Oral History of Jack Ward

Interviewed by:
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Laws: Hello, good morning. At least it's good morning here in California. Jack, I believe it's early afternoon there in Boston. My name's David Laws, I'm semiconductor curator at the Computer History Museum in Mountain View, California, and it is April the 27th, 2021. We are one year into the great pandemic that's been sweeping the country, and this'll be one of the first oral histories that I have done via teleconference. Jack Ward is at his home in Brookline, just outside Boston. Jack has a long and interesting career in the electronics industry. He's an electronic engineer, but he also started a semiconductor museum and has collected a considerable amount of interesting information and documents from the early days of the semiconductor business. Jack also has been extraordinarily generous with sharing some of his work with the Computer History Museum, and providing documents and devices for the collection. So welcome, Jack. Perhaps we could start with you telling me a little bit about your background. Where were you born? Where were you raised?

Ward: Good to talk to you again, David. I miss our somewhat infrequent but in-person interactions that we had prior to COVID. So, yes, I'll be happy to do some background discussion. I'm a boomer, as they say. Was born in '49, and curiously enough, that's approximately the same time, within a year or 2, of when the transistor was invented. I don't know if the stars were aligned, or exactly what. But I grew up in the South, rural South, and did not have much contact with technology for a number of years. I left the South in my teenage years and moved up to Illinois, outside Chicago. So that was a shock in a number of ways. But I remember my long summer days in the South growing up, and at that time, maybe we'll get into this, my father, who worked for the US Air Force, was supplying me with salvage, early transistor devices. And these would be boards that would be covered with this thick shellac, and military grade at the time, just gleaming with transistors, or I would get old junk radios and take them apart. I just have many good recollections of the South growing up with one-hundred-degree temperatures, and very humid. And not much going on, except me sitting in front of a fan with a huge soldering iron trying to connect up some transistors.

Laws: So, you were obviously fascinated with electronics, but this access to radio must also have opened a whole different world than was outside your front door?

Ward: It did, actually. I guess you would call me a hobbyist at that time. And I remember getting my first shortwave tube radio, two tubes, regen set, made by Knight Kit, Allied Radio. I looped this really long wire up around the house and I would sit at night pulling in unbelievable transmissions from across the world, with this little, tiny two tube set messing around with the regen knob, and getting all that squealing going on. It was a real eye-opener, and I think that kind of set the stage for a broader set of interests that I developed. But those are really fun memories.

Laws: Were you able to share this interest with other kids in the area, or relatives? Or was it pretty much alone?

Ward: It was pretty much alone, actually. That's not such a problem when you're 10-years-old. You had other interests in sports, fishing in the swamp, for instance, or chasing alligators, that kind of stuff that you

do when you grow up in the South. But really, other than my father, there was really no one who had an interest in electronics.

Laws:, Kind of different world from Brookline, Massachusetts?

Ward: <laughs> Yeah. No kidding. Totally different. But the whole world's changed. It's hard to think "That was a long time ago."

Laws: Yes, it was. You mentioned your father's background. What did your mother do?

Ward: Well, curiously enough, my mother was-- I guess I would call her an entrepreneur, which in that time, in that place, meant that she had some business acumen. She had started a few businesses, various kinds of service industries, and maybe hotel management, all based on her own go-gettidness [sic], I guess the way to say it, her own motivation and drive. There clearly were no or very few role models. I was impressed, have always been with what she did. She didn't go to college; my father didn't go to college. In fact, no one in my family went to college. But pretty good role models - both from her, with her focus on business and getting stuff done, and my father's exposure to the world of high-tech through the Air Force.

Laws: Sure. Any brothers or sisters?

Ward: Yes, much younger. And so not much in the picture, and delightful additions to the family that I enjoyed very much. But really not involved in the electronics at all.

Laws: How about school? Did you enjoy school? What was your focus there?

Ward: I did actually enjoy school. I don't know if the term "nerd" was around at the time, maybe it was, I'm not sure. I did enjoy school, but I don't think obsessively so. Again, kind of understand the level of instruction and the topics that were available in mid-1950s Mississippi, you can imagine there was not a real focus on high-tech at the time. Although that's changed. But I did, yes, I liked to read, I read a lot. Boy, I sure would've enjoyed the internet back then, but I guess that's not a possibility, huh?

Laws: You had your own international internet through radio. I guess that's about as close as you came?

Ward: It's true, David, when you think about it. That was a real connection to the rest of the world, and it was amazing to me. I think maybe one of the topics we'll talk about is the rapid acceleration of technology and impact on folks. But without that radio, I don't know what would've happened, to be honest with you. Who knows?

Laws: It sounds like your father was the major instigator of your interest in this direction. Can you tell me a bit more about him, what did he do? I know he was in the Air Force. What was his role?

Ward: Yeah, so I think that was his way to be involved in technology and expanding his horizons. He joined the Air Force at an early age and he was initially a jet plane mechanic stationed out of Biloxi. There was a big Air Force base there. He had been an auto mechanic at home, had his own workshop, so he was mechanically inclined. He got really good training in the Air Force with jet engine repair, and then somehow or another, he made the transition from that to electronics repair. I have come across on eBay over the years some of these mid-1950s Air Force training manuals that take you from tube electronics to solid-state. And although I didn't have any that he used, I'm sure he was sitting there with rapt attention looking at here's what tubes do, and here's what solid-state does. So, there was a connection I made with him in that regard. He moved up, he became kind of a supervisor and electronic repairer by that point, mostly all solid-state towards the late '50s, and then became an instructor for an Air Force training school for repair of electronics. And he kept pumping me parts, and books, and would buy me stuff for Christmas, things like that radio I talked about, or every young man's delight, a 50-pound battery that'll last for 5 years that you can use to power all your stuff, or fry all your stuff, if you hook it up wrong, for example. I remember that quite fondly, and that did help me, and I do remember getting a gift from him at the transition from US electronics' supremacy in radios to when the Japanese radios were coming on in the mid '60s. I remember getting a really cool, slick, highly artistic turquoise-blue marvel 6-Transistor Radio from Japan. That was about as good as it got.

Laws: Yeah, I can imagine. It sounds like he was an extraordinary influence and you were very lucky to have that support. You went to college, I understand, and this was way outside of Mississippi. Why the move?

Ward: Yeah, so I went to college at the University of Illinois, which is right outside Chicago, about a hundred miles, and I ended up there because my father was stationed at a huge Air Force base in that area. So that was a pretty good draw and lead-in. I still remember the film that I saw, the training film, when I enrolled in electrical engineering. Oh yeah, that was going to be the path, right? And this would've been in the late '60s. I remember the orientation, there was a video, probably 16 millimeter, or 32, in Technicolor, showing the end point of the career, with about 50 engineers, all men, all clean-cut, white shirts, pocket protectors, over a drafting board. If you can imagine.

Laws: Yes, <laughter> I can. What did you study in college?

Ward: Well, I lasted about a year-and-a-half in engineering, electrical engineering. I did okay, but, really, my heart wasn't in it. And there was a lot going on in the world back then in terms of counterculture. So my interest drifted over to motorcycles, rock music, and anthropology. That seemed like a pretty cool thing to study. So I got my degree in social anthropology and linguistics.

Laws: Very 1960s. <laughter>

Ward: Thank you. <laughs> Yes, it was, and I don't regret that at all because of the way things turned out. But I'm just wondering where I would be today had I stayed in that original role and been one of those engineers with my drafting board.

Laws: Who knows? The turns and twists we take <laughs> along the way that you look back upon. So, you graduated with a degree in anthropology. I doubt if there were too many places you could apply that skill, Jack. What did you do?

Ward: Well, reality sets in at some point. I had my motorcycle, youth, I guess I'll say it that way, traveling the country, and outside, for a while, and then decided to settle down. And in college, I had an internship doing photography. So, I did a lot of work for the university, and at that time, the Computer Center there at University of Illinois was pretty well known worldwide, it may still be. And I left before [John] Bardeen showed up, and I wasn't actually plugged into that at all. But I remember the ILLIAC and taking some pictures of the ILLIAC and some of the circuitry, but of course it didn't dawn on me at the time what I was doing. I was also taking pictures of Indian pot shards that were being dug up from a local dig. But nonetheless, that was kind of an initial exposure. But I had a couple of years of highly memorable adventures, I'll say it that way, and then decided that I probably needed to settle down at some point.

Laws: Did you read "Zen and the Art of Motorcycle Maintenance"? Was that book around about at that time.

Ward: You've been there, David, I can tell. I can tell a kindred spirit, man. <laughter>

Laws: That's for sure. Interesting times. I arrived in the United States in 1968. Walked into Silicon Valley at the height of the Berkeley Free Speech Movement. What a fascinating contrast on opposite sides of the Bay. The techies on the West, and the social radicals on the East, but somehow it all melded together over the years.

Ward: Somehow it did. I'm with you on that. It was amazing to see it all -- and you're trying to pick your career path and what interests you. It's really hard to know. Reality often helps; I really needed a job, and ended up in Ann Arbor with the University of Michigan. And at that time, they were spinning off high-tech companies, like most universities. So I answered a newspaper ad and became the production supervisor for a small startup that was making discrete semiconductor boards, 10 by 12 pc boards, all discrete transistors, well, maybe a couple of the first TTL ICs, but mostly discrete transistors. And these were all peripherals to Data General Nova, 16-bit computer, with a paper tape reader, and my favorite paper tape punch for IO and a screen. It was a text editor. That was the purpose of it, and it would output the appropriate controls, that you could take the paper tape and load it into a typesetting machine at a newspaper. A real niche. They did all the software, which I didn't really get involved in very much. But they designed all their IO stuff to interface around the Nova 1200. So that was really eye-opening. I did the production stuff and helped some with production engineering. It was a really small company. So that kind of got me hooked on I guess you'd call that the minicomputer boom. I guess that's a good way to say it, wouldn't you agree?

Laws: I was at Fairchild, in the early days of Data General, and I remember they were desperately wanting ICs that were in great shortage, and we were busy supplying them to Burroughs, and IBM, and NCR, and all the big companies. And there was this little company, Data General that it turned out a

couple of the Fairchild executives had invested money in. So they got more than their <laughs> fair share of chips. So, I maybe helped your career in some way, Where did this learning experience lead you?

Ward: Well, at the time, I had to do troubleshooting of the Data General and the peripherals, and I guess because my linguistics background was still inkling in my-- back of my ear, I took a part-time job, along with this job, with a tech writer. A local tech writer who was developing troubleshooting service manuals for Data General. It's a matter of looking at a schematic, really simplistic schematics with the tops of maybe ten transistors, right, and explaining the operation. I really liked that, and at about the same time, Data General was expanding. They were really high spurt growth. They were cheaper than DEC, and pretty powerful. So I answered an ad for Data General -- they were starting up a service repair training depot. So I kind of built on my background servicing Data General stuff and tech writing, and worked for a couple of years training Data General service technicians. That then led to I guess it would be a promotion, looking at servicing support for software. So, I learned their operating systems and would be the guy that somebody would call when there was a software problem. I was really happy. I can't complain at all. That was, again, real high-tech growth, and I know you've been out here, David, you drive up route 128, and not that many years ago that was the place to be. Everybody was there.

Laws: I remember-- spent many hours in the old mill at Maynard trying to sell stuff to DEC. <laughs> And then I remember meeting with Dick Sogge at Data General when we were trying to decide whether we should build Schottky TTL or not at Fairchild.

Ward: Yeah, wow. That's--

Laws: Small world--

Ward: -cool.

Laws:, Carry on with the story about how you joined Data General.

Ward: Yeah, I did, and I was working for them for I think maybe three years? But I think the big breakthrough for me, career-wise and professionally, and everything else, was joining Hewlett-Packard. What a difference. At that time HP was building their own minicomputer line, remember the SPARC-RISC architecture? I got into that because they wanted somebody who knew minicomputers, but their sole focus here was medical devices.

Laws: That was up in Waltham?

Ward: Yeah, correct. Exactly right. It's been taken over by-- I don't know who. But they're long gone. I spent many years, 20 years with HP. What a phenomenal place to work. I met both Packard and Hewlett, and then John Young when he was working, and it was just an eye-opener to see how a real company could be run, how people were treated. They had at that time a whole resort area with cabins down on Cape Cod that they had bought for their employees. And during the summer you could sign up for a week to take your family down there, it was just unbelievable how well you were treated.

Laws: And it was a time of great transition for HP as well, growing dramatically in the minicomputer business, their 3000 series computers, and then, of course, into the printer era. Were you aware of the politics on the West Coast?

Ward: Not so much. I was pretty much isolated. The Medical Products Group, which was what I was a part of, really kind of had a life of its own, because of the FDA regulations and requirements. And to be honest, we were kind of used as an example about how to do rigor in software design, rigor and hardware design. In addition to seeing the HP way, I got to see Galactic Headquarters there on Page Mill Road. And I used to love-- take my vacation-– I'm sorry, business trips out to Palo Alto when it was twenty-seven below zero in Boston, and it was springtime there. I just used to love going out there, made a lot of friends, and had I known what I know now with that time, with everything going on, and with Shockley, with Fairchild, with Rheem and Signetics, I sure would've made a better use of that time. But you just never know.

Laws: Well, it sounds like you put it to good use, personally. Did you ever come across Bill Kampe? Bill was involved in high-level quality control at HP. Was there for about 50 years.

Ward: The name sounds very familiar to me, actually.

Laws: He's a neighbor of mine just down the street here in Pacific Grove. He actually served as Mayor for the last four years or so, and he is on my list to do an oral history sometime down the road. I'll let you know when that happens, you might see a familiar face.

Ward: That would be great. And I'm not sure I worked with him, but HP, as you know at that time, really focused on quality. And quality not at the expense of other stuff, but had such a phenomenal reputation. And that was really formative for me, to be with that company. I guess people say that same thing now about working for Facebook, I guess, and for other companies, about how it's so formative. And 20 years is a long time to spend with a company, but I have no regrets about that.

Laws: What were the real lessons that you learned at HP that you applied later in your life, both personally and in business?

Ward: I think how people are treated, and it was with respect. People really wanted to work at HP, and it's because you really felt part of a team. You may remember this management by objective, or management by walking around?

Laws: Walking around, yes.

Ward: Yeah, that's the one, and it was really true. No micromanagement, no weirdness from your supervisors about do it this way. And the higher up you got in the organization, the more you felt empowered to make change, because it was the objectives that you were seeking to accomplish, but doing it in a way that treated people well. I'm idealizing a little bit, but not bad. I mean, it was amazing to me. So, I think just that style of management, and the technology was super cool. I did a lot of software

development there, too, and this was before DOS even. This was a lot of machine code, assembly code, firmware, and so just getting some interest in that whole process I think really shaped my continuing interest in technology.

Laws: When did you leave HP and what was the motivation?

Ward: Yeah, it's curious. So, HP during the dot-com boom and bust in 2000 decided to spin off the Medical Products Group, because it didn't fit neatly into the other buckets that you were talking about; printers, computers, test instruments. So, the spinoff happened and Agilent was one of those spinoffs as well. And Agilent took all the-- kind of the traditional HP business, test and measurement.

Laws: The real HP.

Ward: Thank you, that's the word, yes. And I remember going out working with them for a while. They took the Medical Products Group and then said "You know, this doesn't really fit in to our notion of traditional HP." So, they sold the medical business to one of the three large worldwide medical device companies, and that's Phillips. So that was a big transition and it seemed like a good time for me -- my kids were pretty much grown at the time. So fortuitously, there was a lot of work just, again, by happenstance relating to semiconductor work in the Bay area. And there were some startups that were using kind of really basic semiconductor technologies to build medical products, specifically, gene chips. So, I went to work for Affymetrix, Santa Clara, loved that place. What a change, to go from a large but nice company in Massachusetts, to a foot-to-the-floor accelerator in Santa Clara.

Laws: You physically moved yourself, your wife, family?

Ward: I did not, actually. Because of my exposure to the FDA and ability to work with the FDA at that point, I was able to do remote.

Laws: Interesting.

Ward: Yeah. There was a small group out here that I actually had an office in, and I worked with them. So, I made many trips out there again, and just driving, again, thinking about all the plaques that have been put up, and the recognition for Shockley transistor, and all that I was just driving right by, and I still have an interest in that area. I really liked California.

Laws: Can you tell me about the technology of the gene chip? I don't want to spend a lot of time on it, but I don't think it's anything we've really ever covered here at the museum.

Ward: I've been thinking about that, too. In the strictest sense of the word, it's not a transistor, or it's not a semiconductor. But the methodology is this: C, G, T, and A are the basic building blocks of all DNA, and those are chemicals. And so, in a manufacturing process, you can buy bulks of those chemicals, and then you could use inkjet printer technology, for example, to spot and sputter depositions of those chemicals onto a microscope slide. It was not leading-edge technology for a semiconductor manufacturer, but it was

not bad. Over the course of three or four years, as the density of semiconductors increased, Moore's law, for example, some of that out-of-date equipment could be used for these lesser dense applications, like gene chips. I think Agilent got into business for a while using that same technology. So in the amount of time that I was there, the human genome was decoded. And so, once that sequence is understood and decoded, you can use that as a map for building layers, structures, of C, G, T, and A droplets onto a glass slide. And so, in the end, I think probably-- I'm trying to figure out the dates. Maybe in the mid-2000s, 2005 or '6, after the human genome was decoded, and a few others, Affymetrix was the leader, and was able to deposit the entire human genome on one chip. And the way it's used then is that if you take a tumor sample, cancer tumor, and process it in certain way, it will bind to the appropriate receptor pattern that you've laid down on the chip. So by knowing the location of where you've put these synthetic DNA patterns on the chip, you can determine which areas the cancer tissue sample is binding. And then you use fluorescents to make a visual map of the chip. Things have progressed quite a bit since then, but nonetheless, that's the basic technology in use today. There are ways to use this kind of really elementary semiconductor manufacturing technology to make evermore complex and increasingly complex genetic patterns on chips. All species. For example, when you want to get your dog typed, what kind of dog do I have? So, I think this is still true, that would be a massive chip with many dog species on it, or dog varieties, right? And so. you could determine then by putting the sample on. Those chips are still in use, they're much more complex now, but what an eye-opener that was, I'll tell you.

Laws: And your role for the company was largely with interaction with the FDA, and regulation.

Ward: That's right., I was able to use my engineering background as well, because you have to translate kind of novel, unfolding engineering concepts to a government agency that's wanting to fit that into the existing regulations. That was highly interesting, actually. I enjoyed it.

Laws: And how long did you spend with Affymetrix?

Ward: Around 10 years. Many trips out to good old Santa Clara and Mountain View. I got a pretty good path down. I'd usually stay up in the city, I have relatives up in the city. So, I figured out 280's a much better way to go than 101 in the morning. So, I would take 280 down to either 85 or something like that.

Laws: You'd have passed my house many times. I lived in <laughs> Portola Valley just beyond Stanford.

Ward: I know exactly where that is.

Laws: So then after 10 years, you decided to start your own business?

Ward: Yes, indeed. Things evolve so fast, you reach a certain point in your career, you say "What do I want to do?" And I was at that point through working in that technology, I developed pretty good skillset to work with other companies who needed FDA support. So, it seemed to be a pretty reasonable fit. So, yes, I started my own consulting company, and travelled the world. Saw a lot of stuff, saw some really interesting technologies. I didn't like being a road warrior at some point. You must've had the same thing happen with you in Fairchild with your travels?

Laws: Sure.

Ward: But I still have it. I actually have two sons that I brought into my business. I'm trying to extricate myself as quickly as possible to focus on more semiconductor history, and let them provide me a stipend on a monthly basis. <laughs>

Laws: And so still consulting? Not actually designing and building anything?

Ward: Consulting, absolutely. I do design and build circuitry from the 1950s. I do that, but that's unrelated to my business.

Laws: I understand that's kept you pretty busy through the recent pandemic in the last year.

Ward: It's really interesting. I have not been too philosophical about this. I'm grateful that I'm able to continue doing this consulting, largely because it helps my family. There are a lot of people in the world these days having a really hard time getting a job, or knowing what they want to do. And so I've been incredibly grateful to be in this situation. And it seems like-- I'm sure it's true for other industries as well, but medical device industry is in an unbelievable growth spurt, and has been for the past 10 years. And the pandemic, in my opinion, did not slow it down, it actually cranked it up.

Laws: Yes, an explosion in all aspects of life sciences.

Ward: It's amazing to me. And I think one of those aspects has to do with technology. So now there are even further elaborations on diagnosis technology. Say, for instance, taking a small sample of blood and then using a variety of genetic techniques, and others, to make a large number of diagnosis decisions based on that small amount of blood. And there are many companies doing that, and it's a race. You have to use supercomputers, use artificial intelligence, it goes into machine learning. There are advanced techniques for pulling out the appropriate parts of the blood that can then be amplified through a chemical and biological processing. It's just unbelievable, that field going on, and say if you look at pathology, for instance. There are several companies who are moving ahead to take a look at a slide, a tissue sample slide, and make a diagnosis based on AI. No human involved. Just kind of hurts my brain to think about that. But the FDA is trying to catch up with that.

Laws: Sure. It's a little ironic that probably most people in Silicon Valley know about a lot of this work because of the disaster at Theranos, and the work that was supposed to be being done there. It sounds like there's a lot of real work being done in the area they were attempting to pioneer.

Ward: Correct, and that's the case, and there are major breakthroughs in the offing that, in fact, are based on science.

Laws: And you're continuing to do this today?

Ward: Indeed. I had to cut one of my earlier sessions off because you guys were my favorite today. I do training as well, training for companies that want to catch up on this. I have a grand plan. Everything comes together and I don't feel good about not spending more time with my museum, and I'm trying to rectify that.

Laws: Sure, and we skipped over that because I want to follow your career path, so now let's back up., I read that wonderful IEEE Spectrum article [https://spectrum.ieee.org/tech-history/silicon-revolution/the-irresistible-transistor] about you in 2003 when I first wanted to find out who you are and how you got involved with the CK722.Tell me about what happened there and how did the museum idea grow?

Ward: You know, it's hard in retrospect to look back. This was in the mid-'90s, and I was still at HP, Hewlett Packard, so pretty mature in my career path there, so I wasn't working 80-hour weeks like a lot of people do these days. So, I had a little time, and I started everything-- you know, this seems like ancient history now, and I hate to say that, but it does seem like it. The internet was just becoming more or less available. I got my AOL address at the time, transistormuseum@aol.com. Now I got to tell you, I've kept that same email address since '96. And when I get comments, and I do, all usually in good fun, good nature about, "You have an AOL address?" I point out that oftentimes the person making that comment wasn't born at the time that I got that AOL address. And so, I guess I'm ranting like a older guy right now, but there was a lot happening then, and a positive side, I was able to take advantage of the internet at that time. eBay was just coming online. You could buy a digital camera for taking photos of these things. eBay was still small enough that there were lots of swap meets, you know, ham-fests. So, I acquired for a song and a dance, lots of stuff that was going for the landfill, and I wish I could have done more.

Laws: What was it that attracted you to semiconductor history?

Ward: I think I really wanted to come up to speed with internet technology. I wanted to build my own website, which I did.

Laws: Okay.

Ward: And so, I was looking for a cause, and I had been going to some of these ham-fests, you know, swap meets and stuff, so it just kind of seemed to click. I don't know exactly why, but it seemed like a reasonable topic. When you know, it's electronics. I had experience with electronics. There seemed to be an ongoing expertise for vacuum tubes. There were many websites or many books or a lot of clubs that focused on vacuum tube history, but there was nothing going on that I could tell with semiconductors in terms of historical understanding and preservation. So, I can't put my finger on exactly one thing, but everything kind of came together, and what really launched it was at one of these-- you know, I got a circuit board with germanium transistors for a Nike Zeus missile at one of these ham-fests for $12.50. I still have it. Can you believe that? It's just my mind-boggling. But any case, I happened to meet somebody there who, I don't know what we started talking about, but he said, "You know, Raytheon has a semiconductor historian." And I said, "Oh. I never knew there was such a thing. I knew about Raytheon." As you have documented so well, David, there was a lot of activity here on the East Coast in semiconductors before the West Coast lit up. And so, Raytheon was one of the stars here. And I got the

guy's name and called him up and what a delightful human being. His name was Norm Krim. And I documented his work in a number of ways. I had the pleasure of knowing him for a number of years. And what a story. And I think that really ignited my interest. He started-- graduated from MIT in the teens, became the VP of their vacuum tube business, SubMini vacuum tubes. And took over the hearing aid market. And had the foresight in the late '40s and early '50s to take Raytheon from a leadership position in small tubes to the premier transistor manufacturer in the world. What a guy. And what a genius that he was to do that. And this all kind of rubbed off on me, and I was just fascinated by his stories. And he was a roommate with Shockley for a while. He started the first large-scale production for germanium transistors. Krim did. All for hearing aids. And that just fascinated me. And that really kind of launched my-- I didn't know what a-- difference between germanium and silicon was at this discussion or how this all fit into the great scheme of things. I was just fascinated by it.

Laws: So, it was more the personality and the drive that he exhibited that interested you. That's what I find so fascinating about interviewing pioneers of the business. What motivated them? Where did they come from? Why did they go in this direction, and what were the things that led them there? So, your introduction to the pursuit of early semiconductor history is through Raytheon, Norm Krim and the 722 device?

Ward: That's correct., I can show you one if you want, a CK722.You can imagine what the yield was for these first alloyed junction transistors. Close to zero. There was some testing that was done in these productions. The production was ten miles away. They ultimately moved it to Maine, but barrels and barrels of these things, these little, small black plastic transistors worked okay. I mean, they had some transistor action. But they weren't sufficient to meet the requirements for hearing aids where you need a certain gain and a certain noise factor. So, according to Norm and some of his engineering staff. Somewhere here, maybe it should be a hazardous waste dump, I don't know. There are big barrels of thousands of these transistors that they couldn't get rid of. And so, Krim said, "You know what?" He was a hobbyist as well, and so he would cause those devices that still worked, but didn't meet specs for hearing aids, he met with the editors for a number of the hobbyist publications, radio electronic news, electronics, all that. And started passing these things out by the tens, by the hundreds. And all of a sudden, in the mid-'50s, you would see these articles being published saying, "Use your CK722 as a code practice oscillator. Or build a CK722 as a radio." And those were rejects, fallouts, from the hearing aid line and there was a big fat stamp that said, "CK22" and he marketed those things and is sold by the millions. And it's amazing.

Laws: Raytheon was selling them as their product? It wasn't an independent business?

Ward: Correct.

Laws: Okay, fascinating. And so, you wrote about this, or published a book?

Ward: Mm hm. I have several things. That article in *IEEE Spectrum* was about him. And that got lots of publicity. And my website at the time went from a few hundred to many thousands of hits after that was published. I've written a book on the CK722, self-published. And I've done a number of interviews, oral

histories with Krim and others who were involved at that. It turns out companies following in that path figured out they, too, could take fallout from production, relabel them and sell them as hobbyist devices. GE did the same thing. I talked to their lead designer. Sylvania did the same thing. I've talked to their lead designer and got oral histories from that. Western Electric didn't do that. Either it worked or it didn't. They had really high-volume manufacturing. There are no fallouts that were sold from Western Electric, but nonetheless that opened up a whole avenue of focusing on early germanium transistors and how they were manufactured and what the problems were.

Laws: Interesting. I just have a little aside here. One of my early jobs at Fairchild was finding a way to use stuff that was not saleable as normal product. And we came across the Hong Kong transistor radio manufacturers who were making these six transistor radios. And they all decided to make 12 transistor radios. They soldered six more dead devices onto the boards that were connected to nothing, but it was just for advertising.

Ward: That was a huge business. Huge business. And you and I have to connect on this, because I've moved from the '50s and germanium transistors into the '60s. And we've talked back and forth, I'd like to do some similar work with the glob tops and thank you for educating me that that was a real term. And so, I have maybe the world's largest collection of 1960s fallout glob tops in my museum right now. And they all have various histories.

Laws: Tell me about the two aspects to the museum. There's your physical collection and then there's everything that you put online. How is it organized-- I'm not sure organized is the right word-- how did you go about structuring your online museum, and what are the key aspects of it?

Ward: I have thousands of pages and they started back in '96. So, it's been an evolution. I've restructured a couple of times, and I need to go-- I'm concerned that that stuff's going to get lost or I get comments all the time from visitors to the website saying, "What a fascinating story that you've told. I could spend hours here." Which is good, I like it, but with-- this was built with late '90s web technology, and I've just added onto it. And so, I'm concerned that it's going to get lost, it's going to get hacked. And I'm pondering now when I do get more time to spend on this to try to take advantage of-- what year is this? 2021 technology for the website, and I'm not quite sure how to do it. One of my goals is to make this more easily accessible. I don't have any social media presence, and I know that's really important. There was no social media. There was U.S. Mail back in the '90s, right? Yeah.

Laws: And AOL.

Ward: So, well, that almost counts, I guess, huh? <laughs> Yeah, so I'm at a turning point now where I'm trying to figure out-- I don't like spending a lot of time on the infrastructure. I really want to focus on the content. But I feel as though I need to take a pause. I'm looking, for instance, at-- I don't know what the term is, perpetual storage or forever storage or something. I would like this work to be available somewhere in the cloud. Because you know, in my opinion, just like with the oral histories that you do for CHM, there's really important information in there that I just don't want to get lost. And I'm using Yahoo. Business now as a website. It's been okay. But I'd like to have some more confidence that either through

Google or some other hosting organization this stuff could be saved. I am on a mission now to do both those things. Come up with a better way to organize and store this, and also, I'm looking to-- I have thousands of different types of devices in different quantities. But I would like to have each one of those documented and remembered. And so, I'm looking for maybe a short one- or two-page format with a picture and an actual device that people could get or use as a way of preserving this information.

Laws: Also, you have produced a number of kits.

Ward: I have.

Laws: And you've very generously provided a number of those to the museum for our collection. Are they available online? Are they things that people can buy?

Ward: They are. And so, thank you for mentioning that, yes. And so, I'm doing kind of the old-school way of making these available. These are loss leaders. I don't make any money on this, but I provide documentation about why this device is important, and I provide the device. And I think that reaches a certain audience, but I'm just trying to-- I don't want to have boxes and boxes of stuff, right, in ten years. I'd really like to distribute this as much as possible. And I appreciate what CHM has done with taking some of the rarest devices. That's really been helpful to me. And I'm trying to find some other way to make this-- to kind of preserve this memory. So, it may be all virtual in the end, and the actual physical devices-- I don't know how to handle that yet.

Laws: Do your wife and kids have opinions as to what you should do with all this? <laughter>

Ward: Well, they're all very helpful. I'm not in the mode of having too many boxes that could cause structural damage to the house, thank goodness. I've evolved beyond that. But I do have external storage, where much of this stuff is kept.

Laws: Okay.

Ward: And I got to tell you, David, that some of this stuff is just heartbreaking. Many of these devices are some of the first transistors ever designed. And they were truly historic. And I remember one case a year-and-a-half ago, a woman called me up saying that she was going to an estate sale and there were two boxes of electronics and she was going to pitch them out. And she happened to see my website and called me over. These are some of the first devices made at Western Electric. 1952. Unbelievable. This stuff cannot be gotten any other way. So, I was able to recognize it and I gave her a fair price for it, but how many times has it happened that that stuff goes to the landfill. It just breaks my heart.

Laws: What is your favorite area of the museum? Which topics or which devices or eras?

Ward: Well, you know, I've taken several approaches. One is oral histories. I think that's my favorite part. So, I have several hundred of those. And I just have really enjoyed talking with the engineers and the scientists that were involved in the-- mostly '50s-- most of them have now passed, unfortunately. So, I had

pretty good access in the late '90s. But just being able-- everybody was totally generous to a fault. Wanted to share their-- well, you know how it is. People really want to help people understand what it was like a long time ago and what the challenges were and how they overcame those, and their successes. So, I think that's probably the most important part. And I, again, am struggling with this because there are dozens that I should have followed up on that I didn't, and I just haven't had the time to do that. And that's part of the area that I would most like to focus on.

Laws: Is there one device that you really would have loved to have found and talked to the inventor and something that made a difference in the world?

Ward: Good question. I think it's both the device and the application for the device. I did have a chance to talk to the Bell Labs-- this may be my favorite, the Bell Labs engineer who built the first transistorized circuit that was not experimental, Walter McWilliams, I did his website. He had retired and I got a chance to interview him personally. He built a matrix for gunnery control, trajectory control, that had been tube-based, and he used some of the first experimental point contact transistors in a matrix to do an XY coordinate system. And I have pictures of it, and I have some of the transistors and I have his description of what it was like to follow Shockley around, or Bardeen or Brattain, and get some of those first devices, because he was a young guy at the time. So, I think he documented this. This is the first non-experimental, not developmental application. It was used in the military. So, that got my attention. That one I like a lot. And so, that opened up the whole area of not just the devices but also interesting applications. So, first hearing aids. Some of those first ones were hybrid with small tubes and transistors. That's an area of interest. Radios, medical devices. And currently I'm looking at satellites and spacecraft. Which for obvious reasons had a real need for small lightweight low-power devices. So, I think that's my primary focus now is on spacecraft and I am talking to some designers from the '60s for some of the first spacecraft. And that was my other kind of-- I got in on the ground floor of that first couple of satellites, Vanguard and Explorer. Got a chance to talk to the folks involved in that.

Laws: And of course, Raytheon had a major role in building the Apollo mission equipment.

Ward: Yeah, I'm looking forward to moving to the '60s, David. That would be my next goal.

Laws: Okay, is there someone that you really want to interview that you've just not got hold of yet who is still around?

Ward: Yes. One of the areas of interest to me is, as I said, applications for early transistors. And so, one of those applications is in music. And so, I was not able to interview Robert Moog. I was not able to do that in the time when I should have with the synthesizer. He used some of the first germanium and unijunction silicon transistors. And he has many articles. But there are a couple of folks who did early instrument design. Some of the first guitar amplifiers, transistorized. And that's an area I'm trying to get into. And so, there are a couple of founders of electronics companies that are available and I won't go any further, but that's one of my current paths.

Laws: Yeah, there's a whole branch of technology there that is now a huge consumer of semiconductors.

Ward: Right. So, I think I'm going to try to, if I can figure out how to update the website from 1990s technology and it's something that I can do in a reasonable amount of time, I'd like to branch out with more oral histories. I think that's kind of my goal.

Laws: Any other goals for the museum? When you're no longer here Jack, what would you like to happen to it?

Ward: Yeah, that's-- I'm struggling. You know, along that line, over the years I've made friends, and I'll call them friends. I've met most of them who are kind of unofficial semiconductor, either collectors or historians. They write, they have websites. And so, I'm not unique in that regard, meaning there are world-class collections of semiconductors that half a dozen or a dozen or more individuals have put together. What's going to happen to that stuff? And unless there's kind of a concerted effort, I know what's going to happen to it. And so, I don't know exactly how to address that, but I don't think I'm quite alone. Thank goodness for the CHM. You guys have been kind enough to take some of the items and have them available, and I know they're in a good home.

Laws: And our focus is very specifically in that area, but you've covered a much bigger area than we typically stretch out into. Have you explored the Smithsonian or what their possible interest might be, or ability to manage this?

Ward: I have not, really. I have gone to their website and see that they have quite a bit of semiconductors and so that's a possibility. I don't know what their policy is, how that works. Do you work with them at all? Does CHM work with Smithsonian?

Laws: Not directly. We have worked with them on some specific projects where they've been looking for some information. But Dag may have more information in that area, in terms of who might be interested. But you have a huge electronic collection of documents, interviews and all these other people that you talk about. There might be some way to knit this together in an overarching manner to make sure it's at least all stored and accessible somewhere.

Ward: Yeah, that would be a good goal, I think. I'm still trying to figure out how to get myself up to that task. That seems like a pretty good commendable thing to do. And if I might be so bold, I know you've done such a phenomenal job with wrangling all the various documentation and people and histories, you know, and I would like to emulate some of that if possible. I need to get some more time and focus is what I need.

Laws: You've got the content. It's a matter of figuring out how to make it available and relevant. How would you interest kids these days in what you're doing? Why should a kid care about a CK722?

Ward: Really good question. And I've been struggling with that one as well. I don't know, to be honest with you, who the interest group would be. It's something I'm-- it's going to evolve over time. So, for example, I'm not sure what interest level there is-- you know, this will be-- I'm trying to think about this as a possible analog for coin collecting or stamp collecting, for example. Right? Where there's a specific model or type case structure that could be, you know, it's really close in application where there are different semiconductors from the past 70 years and if they could be made available in a inexpensive way, which I could do, and also in a compelling way, why not? Why not collect semiconductors? I don't think there's a big market for that now, but there could be. What do you think?

Laws: As you've said many times, it's the stories of the people and why it was important. And somehow if you connect a kid to a personality or something that they can relate to, maybe music is the way. It's a long way from your rock-and-roll music of the 1960s to what we listen to today, but there's possibly a connection there.

Ward: Yeah, maybe it's TikTok, who knows? Maybe TikTok is the way to do it, huh?

Laws: Sure.

Ward: I would say this, the Smithsonian is an interesting approach. I'll have to think about that. I-- one of the gentlemen, I had a few visits at my house, which is where my virtual museum is from some of the folks who were really proactive in the '50s. And one of them, a guy named Bob Slade, great guy, was the first transistor engineer at RCA, and he was a prolific writer. And he was responsible for the first RCA transistors. And I had some of them, and he came by and we chatted. What a pleasure. Turns out the Smithsonian had one on display, and he did not know that. And so, once that was discovered, he made a trip to the Smithsonian and got his picture taken next to-- I'm sure it was the device that he personally had handled. It was the point contact device. That was one of the most rewarding interactions I had. That was, you know, I really liked that.

Laws: Looking forward, we talked quite a lot about kids. What kind of advice would you give a young person, male or female who's wanting to get into the electronic business these days?

Ward: Boy, that's a hard one. I tried to put myself in the place of somebody looking to be involved in technology. I don't know, David? What do you think? Is hardware the place to be or is it software? What do you think about that?

Laws: Well, software is clearly what's controlling just about everybody's lives today, but it's the silicon and other technologies that makes it all possible. Are there still going to be people who are making these chips ten years from now, or is it all going to be designed by computers and A.I. to determine what the designs are? And what role can a young person have in helping control and create that? I don't have answers to the questions. I'm intrigued to know. Everybody sits at a keyboard today.

Ward: Yeah, it's true, isn't it?

Laws: Few people go into a lab and have to probe a chip and find out what's broken.

Ward: Yeah. So, I don't know what that means either. I don't have an answer for it whether it's a good thing or a bad thing. But it's the way it is, I think. You know, there's some phenomenal work being done on the internet now with-- I would say engineers, probably middle-aged engineers who have a bent on hardware, so they decapitate chips and do a detailed analysis. I was just looking recently; some gentleman recreated the 555 timer with the vacuum tubes. Have you seen that?

Laws: I've heard of it.

Ward: Unbelievable!

Laws: You have to ask, "Why?" but you shouldn't.

Ward: <laughs> That's right. That is, in my opinion, that's incredibly cool. That is so cool.

Laws: There's a similar replication of the Intel 4004, and other early integrated circuits

Ward: Yeah. And so, the fact that there's enough time for people who are really smart and who can do that level of construction, that's amazing to me. I'd like to tap into that, but I'm not sure how that fits to a single poor performing alloy junction germanium transistor that only works on Thursdays. I'm not sure. <laughs> One thing, you know, it's probably possible to do a 3D print of a transistor now. I'm thinking certainly you could do the case. But I'm thinking it's possible to do the junction as well.

Laws: There were many attempts of that in the early days, particularly at RCA to try to print transistors. The issues were always a matter of control and variability of materials, But then you look at what it takes [to make it happen] A multi-billion-dollar factory covering ten city blocks, just to hold the equivalent of a projection aligner to make a transistor, to make integrated circuits. There are dozens and dozens and dozens of layers on these things. So, they are being printed in that sense.

Ward: Do you mind if I ask you a question? Since we're here. I'm totally intrigued and fascinated by those artistic large statues of the Fairchild Mesa, the 2N697 and the Shockley four-layer diode [on the sidewalk in Mountain View] Can you tell me anything about the story of how that came about?

Laws: The developer, Merlone Geier Partners bought the lot that included the old Shockley Building at 391 San Antonio Avenue in Mountain View. I'm sure you drove past it many times.

Ward: I did, yeah.

Laws: There was a movement to try to preserve the Shockley Building, because of its historic importance. – although that failed, part of the deal with the developer was that they would invest, I think, about a quarter of a million dollars in various kinds of artwork to document what went on there. That was the basis for it. There are two IEEE milestone plaques that we placed there. One for Shockley

Semiconductor Lab and one for Moore's Law. And each of those are associated with these artworks. Moore's Law has a 20-foot-high silicon molecule representation standing behind it. The transistors out on San Antonio Avenue were one of the proposals by artists in response to a request brought about by the developer to create sculptures to record them. So, they were funded by the developer as part of being able to knock down the Shockley Building. I did have a conversation with the artists. If you look closely at the leads, they are bent. They thought that was a nice artistic touch. "But those parts would have been rejected by any manufacturer that you sent them to back in the '60s," I told them.

Ward: <laughs> Yes, indeed. So, still impressive, and I don't know why they came to mind. You know, a lot of those early Fairchild devices are artistic anyway with the stylized F stamped in the top of the case, and the various-- I mean, there's art. There's real art there as well in that process.

Laws: Yeah, so that's the story behind the sculptures. -- I forget the name of the place, - Technology Plaza I think they call it. There's a Disk Drive Road and a Semiconductor Drive in the development. And at least it is a place now where the history is recorded. Where people can go to look and touch something which relates to what went on there all those years ago.

Ward: Yeah, good for that whole effort. That clearly was a fundamental milestone in semiconductor history.

Laws: Jack, it's been fun talking to you. Is there a message you'd like to leave for people who are going to watch this 200 years from now and wonder what Jack Ward was doing in his basement in April 2021?

Ward: Yeah. No, I just, you know, in life, you can never do everything that you want to do. I'm being a little philosophical here. But you know, in my particular case, and there are others, trying to get a handle on changing technology and the impact it had on me personally, and how I'm documenting that and how I'm hopefully making some contribution that allows it to be around for a while. You know, I know I'm not alone and this doesn't apply just to semiconductors. People get attached to stuff that was impactful to them, you know, and want to try to do some kind of contribution, I guess, to keep it living. That's what I'm doing. So, if you ever get bored, spend hours at TransistorMuseum.com and help me as I transition to a more perpetual storage and more ease of access. That's the message, David, I'd like to get across.

Laws: Well, thank you for your time today, Jack. It's been delightful to catch up on your background and understand a little more about what motivated you and what keeps you working to preserve this history. Thank you for joining us and we hope to see you on the West Coast again when such things are once more possible.

Ward: Thank you very much, David. I appreciate you taking this path. I'm hoping that we could in person collaborate at some point, because I don't know, there's a lot of stuff that you also have brought to bear, and I know you've been interviewed, but I'd like to take that path as well at some point.

Laws: Well, it's been fun, Jack. All the best to you!

Ward: Thank you.

END OF THE INTERVIEW

