circuit tester built before the 4000 by Bill Hafner of Vic Grinich's group. And I think he deserves the credit for it. We never got to use it, because Micrologic came and went in the years after that.

Sakamoto: Thank you, Harry. So with that, why don't we go ahead and Jim, maybe you can pick up from there and talk about the commercialization of that technology

Healy: Right, well, when Fairchild invented these integrated circuits and started selling these products, the company, like my company, TRW Systems, and Science Space Technology Laboratories, says, "Fine we'd like to buy these. How do I know if they work?" So that means they had to have a way of testing them. So what happened is then, the Fairchild testing systems group said, "We have to do something about that." And they had a 4000 kind of. But it was kind of bread-boarded. It wasn't really a commercial-saleable product. So we had to take what they had built internally for internal use, and commercialize it. In other words, build it so you could plug it in and somebody could run it and didn't have to know very much about it. At that time, PhD's did all this work. You think about the way integrated circuits work. You think about the way integrated circuits were tested then, we called it a rack-and-stack, with many different kinds of instruments and cables and wires. You hooked it all up to this performance board, you plugged a device in, and you could test it. You couldn't ship something like that to a customer. So to get the business, and to corner a market in ICs, what they did is they commercialized this tester called the Model 4000. And it was the first automated IC tester developed for commercial use. Where they actually sold it to customers. And as I said earlier, in Japan, when they licensed to Japanese, the planar process, then this is the tester all the Japanese wanted as well, to be able to verify that their circuits could work. So the 4000 was primarily designed with resistor-transistor logic ["RTL"]. Which means these are devices that are biased with a resistor. And what that means is lots of noise. So there was a lot of-- when you build an

IC tester, to service it, you need a lot of capacitors to reduce the noise. But it was primarily that RTL logic and operational amplifiers. And there were current sources, and voltage sources, and all different kinds of stimulus sources to the device. And there were measuring units that would measure the device. But the key thing about the 4000 was a relay matrix. Because we have all these different instruments, measuring units, and these different units to stimulate the device. You have to get it to the little pins on the device. So they invented this matrix which allowed you to take all these different sources and bring it into a single device in a very confined area. And that matrix was what made the tester automatic. It was actually programmed with a paper tape, where you could actually program with a series of switches. There were many ways to program it. Eventually, we developed a magnetic disk, which allowed you to program it. It was actually done in machine language, which is ones and zeroes, in a fixed word format. Each item in the word would have a specific requirement to move/close this relay, send this voltage level or whatever it might have been. So that was the first programmable tester as well. So not only was it the first automatic tester, in the sense of being able to plug in the device and do all the different parameters by switching the matrix, it was also the first device that was programmed automatically by a magnetic disk or software. It was the beginning of software for ATE (Automatic Test Equipment) actually. And they also had a data-log capability, so when they measured this stuff they could collect the information. Then they'd go back and look at the information to understand why the device failed, or if it passed. And this basic configuration of the 4000, even today's three/four million dollar testers use this same architecture, the same basic concept. Nothing has changed in all these years. And as a result of this automation, the 4000 became the workhorse of the industry. It was sold throughout Japan. Of course, across the United States, and also in Europe. It was at that time purchased for two purposes. One, mass production. 'Cause if you're going to run thousands-- and at that time, not millions-- but thousands of devices, they have to be done in some kind of mass production at very high rates of speed, or you wouldn't-- the cost would be astronomical. The other reason it was used was for incoming inspection. The people who bought these chips wanted to make sure they worked. These were before the days of zero defects and that kind of thing. So half these chips probably didn't work when people got them. So the customer actually buying the chips would then have to sort them to determine what was good and what was bad. So like I say, that was the beginning of the ATE industry. It was the first commercially available tester, integrated circuit tester. It was programmed with software, even though it was machine code. It was controlled by relay matrix. It brought all of the various functions to the chip itself. And that allowed you then to test thousands of chips. And women operators would sit in front of it and take the chip and plug it in. Push a button, bunch of lights would light, relays would click, and it would go red or green. If it was green, that was a good one. If it was red, it was a bad one. And that went on for years. And eventually [other company or Fairchild?] developed a handler system which automatically handled these chips, so that somebody didn't have to sit there and put them each in. But that was the beginning. I would say hundreds of these testers were sold worldwide.

Sakamoto: Wow, that's interesting to find out about the environment, when the first tester was created and sold. You had a lot of firsts there that you mentioned, and I just have to believe that it was probably a challenge as much as anything to explain to customers, not only why they needed one, but also what this actually was, because none of those features that we take for granted today was probably common at the time. Dave or Tom, did you want to comment on the actual impact out in the field of how it was to have a computer-controlled automatic tester versus whatever it was that they did in the previous times?

Wiesen: You want me to--? You want me to go. <laughter> One of the things on the 4000, I remember was the Nixie displays. It was kind of interesting to show the test that you were on as it was sequencing through. And the other thing was the paper tape aspect of things. That actually poured it onto the next machine that came out, even though they did have the disk drive. Is you still had the ability to do some of that on the very early ones, the 5000s, the 5000D. And then they had the magnetic Burroughs disk drive at that time. That was the first two megabyte drive. So it was a monster as far as the size. Another aspect of the 4000 that I found interesting is that the relays were mercury-wetted relays. And especially in the test head, where these matrix cards were all in. And occasionally you would get called in on it, and it got to where in just a few visits, on certain machines, you knew exactly where to go by the symptoms of what didn't quite come out in the test sequence. And so you'd just open up the test head, pull out the card, and stand it on its edge, and pack it down-- bang, bang, bang. Put it back in; it would run just fine. And you could replace them all if you wanted to. But the problem was the new ones coming in would develop the same problems, and nobody knew how long it would take. So that aspect of it was fairly unreliable, but we had a very good service force there with Fairchild. And it kept us busy, because that's what I was doing is almost seat-of-the-pants learning the machine when I came in.

Sakamoto: So that's interesting. You're actually telling us that you would actually redistribute the mercury on the tips of the switches. Just to free it up so that those stuck relays would come unstuck. And then they'd work normally. I don't know if you saw that, Tom, but...

Hines: Yep. We saw that...

Wiesen: Quite a bit.

Hines: A lot in the field. It was...

Wiesen: And there were other issues that all these things got worked out over time. And they continued to improve the reliability of it. But then they were moving onto the next generation as well. So they had new things coming down, because semiconductor technology was moving along. And integration was starting to come in. The other aspect of it was all of the things that you had to replace, resistors, capacitors, all these things were-- even though they were on boards, you didn't have spare boards. Very rare. People didn't want to buy the extra spares in those days. So you had to go right down to component level, and troubleshoot it. And so it was a tremendous help for me to learn a whole lot more about tests. And especially the instrumentation chassis and work that was done on that, I thought was fantastic. So it was a fun learning experience for me.

Hines: I think in the field, we had tremendous amount of support from the factory, so it made a big difference in the customer's attitude, and made our job a lot easier to get-- if we had problems that we couldn't solve in the field, they would actually send engineers out from the plant to assist us. So the customers were very well taken care of, and they appreciated it. I know that for sure.

Sakamoto: So perhaps, Tom, you could give us a little bit of an idea. What do you think was the failure rate of the machines? How often would you expect one of these machines to fail? What kind of reasons, and how long did it take to fix?

Hines: The failure rate was pretty low, I thought. Because we had like a monthly schedule, calibration schedule. We would go once a month to the customer site, run all the diagnostics on the tester, correct any problems, and in-between the monthly visit to the customer, if they had a problem, they would call us, and we would just go out and repair the tester and they were happy. So we kept moving. But I don't think there were that many problems that we saw. And I spent two-and-a-half years in Germany, servicing testers in Europe. So they were very happy to have the support and the service that Fairchild provided, as well as application support, and so.

Sakamoto: So as a--

<crew talk>

Healy: Speaking about how the customer saw it, I was, like I say, the first customer for the first commercially available one, and we had come up to Palo Alto for training. And you won't believe this, but in the Fairchild training center, consisted of these very large schematics, page after page. There was no written description. You just had schematics. And an engineer would stand in front and explain how it worked by looking at these schematics and telling you the wave forms. And there were no tables. We had to hold the schematics on our laps on chairs, 'cause Fairchild had just-- this division had started, and it was really kind for antiquated at that time. And you had to understand what the instructor was telling you and try to relate that to the schematic. And then when you went back to use the tester, you had to figure out how it all came about. There was no ability to-- no help files. You couldn't say "Help." Okay, there was nothing to help. You couldn't even read anything. Okay, you had to try to understand it. And that's why, as Tom mentioned, a lot of people in the factory had to come out, because the only people that knew it at that time were the engineers who designed it. And for some reason, documentation was just not something that anyone did then. A couple of years later, of course, that all changed.

Hines: I think that was a significant thing for Fairchild's success on the tester was that they had a very open architecture, where they gave you two sets of schematics, two sets of wire lists with every tester. Plus training, and in-house training, or you could send your technicians to the Mountain View to the plant to learn how to use the tester. They didn't hide anything. It was--

Wiesen: Yeah.

Hines: It was very open. Manuals on all the peripherals, everything, so. I think that's why they were so successful in the very beginning.

Healy: And later versions of the test were what they did was they tried to make it more accurate and do things better. So what they did is they selected specific devices in Fairchild that had a special number on them that would allow you to measure a low current or whatever it might be. And when Ando, who had copied it, so they had no access to these special devices, so when the newer models came out, they couldn't test some of the same parts. Okay? This became a trademark of Fairchild for years, where they would select devices that would work with a special internal number, secret from anybody, and made it very difficult to copy, then, what Fairchild had done, because you didn't know what this device went. You had no idea what the spec was. There was no data sheet for it. So you had to have this- this particular device. I thought that was pretty smart on somebody's part. I don't know who's idea that was, but I thought it was a good idea.

Sakamoto: That's great. Okay, Harry?

Sello: Yeah, I have a non-test question from a manufacturer, or a maker of the devices to ask my well-trained colleagues here. Early on, when the 4000 just practically saw the light of day, Fairchild was involved in setting up a company in Italy called SGS, SGS. It was a triumvirate--

Healy: You <inaudible> that.

Hines: We called it "S-ah-G-S-ah." <laughter>

Sello: That's what an American would say. It's only "S." Nevertheless, you came out right. And of course, we were out there, those of us who started this company sent out by Bob Noyce. He asked me to go out there and set up the company and operate it. We needed testers. When it came to testers like ordinary parameters, like leakage current, or current amplification beta, or something like that, somebody would jerry-rig a 575 Tektronix, or they'd jerry-rig and HP tester, and try to test this. So my question, number one, is could you use the 4000 for discreet device testing? You gentlemen?

<overlapping conversation>

All: Yes, yes, absolutely.

Sello: No problem!

Healy: Because an integrated circuit is nothing but a collection of- of discreet devices.

Hines: Discreet, yeah.

Healy: With inputs and outputs. So what you-- each within that-- in a circuit is a...

Sello: And you could identify that it was an ICBO that was out of whack, for example?

Healy: You could make a leakage measurement; you could make a VOL measurement, VOH measurement.

Sello: An FHE measurement.

Hines: Resistant.

Healy: HFE.

Hines: Yep.

Sello: This leads me to-- they fell into my trap. <laughter> This leads me to a second question, which was, SGS was sitting out there on the frontier, a new company, trying to make these new devices, these planar devices, not yet integrated circuits. But just low leakage devices that nobody else in the world was making, And uh.. we needed a tester. Well, in 1964, if you asked anyone at Mountain View in the division to send you a tester, they would turn their backs on you. Especially if you were an employee of Fairchild. Because it had to go to customers. It didn't have to go to internal Fairchild's. Well, that's a little side issue. So a couple of enterprising engineers in SGS reporting to me at the time, without any permission, or just on their own initiative, very strong Italian property of initiative, <Italian>, they came up with a-- they called me in one time, they came up with-- I had to ask them, "Where the hell did you get that 4000?!" And they had a 4000 sitting there.

Hines: I worked on them.

Sello: Did you work on that?

Hines: Yep.

Sello: It wasn't a 4000! It was one that they built with digikeys instead of any kind-- instead of electronic switches.

Hines: Uhm hm.

Sello: And they were trying to sell it back to Fairchild in Mountain View, to the instrumentation division at the time so that we could get something shipped out of Mountain View that was finished. It never worked. Noyce came out, Charlie Sporck came out, everybody but-- oh, Sherman Fairchild himself came to see the operation. And we all pleaded for a tester. "Send us a 4000." And they would say, "But you got one!" Which was just a sham. It was an SGS-built 4000. So my question to you is, "Could they have done it with digiswitches?"

Healy: Sure!

Hines: Yes.

Healy: Just it’s a longer program.

Sello: What did they copy then? Did they have to a 4000?

Hines: No, they copied the 500 transistor tester.

Sello: Oh, oh! Is that what they done?

Healy: The 4000 also had digiswitches.

Wiesen: Complete with vacuum tubes.

<overlapping conversation>

Sello: They also made digiswitches?

Hines: The 600 transistor tester as well, yeah.

Healy: Right.

Sello: Well, when Bob Noyce came to visit SGS and we offered to sell him a 4000 as a joke at dinner one night. And he said, “What in the hell are you talking about? We don’t have any 4000s enough at Mountain View from the Instrumentation Division? Where did you get the 4000 that somebody pointed out to me?” Well, I had to say, “The boys made it!” <laughter> But I was lost, I couldn’t say anything more about how they did it. How did they manage to get to a 4000 to copy it?

Healy: Well, it wasn’t an IC tester, was it? It was a transistor tester.

<overlapping conversation>

Sello: It had to be a discreet device.

Healy: It was a transistor tester. And uh...

Sello: So it does complete the loop. They could have done it. But they couldn’t test ICs.

Healy: But see, if you remember there was a Model 300, and the way you program Model 300 is you had a card for each parameter.

Sello: Yes.

Healy: You had to kick the resistors and put them in to make the parameter work. All the 4000 did was had a bank of resistors-- I mean the 500-- a bank of resistors and you could select with a digiswitch, you'd select which resistor you wanted to use for that particular parameter you were testing. That's what they developed.

Sello: I see. Well, they put it to work, but it was so slow!

Healy: Like Tom said, you used to work on the, right?

<overlapping conversation>

Hines: Yeah, I went to Milan and worked on what they called a 4000.

<overlapping conversation>

Sello: They had to switch by hand every single device that came through.

Healy: They called it a 4000, but it wasn't this 4000. It was different. It was a transistor tester.

Sello: I'm glad you--

Wiesen: It was an S-ah-G-S-ah.

<overlapping conversation>

Sello: It's taken something like 70 years to clear up that point. I'm glad we...

Hines: They had more than one digiswitch, right?

Sello: Oh, that's right. They had two banks of them.

Hines: And they would sequence through each parameter with just--

Sello: One at a time, click at a time.

Hines: Yeah, that's right.

Sello: Where did you see it?

Sakamoto: That's actually interesting, if I can interject. So that was actually a programmable-- there was a programmable tester before the 4000. But it sounds like it was not computer programmable, it was some other...

Healy: Well, the 4000 wasn't computer programmed either.

Sakamoto: No, just a machine language.

Healy: The 4000 had one single digiswitch, a long switch. That was called your fixed word format. Okay? And there behind it was either a paper tape reader or a magnetic disk, and what it would do then is it would read-- you'd digiswitch the program, and push a button, it would remember it. Digiswitch the program, next test, push a button, it would remember it. So the magnetic disk would have to have a series of- of the switch settings for a whole series of tests. So when you push the button, then you would go-- the relays were all closed based on which digiswitch they were going at the time. And you could take manual control of the tester by going in there and programming it manually, or you-- the automation come from the fact that the magnetic disk stored the values of these digiswitch, one for each different test. And then it would run through it all at one time.

Sello: So the parameters worked.

Healy: In the case of the 500 transistor tester, each digiswitch did one thing. Then you had to go to the next. So it would sequence through each switch. But there wasn't a memory behind it that would maintain or have that data.

Sakamoto: So it's fair to say that the 4000 was in the first automated program, or stored program sequencer. It had an automatic sequencer, but not really a computer.

Hines: Right.

Healy: There was no computer on the 4000.

Sakamoto: Interesting.

Sello: And there was no computer program as such. Where did you see the SGS?

Hines: At SGS in Milan.

Healy: He was there for four years.

Sello: Do you remember the year by any chance?

Hines: It's...

Sello: Sorry, I don't want to ask you a personal question. But...

Hines: No, no, that's-- '69. 1969.

Sello: That figures.

Wiesen: That's when I started.

Sello: That's exactly right.

Hines: Yeah.

Sello: We just couldn't get it sent-- we couldn't get anything sent out of Mountain View. That was impossible. It was all going to Japan for one thing.

Healy: I was pretty tough over there.

Sello: It was pretty tough.

Healy: I grew them ____________.

Sello: And Noyce and Sporck came out to look at what we were testing.

Hines: Uh huh.

Sello: And he said, “Oh, look at-- where’d you buy all those Techtronic’s devices, the 575s? Where did you buy all those HPs?” “We bought those ’cause we couldn’t get the 4000.” “Well, next year or two, we’ll send you one.” But they went ahead and they did make this.

Hines: I know, I thought they just copied from the schematics, the 4000 that uh...

Sello: You could be quite right.

Hines: But physically, it looked exactly like a 4000.

Sello: It looked exactly like it, because they-- I was invited to get a picture taken standing next to it. A picture taken. And I thought they- they had sent out a squad from Sicily to steal a 4000 and bring it from Mountain View and bring it to SGS in Milano. <laughter>

Sakamoto: So maybe just to kind of round out this section of our discussion, we could go around and each one of you could discuss, like one of the big difficulties you had of actually commercially introducing this equipment to the general marketplace. The initial bring-up sounds like it kind of happened within Fairchild and its close associates. But after that, when you get out to the next tier of customers who were out of that sphere, there must have been some challenge in explaining *the* first automatic test equipment to them. And maybe you each could go around and talk about something that could be funny.

Sello: Well, I can certainly add a piece of old history, which probably Tom knows even better. And that is when these planar devices, low-leakage devices, which we were manufacturing at SGS, finally, didn’t work, we were forced to always say this is the 5000. It’s the 4000 that isn’t doing it, because it’s not really an exact 4000. Well, that was deadly. I mean, if you said that to a user, he wouldn’t accept that. You know? But that was the only problem that we could ever face. But if I had known that, we could have built more of them, maybe sold them back to Mountain View!

Hines: <laughs> Really. No, I wasn’t personally involved with selling. I was just a field service engineer. So I was there to fix them.

Sello: Well, I did want to add that none of these gentleman inferred, then maybe I can close out my little section of the monologue-- with the polylogue here. And that is what I first ran into about the 4000 on the manufacturing side of low-leakage devices was the excellent support from test engineers.

Healy: Yeah.

Sello: Nowhere later in my own long history at Fairchild, did I ever see such a direct spontaneous fast level of support directly to a tester. Not even in the height of the Sentry systems. We’d get-- Sentries would get good service, and Jim was part of that, but it took a little time, because it was a big world to get around to. But at SGS, we did not want to talk to anybody except somebody who had designed <laughs> the 4000, and they came, and solved our problem for it, on the spot.

Sakamoto: Great! Jim?

Healy: One of the experiences I had is in Japan, naturally. And the way these testers worked, you'd have an operator putting a device in eight hours a day. And the relays were noisy. <click-click-click> So you had to relay audio signature that they would memorize-- they would know it. And they'd say, "Problem!" they'd say-- they would listen to the relays. And they could tell you where the problem was. Not specific where it was, but there was a problem, okay? And they could-- for example, you had to measure these devices, and then you later on looked at the results. They could tell you upfront, they'd say, "That's not right. Something's wrong here." And it would find out that there was a leakage problem or some other problem, because one relay was stuck or whatever it might have been. So I find my first line of defense was find the operator and say, when they called and said there's a problem, there's a yield box or whatever, I'd find the operator and say, "What's going on?" She say, "When I do this, this happens." That was the first line of defense that I-- the second issue was, as I said earlier, the RTLs, they're noisy. And we had situations where it seems like between noon and 12:30, a lot of the testers would fail. <laughter> And why, right? And I'm trying to troubleshoot these things, and I have no idea why. I'd have scopes hooked up and everything. Couldn't figure out why they were failing. But I did notice it was specific times of day. And it was interesting, because it was lunchtime when people went away. And the load changed, and the ground actually moved because of the noise, and the tester would start screwing up. You wouldn't get the right measurements. The solution to that was we actually took copper bars and put them into the ground and then wired the cooper bar to the ground line on the tester to drive the noise down. So those kind of problems you're not going to find from engineering, and you're not going to be able to find in any book.

Hines: Right.

Healy: You got to experience it, and it really was. There was a close emotional relationship between the operators in those days and the equipment.

Sello: Yes, there was.

Healy: It was like having a pony or a horse which you got close to. These things were-- each one was different. They're all-- 'cause they're all kind of handmade. They weren't done today. The specs were a little bit different. So each had their own personality. Each tester.

Wiesen: Yes.

Healy: It was very interesting to understand the personality of the different testers. Which probably makes no sense today, but that's the way it was in those days.

Sello: It paid off.

Healy: Yep.

Hines: So I have a show-and-tell thing in my briefcase, if Wes could-- I just-- to answer Harry's question here with--

<crew talk>

Sello: I'm learning stuff about SGS that I didn't know when I started. <laughter>

<Tom is taking some items from a briefcase>

Wiesen: <laughs> Oh, I've seen those, yeah. The test boxes.

Hines: This is an old load board.

Wiesen: Oh, yeah, that's the later version.

Sello: The later platform.

Hines: Anyway, put this behind me.

Wiesen: Is this a 4K load board?

Hines: Right there?

Healy: Wow.

Wiesen: Is that a 4k load board?

Hines: No, that isn't.

Wiesen: That's Sentry, yeah.

Sakamoto: If we could angle that up just a little bit for shots?

Hines: So this is what we tested the tester with. In this little box is just precision resistors. That's it. And so we would force a current, know what the resistance is, and you would know what the voltage would be, so if the thing failed and you had to dig in the system and find out what exactly was going on. So you know, when you have the digiswitches, and you just dial up the voltage, or whatever parameter you're trying to measure, whatever pin, and you plug a couple leads in here, and...

<overlapping conversation>

Sello: Would you have to go to each setting on the digiswitch to do that? Or just run, you know?

Hines: Well, yeah, you would just flip through the digiswitches.

Sello: Flip through them, I see.

Hines: Set them to whatever voltage you needed. So.

Sello: Where were you when we needed you? <laughter>

Hines: Jim taught me this. He hired me into Fairchild back in '66, and first thing he said I had to build was one of these things. And I did. And this it! <laughter>

Healy: I saw that.

Sello: Was that in Japan?

Hines: No, it was in LA. Los Angeles office.

Healy: He worked with me in Los Angeles.

Hines: And I think I was hired into Fairchild, Jim hired me into Fairchild in the Los Angeles office. I worked for six/eight months before I ever got to Mountain View to sign the papers to become an employee. <laughter>

Healy: Those were the days.

Hines: Those were the days, yes. I couldn't even get in the-- when I did finally go up to the plant, I couldn't get in, because I didn't have a badge. And they had to come out and escort me in to personnel, so I could--

Healy: Sign up.

Hines: Sign up. In the meantime, he was training me on the testers, so by the time I got to the training stage, I knew as much as the trainer knew.

Healy: That's right.

Sakamoto: That's super. That's back in the days of super high growth.

Sello: Who built the board?

Hines: This is actually a pier electronic, a pier board. But this was a load board for like a Series 21. This is eventually what-- the devices got so big and so complicated that all this extra stuff out here is just to stimulate the device under test. So that's one thing the later systems had, PBFY, tester verification programs and load boards, which were just a bunch of resistors, precision resistors.

Healy: That replaced that over time.

Sello: I see.

Wiesen: But we also had punch tape, too. Remember? We used to do our own diagnostic tapes. Remember that? Offline, we'd go ahead and program it up ourselves. And the ones that would work, you'd figure out for what were the sequences you were having problems with.

Hines: But they also had...

Wiesen: And you could go run those. And once you had them, you carried that with you. That was your--

Sello: That was when support engineers had to work.

Wiesen: Your backup. Oh, yeah, it was fun, though. We had a lot of fun.

Hines: Yeah, but they also had punch cards. Remember the IBM punch cards?

Healy: Yep, that was paper. Yeah.

Wiesen: Yep.

Hines: Yeah, so.

Sakamoto: Well, that's great. I think that's super. I think what we'll do now is why don't we go ahead and adjourn this first part of the discussion. We'll take a brief break. And exchange the fourth seat.

Sello: Fine, perfect.

Sakamoto: And then get on with the second half.

Healy: We're tired of listening to you.

Sakamoto: So we're ready to go ahead and being the second section of our discussion which will really focus on the user experience, and for that we have added Mr. Wesley Wong. And so Wesley, could you reintroduce yourself, and talk a little bit about your background, and how you intercepted the 4000.

Wesley Wong: Great. I was going to school at the time, and I was looking for an evening job, so I started working for Siliconix in 1985 while going to college. And the reason they hired me was they couldn't find people to work the late shift. They wanted someone like a guinea pig to kind of service these testers, to get it through the night shift in order for the day shift to take over, more experienced people there. So I worked on the 4000 for about two-and-a-half years during that time. So then after that, I've since gone on and gone into project engineering for several companies, and manufacturing engineering. And the last 15 years, I've been working for the subcontract selling test services, so I worked with a lot of renowned test companies, such as STATS, or UTAC in that area. And saw the migration of the early 4000 to more renowned testers, the way we're seeing these days here. Currently, I'm also working for Jim at Sony these days, running Sales and Business Development for him.

Sakamoto: Great, thank you! So going forward, after the original generation of the 4000 we've discussed, and all the factors that caused that to happen. It's now in mass production, and it's being used a lot. Maybe we can sort of discuss a little bit about some of the interesting challenges that arose as the 4000 started to reach a lot of broad acceptance and it was used to produce millions and millions of devices. So if we could get someone to kind of lead out with your experience. Perhaps, Wes, you can talk a little bit about how it was to be a user of this piece of equipment that had been out for a few years actually.

Wong: Right. So at the time of Siliconix, I feel, listening to these gentlemen here, it was almost like the dinosaur era, <laughter> and then I was coming into the mammoth wooly portion, right? So there was a fight between continuing to maintain using the old systems, and integration of the newer systems, such as the Sentry 21s and some of those testers that were coming onboard. But in many you find at the time that many of the operators and engineers preferred using the 4000 just for the fact that it was the ease of use, and the uptime was always very quick on those systems versus the newer systems that were coming onboard. And we found that production throughput was always much better on those systems versus the newer systems at the time.

Sakamoto: Interesting. What was your experience actually using it? Did you have to do any of the paper tapes?

Wong: I did the paper tapes. I had to set up for the operators. I did the PMs [preventive maintenance], the calibrations. Replacing the mercury-wetted relays. And basically replacing everything in the system. So that was part of my job as an equipment maintenance technician responsibility is to replace everything in the system when it failed. Changing the power supplies, changing the little pins on the connectors. So you name it-- everything I've done in that system.

Sakamoto: When you compare the 4000 series testers and the newer generation machines that you mentioned, what were some of the major differences from your user perspective?

Wong: Probably physically actually seeing things there versus something on a little small board, where you have to take it to a bench, or running a diagnostic on several pieces of equipment. You can actually physically see things happening. As Jim talked about earlier, you can hear the relays clicking on and off. You kind of knew, it's almost music to your ears. You can almost feel when things were working or not working. And you immediately knew which DPS had a problem and which didn't. And just the fact that you could actually, like I said, see and feel the things that were moving around.

Sakamoto: That's a very lost experience for folks today. How about for some of the rest of you? What were some of the challenges in continuing to sell the 4000, or even its immediate successors?

Healy: Oh, I'll tell ya one experience I had is that as time went on, they started building various kinds of options, like they'd have a plug-in option to do AC parameters, or low-leakage tests, this kind of thing. So there was a new option which came out, it's called a low-leakage measurement option. And it cost $1,650. Now the tester itself in those days was $40,000, a lot of money. So $1,600 back in the '60s was a lot of money, and it would buy this option. The option consisted of a resistor. And you had to go in and take the old resistor off, and put the new resistor on. Now that could be quite embarrassing. <laughs> If you go in there with the option. Right? So I had to hide it. I would hide it, and would not let the guy see. "Yes, there's a lot of work here. Lot of work. Lot of work." You know, and I'd go in there, and I'd go in the back of the machine, open up, and started playing around, when no one's around, then I'd finally get around and switch the resistor. I'd say, "Okay, your option's installed." And that's what I had to go through. And in those days, they didn't have like inspection coming into some central area and then they'd-- they bought the option, I brought it down as a service engineer to install it. So I had to make a lot of mechanizations, I did a lot of different things so the customer didn't know what he was paying $1,600 for. Because they could have bought their own resistor and plugged it in.

Hines: Yep.

Sakamoto: You know, to put that in perspective for anyone who is listening to this discussion later, about how much did a new car cost in that part of the '60s, relative to the $1,650? It seems to me that that would have been pretty close. Do any of you remember?

Wiesen: That would have been what? ’65 or so?

Healy: I don’t know.

Wiesen: Was that ’65? Around ’65 in that area? Probably, no, they were running-- Fords were running at about, as I recall right, something like $2,500 for the Fords.

Hines: Yeah, interesting.

Wiesen: For just a-- I mean, a well-equipped Ford at that time.

Healy: So the little current option had a lot of margin. <laughter>

Sakamoto: Yeah!

Wiesen: Matter of fact, that was the introduction of the Mustang was in that area.

Healy: Do you recall that option?

Wiesen: Oh, yes, indeed! I had to do that for Fairchild once at their R&D Division. I had a 4000 problem they had there, and I was in there just trying to figure out what was going on with this, and then all of a sudden we realized, well, something was wrong with the measurement resistor in the instrumentation chassis. And they didn’t have the right range. <laughs> So I forget which-- I don’t know what the size of the resistor was from an ohmage standpoint, but it had to be this precision.

Healy: One mg.

Wiesen: It was a one mg, okay. And so I had to do that. And they caught me while I was putting it in. And the guys says, “Is that what you’re charging us...,” there’s was $750, because company.

Healy: That was internal.

Wiesen: Internal, right? And, “Is that what you’re charging me $750 for?” I says, “Don’t shoot me. I’m just the guy doing the job. But I’d like to ask you, “How long has this system been down? While you been waiting to get this thing fixed?” And he says, “Oh, quite a few hours.” I says, “I think this resistor is probably worth it.” <laughs> I didn’t know-- I wasn’t a sales guy! <laughs> You know? And the guy looked at me and says, “Oh, you’re right!” <laughs>

Sakamoto: That's amazing.

Wiesen: Other things, though, that I found is the plugging in and taking out of the load boards and things was-- there were a lot of problems with its sockets going into these things. So that was a lot of maintenance there. And people gladly bought the service contracts. And we were religious about going out there and making sure, as Tom pointed out, making sure that we-- their diagnostics ran. And then we would develop for different programs where they would have problem relays that would show up in the same spot all the time. We developed special diagnostics on our own that would help us go in. And we'd punch our own tape, and go in there and load it in, and run that, and make sure, absolutely sure that that function was going to be reliable, more reliable than it had been. But again, mercury-wetted relays were a lot of the problem.

Hines: I think one of the major problems was environmental. You know, most customers didn't understand that these testers had to run at a cooler temperature than humans run at. So they wouldn't have enough air conditioning in the building to cool a tester, so they would sometimes just run them for a couple hours till the room became so warm, and then shut them off. Wait till things cooled down, and turn them back on. It was crazy!

Sakamoto: That is interesting. Now at the time, did the 4000 connect to robotic or automatic handling equipment? Or was it pretty much all still manual testing?

Healy: Well, with the advent of the DIP circuits, Dual In-Line Circuits, Dual In-Line Packages, they were like little caterpillars, right? We had little-- I don't know if you know what a Dual In-Line looked like. So with Fairchild they developed a handler to handle them automatically, so you didn't have to have a lady sitting there pushing them in and out, and taking them out. And the handler would have a rail, you'd have these little tubes, you'd put the thing at the top, and then they would ride down this rail, okay? And when they got to a certain point, a contact would contact it, and then the cables went back to the 4000 tester, and it would be able to test it. So it's testing automatically like this. Okay? On this rail. That worked pretty good. I don't know if-- it'd jam once in a while. But then I got the idea, "Well, now we gotta do environmental testing: hot and cold." Right? So they would cool it, and of course, things froze and things stopped. And it was just a disaster. <laughs> What had to be the worst piece of equipment the company ever invented was this handler. Of course, later on, a whole industry developed around handling systems.

Hines: Right.

Wiesen: Yeah.

Healy: But that was the first handler that I remember. Now they did have for the TO, sort of-- other kinds of packages that had a rotary handler.

Wiesen: Yeah, with a-- it vibrated ____________.

<overlapping conversation>

Healy: Not for IC. It was really a DIP circuit that created the need for handlers. And it took time before they got something that worked. What was your experience with the handlers?

Hines: Yep, same thing. They-- well, they were always a problem, handlers were. If you could prove that at the test head that everything was running. Then the handlers were somebody else's problem. <laughs> Not ours. "Call the handler company." But yeah, and it was pretty easy to prove, if you took the device and the same device that was failing on the handler. And you just plug it in the socket at the test head, and pass-pass-pass, so that was not our problem, so.

Wong: When we had the 4000, we started interfacing in time, the Simtech handlers, and the teleprobers to them. That was time they were trying to introduce, like Jim was saying, introduce non-- people not to be touching the parts. They wanted equipment to handle that. And you start plugging the LN^2 tanks next to these equipment, and we started finding out, after time, that the Freon that was spilling out from these LN^2 tanks were getting onto the 4k systems and creating a whole bunch of different issues with them. Busting the pins, etcetera. And we started realizing, "This is creating a different problem with these handlers with the tester." So we had to find ways to protect the LN^2 Tanks from the 4k systems. They realized that the moisture building up on the systems was creating problems with these.

Wiesen: Wow.

Healy: I remember-- maybe Harry will remember this, it was when Fairchild joined divisions with TDK in Japan, called TDK-Fairchild to develop the integrated circuits. And they, of course, had some 4000s come in. Now TDK made ferrite quartz. Ferrite is iron, right? So the whole place had ferrite dust everywhere. It was unbelievable. And you would try to explain in Japanese, you can't put these-- it won't work here in this environment. They wouldn't understand that. They didn't believe that. And this ferrite dust would come in, and you would have some really unique problems to go solve. <laughter>

Hines: Yeah.

Healy: You remember that?

Wiesen: Yeah, and the other aspect was pulling the cards in and out quite a bit, then the copper would wear off, and then you'd get all kinds of intermittent things that were occurring there, and it'd be a real challenge to figure out what those were.

Healy: One of my best tools for fixing testers...

Wiesen: Eraser.

Healy: ...was an eraser.

Wiesen: Eraser.

Healy: Things didn't work, I'd unplug the board, erase the connections.

Hines: Yep, absolutely.

Healy: And then put it back in.

Wiesen: And that passed on to future generations, too, so.

Healy: The eraser. You always had a good eraser with you.

Wong: I used it. I used it.

Healy: You used an eraser, too.

Wong: Absolutely. Absolutely. <laughter>

Hines: It's true.

Wiesen: Modern-- those were the advances in modern science from a field service point of view.

Wong: Be interesting to see whenever you do the PMs on these, you would find eraser dust in there, and you'd wonder what's going on. You'd find finger cots, eraser dust all within the chassis and everything.

Wiesen: Sometimes some food in there. <laughter>

Hines: The operator...

Wong: Cigarette ashes.

Wiesen: <inaudible> but that was a different configuration.

Hines: The operator would accidentally knock a cup of coffee over and dump it right into the test head. That was always-- with lots of sugar in it, too.

Wong: Because you could smoke on the floor back then.

Sakamoto: That's an interesting point, I guess, back at the time, it was-- people smoked cigarettes in the building.

Healy: Yeah.

Sello (off camera): Oh, yes.

Hines: Yeah.

Wong: Yeah.

Wiesen: You get films.

Healy: Drank coffee.

Hines: Yeah.

Sakamoto: It is interesting. Is there any kind of like particular-- you know, in my experience in testers, every new test system has its moment of calamity as it's being developed before it's perfected. There's always the ones that ended up shipping, they were okay when they left. They died the moment they hit the customer floor. They catch on fire. You know, liquid- cooled systems inevitably leak water. Can you think of any particular calamity that happened with the 4000 that-- I think the statute of limitations is over now, so you can like mention? <laughter>

Hines: I can't uh...

Wiesen: I didn't have any meltdowns on 4000s.

Hines: No.

Wiesen: Grounding problems.

Healy: Grounding problems, I mentioned. In fact, since I solved the problem in Japan, I was called back from Japan to Portland, Oregon. Portland-- excuse me-- *Maine*, to the Fairchild factory, because they were having similar kind of intermittent problems, and heard I'd solved the problem in Japan, so they flew me from Japan to Maine to do-- and I said the same thing. I said, "We got to put a copper post into the ground." They thought I was crazy! And then they really did it right, though. Then they dug holes and they put some kind of rocks in there. Then they put the copper posts in and they had these all lined up. So that noise, the noise level, the shifting. And I think that the unusual problems I always find from time to time was something like that. The noise would shift it. The noise around it. In fact, something that's totally independent to the tester, the environment had some impact on the tester in those days. It really became-- I know one-- you were talking about a prober, they had probers one time that every time the prober moved, it was always going on the tester somewhere else, would impact the tester. Because it'd spike on the line.

Wiesen: Spikes on the power lines, yeah.

Healy: Because at that time we didn't have power line filters.

Hines: Conditioner, yeah.

Healy: So I would say the thing I would find is the tester itself was fine, it'd work. But the environment would impact it. Where, nowadays, less of impact.

Wiesen: Yeah, I had to get the machine shop over at Raytheon on a system there one time. Same problem. They had moved the machine. And they had moved it from where it was running just fine, they moved up on this floor that just had a linoleum tiled floor. It was not a special room for it, but had been like a big work area before that. And it was having all kinds of weird problems. So I decided, "Well, what the heck. Let me see if I can get a cable, a braided cable, and ground strap." And I took it into the bathroom. I got it from their machine shop. They had one there. They just put a clamp on each end of it. So I put it on the bathroom pipe underneath the sink, and all of a sudden, everything came on, and it worked perfectly. And they thought I was a genius. <laughter> It didn't have anything to do with being a genius. Just common sense, you know?

Hines: I had the same problem in Mexico City at Fairchild Semiconductor in Mexico City with noise. They were running 220 volts with no ground.

Wiesen: Ooh!

Hines: I mean, it was just floating. People would touch the tester and get shocked.

Wiesen: Amen, ooh.

Hines: We had to tie them all together and ground them. So.

Wiesen: I had that problem on a 5000. I had Delco, and it was just by accident, I had my screwdriver in my hand when I moved that scope cart. And thank god it was touching the rail of the cart, and it touched just the system itself, ’cause they get a memory drop-- it’s not 4000, but just to show you the danger of something like this. They’d been operating this thing for three years in the same exact spot. I asked them, “Have you moved the tester?” “No.” “Bam.” Ended up there was a disconnect, there was no center tap on the “Y” transformer that was connected to ground. It was floating. It was absolutely floating, and the cart was plugged into the system ground, because it was properly grounded. The cart was grounded properly, the system wasn’t. It blew a quarter inch off the tip of that screwdriver. Quarter-inch screwdriver.

Healy: Dangerous days.

Wiesen: Yeah.

Hines: Yeah.

Wiesen: But anyhow, nobody got hurt on that one, thank god.

Healy: One of the other things about the 4000s, up until that time, all testers, basically, were parametric testers. Measure, send the current, measure the voltage, whatever, measure the power. And the 4000 was the first tester to have-- with burst patterns or pulses to the device because these were ICs now. The IC, unlike the transistor, there’s ICs within the part, transistor of the part, and they turn on and off. And so you send a pattern, you’re expecting a certain pattern out. All right? And no one had done it that way before. So the 4000 would burst these programs-- you’d actually program the wave form that you wanted to go in, and then you would measure the output. And that could be-- that was very interesting, because no one quite knew that had not been done before, to be able to actually functionally test the part to see does one-plus-one really come out to two? Or what does it come out to? And so that was the beginning of functional testing of the chip itself to see not only did it work parametrically-- in other words, are the currents and voltage right-- but if you put a certain input, did the output, did you get an output that you were expecting? That was, I think, the 4000 first tester that had that capability.

Sakamoto: Well, that brings another question which his, first tester to have that capability, first tester to really be able to test the functionality of early digital integrated circuits: How did you prove this concept to your early customers, because they didn’t have a tool like this before outside of their labs. And my guess would be that probably observed the output of their early ICs perhaps visually on an oscilloscope or other instrument. Now you’ve generated essentially a box that gives you a light at the end, and says it’s red for bad, green for good. I think it’s what we discussed earlier. And so now you’ve got this different level of confidence that exists or not that it’s actually done something. How did you prove this to anyone, and even much later, how do you have anything to correlate to a tester that by then is 20-years-old, Wes?

Wong: That’s true. Well, during that time, thankfully, we had the data log capability, you know, the 4k had that capability, so whenever we were audited, we had data to show the results. And we also did bench tests to prove the same results, too, within the certain amount of tolerance with the device. So I think from that point of view that customers never challenged whatever the 4000 results were, because we had that capability in hand.

Sakamoto: Interesting. How about back in the beginning?

Hines: Well, you had programs and a golden device.

Wiesen: Golden parts or quartz parts, yeah.

Hines: Golden device you'd call it that you'd carry in your service kit, and put the program in there and hit the button, and they would pass. <laughter>

Wiesen: Seriously, that's about the best we could do in those days.

Sakamoto: Wow, you guys were lucky. You had nicer customers than me.

Wiesen: Well, scopes were improving, too. So you could still look at things, but then figuring out how to get the right kind of sync pulse, and things like that. It just took some pretty tricky things that you had to do try and figure it all out before all the added sync points and things like that were put onto the platforms. So.

Healy: The easiest way actually, as Wes said, is look at the data log results. You got one/zero/one/zero and then you look in there and say is that one/zero/zero/one/zero the correct output? If it is you're okay.

Sakamoto: Now another thought is in the beginning all the testers were located at Fairchild, right? But eventually as they got located in further and further away places. You know, today we know that there is automatic test equipment in garages in unknown places in the world. But during those early days, what was the most unusual place, you can remember, from the first ten/fifteen years, or these 4000 systems being placed? Where did you find one, or sell one, that was kind of unexpected?

Hines: I had a couple experiences in Europe. One was to install a system on a shipping doc in the sheet metal factory. They came up with the story that they were going to move the tester to their facility, which was under construction. And so when I went to install it, there wasn't enough power to even power it up on the shipping dock. And so they said, "Well, just make sure it's all there." And so I did. And they signed the installation report, and I went on my merry way. And a couple of years later, I was back in the US, and I got a summons from the US Customs Service to go to Washington, DC to give depositions about a tester that went behind the iron curtain. Which is the tester I installed. They had the original installation report with my signature on it. And so I couldn't lie about it.

Healy: You’re the culprit, huh?

Hines: And Fairchild had a corporate lawyer from New York meet me and go with me to make sure I didn’t say the wrong things. And it was pretty funny because they asked me if I’d ever had any other kind of strange installations in Europe. And I said, “Yes, there was one in Wiesbaden where I completely took a 5000 system apart and pulled it through a window into this garage under this house. They had paneled the whole front of it up. And then reassembled it inside this garage. And he was using it for a test facility.” And they said, “Well, what was this guy’s name?” And I said, “It was Wolfgang Prenosil.”

Healy: Yeah.

Hines: <laughs> Jim knows him. And they knew who he was, and they said, “Well, what did you think of this guy?” And I said, “Well, he’s kind of like your average gangster.” <laughs> And the attorney grabs my arm, and he says, “You can’t say that! You can’t say that!” <laughter> Too late! I already said it. <laughter> So they already knew about him. So he was on their list.

Sakamoto: That’s interesting. About how big was the 4000 that they had to pull it through windows?

Hines: It was a 5000, which was the next tester. It was five bays. Like a 4000, only five bays, I think.

Wiesen: Oh, that was a big one, yeah.

Hines: Yeah, had every option on it.

Wiesen: Yeah.

Sakamoto: Wow, and so maybe for folks who are kind of outside this, a bay is about the size of a refrigerator or so?

Hines: It’s about this-- what two feet?

Wiesen: It’s like, and then about what six feet high, something. Five-and-a-half feet high, yeah.

Sakamoto: So that had to be an interesting install.

Hines: Yes, well, it’s all just rack now. Everything is on rails, so you just had to de-cable all the back stuff, take it all out. Pass it through the window, and then take the bays apart and tip them over and hand in through the window.

Healy: I had to repair one once, actually the 500 in Ipoh, Carter Semiconductor in Ipoh. Ipoh is a city half-way up the-- it’s in Malaysia about 100 miles north of Kuala Lumpur.

Wong: Up the west coast, yeah.

Healy: And you go into KL, and then from there you had to get to Ipoh. And right now there’s a superhighway goes right up there. At that time, there was no superhighway. There were these winding roads that you had you had to travel on. You had to look out for two things-- this is not a joke-- gangsters and tigers. <laughter> And I am dead serious. And this place was like in the middle of nowhere! In a jungle! And the charter was a Hong Kong company that then set up their factory over there in the middle of nowhere. Ipoh is now a pretty big center.

Wiesen: Industrial, yeah.

Healy: Industrial, but at that time, the early days, look out for the bandits, and look out for the tigers. You don’t get out of your car.

Sakamoto: Check.

Healy: Because I put testers all over Asia. Places I remember: in Cebu, an island in the Philippines. That was a difficult place to even get to. Okay, then you had in the Philippines you also had a beautiful area, I forgot the-- Baguio, where TI is basically set up. That was gorgeous. That was just a very nice area to go to. So they were all different. I remember one installation I did at Fine Products in Taiwan, early, early days. Because RCA set up in Taiwan. The first-- the Fairchild of Taiwan was RCA, because they were the first company to go into Taiwan. And of course, they had the 4000. So I used to repair them and train them and do all these things. So then Fine Products, which was actually a textile company decided to get into the semiconductor business. So they bought a 4000. I had to go and install it there. And it was in a textile factory. And if you think about textile sweat shop, that’s exactly what it was. Girls were over there sewing things and that kind of thing, and I’m putting a tester... <laughs>

Wiesen: Right in the middle.

Healy: Among all this stuff with these sewing machines going. It was unbelievable. <laughter>

Wiesen: It was a clean room, right? Because they washed the clothes, I guess. <laughter>

Healy: Interesting place.

Sakamoto: How about applications? What was the most interesting component that you saw go through the 4000 that comes to mind?

Healy: Well, I know we used to do a lot of different kind of modules on it. They were weird. You didn't know what the module consisted of, and we would jerry-rig it up with. And then you had no idea what it was. But I can't recall any...

Hines: I think the most interesting one I saw was-- it was Nitron, they were building fuses for bombs. And so my question was, "How do you test a fuse?" Once you've blown the fuse, throw it out. But they tested them on the 4000.

Sakamoto: Well, I was thinking that might actually have resulted in more tester sales, right?

Wiesen: Yeah, the damage. <laughs>

Sello (off camera): I wonder if that's where their name came from.

Healy: How about just the overall impact that this had? This was a revolutionary capability for mass production at the time. So it must have had a tremendous impact on the industry. Do any of you kind of recall any of the macro factors that this influenced outside of just the actual machine itself?

Healy: Oh, mass production?

Sakamoto: Yeah.

Healy: There was no mass production product. Maybe the circuits were mass produced because of the tester. You couldn't mass produce them any other way. If you had to test them all by hand forever...

Sello (off camera): Oh, your overhead cost would be ridiculous.

Healy: You think before the 4000, a stack of instruments, you'd have to wire everything up and hook it up and then measure it and try to figure out each one was done manually, so it might take you three or four hours to test one chip, where here you do it in a couple seconds. So it's the ability to facilitate a mass production, I would say is the thing that really created the mass production industry.

Hines: And I think with Fairchild, what they did is they actually got their engineers together with the semiconductor companies, engineers, and they signed nondisclosures, so that they knew what the new product was going to be, and they would develop the tester to test that product before it was seen on the market. So I mean, that opened huge doors to the selling of the testers.

Wiesen: Yeah, rolling back on the 4000s, wasn't the first memory that they used on it, wasn't it a drum?

Healy: Yep.

Wiesen: They used a drum memory first. And then it migrated to the disk.

Healy: Mag drums were fun. Remember those? Because you had the little sensors. What do you call-- that picks up the-- I guess they're called sensors. I don't know which-- I can't remember the name you call them.

Wiesen: The head, you'd see the back of the head. So these big drums would roll, and then you had little holes all across it. And the sensor was in the hole. Now the way you adjusted it was physically move the sensor back and forth until you got a good signal. Then you had to hold it in place. And there was a hundred of these sensors. You remember those? Working on those? That could be fun. Because the tester would start failing devices, you got yield loss. You go in and find out that it's getting the wrong information from the drum.

Wiesen: Or the drum would wobble.

Healy: Or it'd wobble, or what I'm saying, you'd have to go in and manually adjust each head.

Sakamoto: Wow.

Wiesen: And torque it.

Sakamoto: So Wes, when you intercepted the machine as a user, once again a few years later, did it still have the old magnetic drum memory, and all these other features?

Wong: It did. And we started integrating-- we started putting the drives in there. And it was an option that you can put in, but then I like to share with them. I dropped one of those drives on my foot, because the brackets at the time were so thin, and the drives were so heavy that when you pulled it out, it would not support the weight as well, and one time it just dropped. So that was like-- I was in the middle of a case where they were trying to shove more options into this system. They figured, “Hey, let's put a drive in here,” and based on the chassis itself, it wasn't able to support the weight possibly. But the main way to improve the system, our team decided to fix the bracketing system they had in there. But it was interesting to see that transition where they went into-- making a drum into an actual drive, so that people could store programs on there and their data logs.

Sakamoto: Did you ever have to develop a new program for the 4000?

Wong: No, never did that.

Sakamoto: Just curious, because it would be interesting to get a comparison of the program development for the 4000 versus say the next generation of machines.

Healy: Well, it's very easy. The 4000 had a series of digiswitches. So all you did was say how long-- what value, what do you want-- these four control one pause phase, these control the next pause, these could control the ones and zeroes for the functional patterns. So you just sit there with a paper and you just plug them in. And later on, you program it into a paper tape.

Wong: Paper tape.

Wiesen: That's when I was onboard.

Healy: That became automation. So now you do the same thing and just program them-- you remember it's a fixed word format. So the word had one meaning. So it was really easy. I think on the 5000 with the HP computers, became a whole different ballgame. I'm sorry, DP-PH first.

Hines: Yeah.

Wiesen: Yeah.

Healy: Where you had to think octal. For years I thought octal. <laughter> Everything I did was octal.

Sakamoto: Yeah, amen.

Hines: Yep.

Healy: So actually, it was very easy to program.

Wong: You just flick that switch on and then reel the tape in, and then you program it.

Sakamoto: So actually in a way, it took a lot of years for the industry to get back around to making it easy again. <laughter>

Hines: True.

Sakamoto: So I think actually, Tom, you brought another load board in in the middle of the table. Maybe it would be good to just discuss what that is and how that relates to the 4000. It's a later generation machine.

Hines: Right. This is off a later generation, which I think it was probably a Sentry 7. Well, Fairchild went through so many testers, it was incredible. Remember, they went from the 5000, they went to 600, and then the 610, the 670, the Sentry 2.

Wiesen: Sentry 1 you missed. Cassette drive.

Hines: Yeah, the 100.

Wiesen: Cassette loaded. <laughs>

Hines: Yeah, Sentry 100. Anyway, this load board pretty much fit all of those testers. And so as the testers got more complex-- not the testers and the device, then you had to put more and more external circuits on the load board. This is a load board. The device goes in here. Device under test. Or you would hook a handler to this center portion, and it would run through the handler. But as they got more and more complex, you had to get more exotic with your load boards. And then speaking of load boards, that's another thing where they were very open architecture about, because this particular load board was built by Peer Electronics, which was a startup that just load boards for the Sentry Systems. And he was very successful at it. He had a real broad product line for Sentry load boards. I think Sentry buying-- or Fairchild started buying them from Peer Electronics in the later years.

Healy: I think you made a good point. One of the reasons-- another reason for the commercial success of the 4000 is as Tom says, it's an open architecture. Which means you would allow other companies to build things for us, even spare parts for us. So people anywhere in the world had access to what they needed to make this base machine work. It's like the PCs versus Apple. Apple is closed; PC was open. Sun was open and Apollo was closed. I mean, so they had an open architecture. And a lot of people today write apps for Apple iPads. These guys wrote programs, and built load boards. They did all kinds of things for the tester to use for specific applications. So even though it was designed to do, one thing, test ICs; it did a lot of other things as well, because of this open architecture and the ability to-- Fairchild taught you how to make one if you wanted to, which Ando did.

Hines: It started a lot of industries. Like Jim said, programmers, if you didn't like the cost of a Fairchild program, you could hire another company, third party that would write the program's software for you, and do the programs cheaper, and they were actually trained by Fairchild, all of them. So they went on with it.

Sakamoto: Well, it's interesting to note, 20 years before the birth of the PC, we have this kind of unsung hero of an industry that gave rise to what we've already mentioned, handling equipment. Now these interface load boards to hook up to that equipment.

Healy: Probe cards.

Sakamoto: Probe cards. You've got-- and the programmers themselves. Any other thoughts about other industries that this helped generate?

Hines: Well, third party service companies like my company for 20 years. I enhanced the Sentry line and sold options and competed with Fairchild. Actually they were purchased by Schlumberger, by then, the French company. And so as far as Fairchild is concerned, the upper management was very upset about me. They didn't like my company competing with them in the field service. But the sales and marketing department loved us, because there was another option. If they didn't like the Fairchild field service, they would have the third party to go to. And cheaper. So we brought prices down big time.

Sakamoto: So that sounds great and helped grow the industry overall. So why don't we go through and get any kind of last comments that any of you have, or thoughts about the 4000, and collect a little bit of your thought about how that actually, once again, we talked about it helping start mass production, but any other thoughts about the impact that it had, and what it led to? And just any other comments that you want to make are fine. So anyone want to start?

Healy: Well, I think it led to standardization. Because of the automatic 4000 tester, people started doing all the tests the same way. A specific way. And that created a whole industry in quality, and a whole industry in the sense of the way things were done. So that if you could take a device and plug it into a 4000 tester anywhere in the world, you'd get the same results. Okay? So it created a standardization of the way you tested. Prior to that, testing was done by everybody in all kinds of different ways.

Hines: Right.

Healy: And it became the standard. And people say, "If it doesn't run on 4000, we don't buy it." It doesn't work. So I would say the biggest impact in addition to automation in the sense of mass production, was standardization of test process.

Sakamoto: Okay, so that's interesting. So previously, they weren't really interchangeable parts across different systems and designs. This now enabled someone, with confidence, to understand that whatever it was supposed to be is however it was.

Healy: Right, if it passed on the 4000, and then you had bought from another company, and it had to pass as well.

Hines: Pretty much it was incoming inspection. And so every customer had an incoming inspection, so they had to pretty much standardized on the 4000, which the manufacturer used to test that product on. And then it would go to the company purchasing it, and they'd test it on a 4000.

Wiesen: Some of the processes that were generated then got passed up the line as you made new generations of testers. So it was sort of the baseline for process control for testing.

Sakamoto: It's interesting, 'cause Jim had mentioned earlier that this was the proto-design that was still followed at some level today by all modern test equipment, and actually is the process around it. Sounds like it was also the progenitor of that.

Wong: Things got a little smaller. Miniaturization. I think once the 4000 was popularly used in Siliconix, for instance, folks were developing other testers, smaller bench-top models based on that same concept used for the 4000. We had a tester called a Velox Tester, which basically became TMT, that was sold into Credence. That came from that same concept of the 4000. So you know, from that point on, I could see a lot of the portions of that becoming miniaturized and getting into a different area.

Sakamoto: Okay, well, any last comments from anyone? Okay, if not, we'll go ahead and we'll wind up. Say thank you all for sharing all of your thoughts and memories about the 4000. It's interesting to hear about the source, or the DNA, of our whole test equipment industry. And the billions of dollars of equipment that have been sold since then, of one of these early, unsung heroes of making sure that the IC revolution can become the piece of the computer revolution that it has been. So with that, thank you all very much again. And we'll close.

Wong: Thank you.

Hines: Thank you.

Wiesen: Thank you.

Healy: Thanks.

END OF PANEL SESSION

