Oral History of Frederick (Rick) H. Dill

Interviewed by:
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David Laws: Good morning. It's June the 11th, 2015, and we're here at the Computer History Museum in Mountain View, California. And I'm going to spend some time with Rick Dill today to learn more about his involvement in early technology development at IBM and many other areas in which he has contributed to technology. So welcome Rick, and thank you for joining us today. [For the record, Rick spent 44 years at IBM, where he was a Distinguished Engineer. His many papers and patents are published under his full name, Fredrick H. Dill]

Rick Dill: Thank you David. I'm glad to be here.

Laws: Perhaps we could start off with a little bit of your background Rick-- your family, where you were born, what were the early inspirations in your childhood?

Dill: Well, I was born in the middle of the Depression, when my parents didn't need another kid. And in Sewickley, Pennsylvania. That's a small town outside of Pittsburgh. My father was a civil engineer working for the American Bridge Company, migrating from his dream of doing bridge designs to welding and metal joining, which became his technical career after he discovered that bridge designs were now done in grand fashion by architects, and the engineers just got to run the slide rules.

Laws: You grew up in a big family Rick?.

Dill: I was the second kid by a year and a half, followed three years later by a daughter. And later on, over many years, there were three other kids. There were six all together.

Laws: And what kind of schooling do you enjoy?

Dill: Well, I went to small schools. Sewickley wasn't a very large town, but that's where I went to start elementary school and finished high school. But we moved to the next town of Edgeworth, which was an even smaller school. I graduated from ninth grade with 13 kids.

Laws: Any particular memories of the school days? I know you were pretty heavily involved in a science fair engineering project at one point.

Dill: Well, my school days were interesting, because I was accommodated. For instance, in my ninth grade, the last year in Edgeworth, the principle let me study on my own in algebra, rather than have to stay with the class, something that took me a year before I had the courage to ask in the bigger Sewickley High School, where there were 60 some of us. But those kinds of accommodations somewhat again, in ninth grade, frustration with our general science teacher, because he seemed to know less about it than I did.

I would complain when he misgraded exams. But it was basically good times. I had another kid in town, John Shields, who did never quite finish high school, but went on to a technician level thing who was bright and inventive. And we just did electronics together.

Laws: Any particular projects that come to mind?

Dill: Oh, we did everything from starting out with the crystal sets, and ending up with Hi-Fi. He built the first Williamson amplifier I had ever heard. And I went home, and looked at my junk box, and realized I didn't have $40 for an output transformer, and so I was going to make my life devoted to medium-fi.

Laws: And wasn't there a prize in high school that you won?

Dill: Well, in Pittsburgh, the city at the Buhl Planetarium, they had the annual science fair. And I, with another kid, put in a trivial display [in our] junior year. And senior year, I got the idea of I'd like to build something fun. And having built a few RF oscillators and used them to light up fluorescent lights, play games with, I decided I'd make an induction heater, scrounged around with friends in town, and got a carbon plate transmitter tube [and]a high voltage transformer. I put together an induction heater that heated up a nail red hot about five seconds.

I had to solve not technically, but experimentally, lots of things, and that got me first prize in engineering in the tri-state area and offer of a full scholarship at Pitt [University of Pittsburg], which I visited, but didn't go to.

Laws: OK. So where did you go to college, and what was the choice that you made there?

Dill: My choice of college was a little funny. I looked at both going to take physics and liberal arts, which my mother, who was a liberal arts major, favored. And I got a scholarship from Oberlin and accepted it. And then about three weeks later, I got the US Steel Scholarship, which was my father's employer, at Carnegie [Mellon University], which was full tuition for four years. And I called up Oberlin who said, I'm sorry. I'm going to Carnegie, and it was a choice I didn't make.

It's a fork in the road, and it worked.

Laws: It sounds like a fortunate choice to have to make. So what did you study at Carnegie?

Dill: I was a physics major.

Laws: OK.

Dill: It made sense to me, that that was the pure science. I did just fine, but as I got up at the senior level and some of the courses got highly theoretical, with a Professor lecturing in words, as he wrote different things and equations from one corner of the blackboard to the other, in monotone, without conclusions, I didn't do as well.

Laws: I can sympathize with that. I took physics and went through the same transition.

Dill: And I almost went to graduate school in physics. But I walked across campus to the electrical engineering building. I'd only been in one time previously, talked to the head of the department, [Everhard Williams] and signed up.

Laws: What was it that impressed you about that single meeting?

Dill: Well, it was a sweet very small department, with a very strong graduate school. Carnegie was at the time, turning out almost as many PhD's as MIT, with a much smaller department. They were essentially four senior professors. So you had to learn everything each of them knew. But also, I had a great deal of support, and encouragement, and freedom to do self-initiated things. [Williams built an amazing department and was eventually my thesis advisor, even if it was outside of his field]

Laws: Sure.

Dill: And that is what drove me through [graduate school]

Laws: At some point, you experimented with a Bell Labs Kit from Murray Hill that somebody brought back. Was this as an undergrad or graduate?

Dill: That was undergrad.

Laws: What was the kit, and what did you do with it?

Dill: Well, the first summer in college, I worked for the physics department, making new experiments for the undergraduate labs, or lecture demos for the physics courses, some of which I hadn't taken. And that summer, two professors, but particularly, the professor who I'd later had for optics, had gone to the school Bell Labs course that summer. And he brought back this kit of physics experiments, a PN junction diode for you to measure the germanium IV equals QV over KT, QV over KT.

And you did that. But every time we needed another experiment, there was another friend of mine in an undergrad school, Jim Boyden, who last time I talked to him, was working on as a top technical advisor on the XPRIZE.

Laws: That's the space vehicle?

Dill: Yes. He was the PhD from Caltech.

Laws: OK.

Dill: And we just picked one experiment up. You made micro manipulators, fabricate them crudely, and make a point contact transistor, and play with it.

Laws: You were introduced to semiconductors at a very early stage.

Dill: And there was a long rod of germanium that we managed to etch the contacts off and did figure out how to replate them back on, and used to measure the mobility of electrons in a bar of germanium by putting a field between the ends, and having a point contact which injected electrons at some distance away that you carefully measured, or fairly carefully measured, another point which was reverse biased and observe the pulse passing by.

Laws: Interesting opportunity for undergraduate in those days.

Dill: And every time physics had an open house, even while I was a graduate student, they demanded I come back and set up the experiment. Good show and tell.

Laws: Tell me about your graduate studies.

Dill: Well, graduate studies [my first office was in lab where. everybody else in the lab had a set up where they were working on a rather degenerate form of parametric amplifier, where they used the non-linear voltage dependent capacitance of barium titanate to change the resonant frequency and thus, change the magnitude of the oscillation. They were building amplifiers on a contract, which it was hoped they would get nice, low noise, also sought for later.

And after looking at that and realizing that I knew that PN junctions had a capacitance which varied with reverse voltage because the field zone between the P and N regions was enlarged by a higher reverse voltage, I found myself a big germanium rectifier and did a setup. I didn't have to have an oil bath for my capacitor. And wrote that up second year, and published a paper at the IEEE convention, kind of obscure place to give a paper. But my co-author, who was my electronics teacher when I proposed doing this instead of writing my lab report, it was his first paper because he hadn't published his thesis.

And around a year later, still enamored with the same thing, I replicated the classic Hewlett & Packard audio oscillator in which I was able to get the full decade of frequency out of an oscillator under voltage control.

Laws: Interesting. Now, at some point, you took a summer job at IBM.

Dill: Between undergraduate and graduate, I took a summer job at IBM, and it was an incredibly interesting thing. I took the train overnight to Poughkeepsie, got off the train, took a taxi to IBM, with all my luggage, started work, and found a rooming house that night. I was working for Joe Logue, who you've also interviewed.

Laws: Sure.

Dill: And Joe's assignment to me, as a kid, was he showed me the neon decimal ring counter tube and talked to me about building functional things in semiconductors that would be a higher function than the transistor. Now, you recognize that at that point, we had two kinds of common transistors. We had the junction transistor, and we had the point contact. And in fact, because of the negative resistance capability of the point contact, it was one level up in function. I looked around at things, thought for awhile, and decided that maybe, if you took a unijunction transistor you're injecting carriers into a relatively high resistance bar of germanium, and you get a negative resistance because those carriers change the conductivity of the bar. And if I put multiple contacts, or even better, single contacts that were slanted that then, if you pulsed alternating pairs, you could move the signal, this plasma down the bar and count.

Laws: Essentially a counter?

Dill: Yes. And I then went down to a very early group of guys working down in what they called the Pickle Factory, which was a lab down right on the Hudson River, where they'd built rifles in World War II as munitions manufacturing. But it was really IBM.

Laws: OK.

Dill: And there, Dick Rutz worked with me, and we built a [counter] stage that let me show the feasibility of this. Just a few emitters.

Laws: And this was a point contact [transistor]?

Dill: No, no. This was a uni-junction [transistor]. And I also conceived another functional device of taking the Shockley-Hall experiment and putting [it] on a wider bar, and putting lateral contacts on that so that you could deflect the plasma to one of multiple collectors and make a full adder.

Laws: But you didn't build one of these?

Dill: Didn't build one of those. More than a decade later, somebody in a small university claimed to have built it, and it worked. But very frankly, it was functional, but not very interesting.

Laws: But your counter was unique, in that it was probably one of the first integrated counters that anybody had made.

Dill: Although, when I came back to IBM, I discovered that I already walked in with a certain level of reputation, because Joe Logue had advertised the “Logue-Dill” adder which we didn’t try to build.

Laws: Joe took some credit for this?

Dill: Well, he was my boss. He told me to do it, of course and listened to my ideas.

Laws: Sure.

Dill: But it was a very interesting time, because Joe had just come off doing the memory for the 701, which was a Williams Tube. And I got see those, see the dots on the screen, and look at them there. IBM, at that time, took all its vacation for two weeks in the beginning of July, and they had their new employees. And they had their summer kids. So they just threw us together down in Main Plant and had a course for three weeks on IBM, on technology. And it was like drinking out of a fire hose. For me, it was just absolutely fun.

Laws: Right. And you were still an undergrad at this point?

Dill: I had just finished undergrad. But it was just fun. We had R. K. Richards teach his logic. We had Joe Logue talk to us about technology, everything from the Williams Tube, to cores, and to a little bit about transistors and transistor circuitries. At that point, and about all of IBM's old machines and the electromechanical stuff that they had in the printers that was basically a Marchant calculator automated, run under plug board control. And it was just really fun stuff.

Laws: Just a wonderful way to spend the summer.

Dill: And by the way, the notes from that course, including all the notes I made, are at the Computer History Museum.

Laws: Excellent. Now, the counter that you built, wasn't that validated at Bell Labs shortly after by a group under Ian Ross?

Dill: Yes. The next year, I worked at RCA Labs. Those were the only two real jobs I had. I worked on silicon diodes, which have a different IV characteristic, the germanium. It's E to the QV over nKT, where n is typically something on the order of a half. And that didn't follow Shockley's simple theory, and there was no explanation for it.

Laws: Mhm.

Dill: So I was making diodes and measuring them.

Laws: OK.

Dill: But because IEEE's device research conference, one of the early ones, was in Philadelphia. We went down from Princeton and went to the conference. And there, I saw Ian Ross present a paper on exactly what I had built, except at Bell Labs he'd had a little more support. And they built it, the whole thing. And nothing came of it there either.

Laws: Right.

Dill: But fun.

Laws: But again, I think a lot of people forget that there was a lot of work going on throughout the industry, in terms of trying to integrate devices, long before Jack Kilby came on the scene. And these are two interesting examples of that work.

Dill: Well, the other interesting example was Dick Rutz, who was the guy who helped me get my devices built, built a full adder transistor. It was a point-contact like transistor. I say like, because they had realized that the collector on the transistor was probably an N-P junction, which is why you got the negative resistance there, which was a neat finding. So he had two collector contacts and one emitter, and if you put one unit of current in the emitter, the sum collector would switch on at one level and when you applied two units of current, that collector would switch off, and the other one (carry) would switch on. And then when you applied the -3 times the current, —both collectors (sum and carry) were switched on [you got] the sum plus carry.

Laws: Fascinating.

Dill: And they actually built a little shoe box kind of demo- of the full-adder transistor. And I'll come back to that later when we talk about the transistors for the 360 family.

Laws: OK. So the second summer of grad school was at Sarnoff Labs.

Dill: Yeah.

Laws: And then when did you graduate? What was your thesis in?

Dill: Well, I went back after RCA and I told the head of the department that I thought I could set up a lab to build semiconductors. And he gave me $1,000.

Laws: That was a lot of money in those days.

Dill: That was quite a lot of money. And, I have to admit, I wasted half of it, but achieved the aim. I got a Bausch & Lomb binocular microscope. I built hot stages like they used at IBM. I was thinking I'd have to do my alloying under vacuum, so I played with getting the glass blower to make me a vacuum system. But I ended up doing it under hydrogen. I was going to use forming gas but I never got it dry enough to work.

Laws: Hydrogen. That sounds interesting.

Dill: Well, it was interesting. That's what we'd used at RCA.

Laws: OK.

Dill: And I had one incident at RCA, when having just been told how to do this, but not enough detail, where I did manage to turn the alloying heater up a little early and it blew up. Fortunately, I was looking in the microscope, watching what I was doing, and I simply shut everything down and went down because it was coffee time. (I’d learned you have to purge longer before having any heat!)

Laws: OK.

Dill: But I ended up building my own structure (alloying heater) with a heater under plate glass and looking through the glass window. And it never blew up on me. But the lab I built had the assistant department head's office off it. So you had to go through the lab. And he did not want hydrogen. I had a rock climbing friend, Sayre Rodman. My mentor in rock climbing had a small factory. And he gave me a bottle of hydrogen and a bench in his little factory, where he reprocessed palm oil, which was used in rolling hot dip tin plate.

Laws: So you built the lab outside of RCA?

Dill: I just carried all my stuff outside off campus, and did all my fabrication there.

Laws: Fascinating. So you were making transistors while you were at grad school?

Dill: My thesis-- first of all, I didn't really have an advisor. The assistant professor who latched on to me as my electronics lecturer, it was great. But every time I saw him, I had to explain what a semiconductor was. And so I went to the end of the head of department, Williams, and said, look. You're it. And we sat down, and we discussed thesis topics. I said, there's this problem with silicon diodes that I really don't know the solution to. And it's fairly deep physics. But it would be very nice to understand.

Laws: Mhm.

Dill: I said I was interested in unijunctions because the understanding of them was just a hand waving. There wasn't really any model that lets you understand how they behaved. And the third would be to stay working with semiconductor capacitance, which would have been easy, and a shoo-in, but I was bored with it.

Laws: Mhm.

Dill: Sorry about the short attention span. We quite wisely decided on the unii-junction. About a year later, Shockley, Noyce, and Sah wrote the classic paper that defined the physics of silicon diodes.

Laws: Right.

Dill: I didn't really get into that diode theory until I was teaching 10 years later at Berkeley and teaching stuff that wasn't in the literature when I was in school.

Back to my thesis topic on a model for how unijunction transistors work. So I now had a pretty good idea. I know how many electrons I'm injecting. I know the mobilities. So if I know fields locally, I can tell how much force I'm putting on the electrons, and so on. All good stuff.

Laws: Mhm.

Dill: But the equations were typical non-linear differential equations. And my mathematical skills were inadequate, and I decided the way to solve this is numerically. And I guess in fact, I did one of the first numerical solutions, Poisson's equations for semiconductor devices, and published it so obscurely, nobody knows where it is. For me it wasn’t pioneering research, but just solving a problem.

Laws: Is that right? Now, didn't you use a computer in this?

Dill: Oh, yes. You don't do numerical computation by hand even then. The campus had just gotten the 650. I had a good friend, Karl Konnerth, who worked with me and for me many times later in my career, who was fascinated by the computer, and was over there, and starting to program an assembly language. And I talked to him about this, because he was the one person I knew who had used the computer

Laws: So this was a computer on campus?

Dill: The FIRST computer on campus.

Laws: And the machine, what was it?

Dill: IBM 650.

Laws: OK.

Dill: Vacuum tubes, drum memory, all the good stuff. 2,000 10-digit words. And we talked about it, and he pointed that there was a program from Bell Labs called either Wolontis or BLISS, Wolontis being the author, and BLISS being Bell Labs interpretive system, that gave you an image of a three-address computer. It used half the memory, so you had 1,000 spaces. Your words were 10 digits. The first one was simply the instruction, if it was simple.

One was add, and then you had the three addresses. Add a to b, and store in c. Now, this is not efficient on a drum memory. And so if you were a computer scientist, you would just laugh. But if you were a dumb engineer who wanted an answer, if you could just get enough computer time, you could get your answers. (Also it was floating point so you didn’t have to keep track of the decimal point!)

I had a five minute introduction of the computer, how to turn it on and off, where to put my cards to load, where they, the output would come out. And all worked just fine. And then I went in at 6:00 in the morning to solo, and put my cards in, and nothing would happen. I finally went home, and it turned out the belt driving drum had broken.

And I should have known that, but I didn't know to listen for it, the scream of the drum. But after that, I got to were, all right, so I wrote programs, and they didn't work. And I fixed them, and I essentially used Runge Kutta to start and then - go into a higher level of numerical modeling. Years kater found two guys at Bell Labs who'd done the same thing, one of whom (Friedolf Smits) is still, a very close friend. And I probably got far better results out of mine than they did, because they assumed the right answers was because their boundary was out of infinity. And eventually, it would blow up positive or negative.

They assumed the right answer was between those two. For mine, I had a distinct boundary and an artificial input at the front. And if that artificial input was still working (matched at the end), it was good.

Laws: So how did you get all this computer time?

Dill: [I got lots of computer time once things were running by working midnight to 6 am. Little competition at that time. And I was eventually able to do computations. The only parameter I didn't know well was recombination. And so in truth, I was able to model any device I built by varying recombination. But I did put together a model that worked end to end in one dimension, and published that. And I finished up in 3 and 1/2 years, including changing from physics to EE.

Laws: OK. Good. And so this was the thesis that you published?

Dill: Yes. And halfway through, IBM came back, and one of the young faculty had spent a summer at IBM after I did. And he came back and wrote three contracts. One supporting me. Paid me $200 a month, which was twice what I was getting. And one was for Dale Critchlow, who ended up being one of the key technical managers in IBM's trench memory. And the third was for Bob Dennard who everyone knows.

Laws: [Inventor of] The single transistor DRAM?

Dill: A single transistor DRAM and scaling.

Laws: Mhm.

Dill: And all good friends.

Laws: Well, interesting. And so as a result of this, you were then hired by IBM after you graduated?

Dill: Well, no. As a result of this, I had no commitment to IBM. But they did want me to come every month and tell them how I was getting along. So about every six weeks, I would get myself to Poughkeepsie. It was fun. I travel. Sometimes, I find a friend in New York and see a show. But among other things, I could get all the 650's I wanted at IBM. Together, I discovered that if you sign up for midnight to 6:00, there's not much competition.

Laws: I think a lot of people found that out too in their early years. Well, what else did you do on campus, Rick, outside of your studies? You were involved in theater, and on the newspaper, and other things?

Dill: Undergraduate school, we had something called scotch and soda, which involves the drama department and anyone else on campus. And I participated in that on the technical side, did lighting, or whatever needed to be done. One time, we moved from first year being in a high school, where you had to install everything in two weeks, to a large gym, where the acoustics were so bad, we literally had to build the sound system, which I didn't do, put up baffling to help reflection for the ceiling, and sew together curtains to go around the entire audience area, and then build stands for the seats.

Laws: Wow. Weren't you also involved in the newspaper, the student paper?

Dill: I was involved a little bit in their technical journal, but I wouldn't say heavily.

Laws: OK. So you graduated when, in late '57 or so?

Dill: I got my PhD in February of '57, early '57.

Laws: OK.

Dill: They had a mid-year graduation, very rare.

Laws: And then you joined IBM in--

Dill: I shopped for jobs, and finally decided I would go to IBM.

Laws: OK.

Dill: Graduated on Saturday, started work on Monday. I was told I would graduate on Friday.

Laws: Wow.

Dill: But it all worked.

Laws: And at IBM, what did you do? What was your first job there?

Dill: Well, I had a certain level of choice, and I decided I wanted to look at something outside of semiconductors. And they had a group that was just starting to ramp up, looking at logic done with combinations of transistors, and multi-aperture cores.

Laws: Mhm.

Dill: And it was really fun, because you could figure out circuits, three transistors, and two cores, or two transistors, and three cores, something like that to build a full adder, and so on. Just fun stuff. And a small group of us, which it turned out, included Hwa Yu who was my office mate in early years. And also, Dennard and Critchlow joined the group.

Laws: Aha.

Dill: And it started in Poughkeepsie and then moved down to an old hospital in Ossining, and anticipation of research, is moving to Westchester.

Laws: Mhm.

Dill: And there, the management was pretty wimpy. We wanted to build a 1401 using this logic, and it would've been fun. But they never got any traction. And I finally just got disgusted, because this isn't going anywhere, and went back to Poughkeepsie and joined Dick Rutz’s transistor group.

Laws: To semiconductors?

Dill: Semiconductors.

Laws: Mhm.

Dill: And he handed me a fun thing. He handed me a paper written by Leo Esaki--

Laws: Tunnel diode.

Dill: --on what we called the tunnel diode after GE renamed it, the Esaki diode until it was renamed tunnel, and said, make these. And so here I am. I'm sitting in with the techs. Nobody's explained to them who I am. They thought that I was across the hall in an office, because they ran out of space in the lab, which was fun, because this was a bunch of really talented-- not college grads. Earle Hardin was a superb machinist, classically trained, very smart, who taught me automotive mechanics, as well.

But he (Earle) could lap anything flat. He built many of the prototype transistors, along with Ralph MacGibbon. [That includes those in the 1401]

Laws: Mhm.

Dill: But these guys were good. There was a certain atmosphere there of playing jokes, putting a little dry ice in a Tygon tube, and putting hose clamps on it, and having it blow up.

Laws: OK.

Dill: Or dropping a pile of just scrap metal under somebody's bench, where they could pull a string, and make a great noise, just as you were doing something touch sensitive. So you learned a little. But these were the guys that were building the advanced devices.

Laws: OK.

Dill: I was there one time at my lab bench in Poughkeepsie, where we had a guide who brought around the executives, and customers, and other people. And I'm there, working on alloying a tunnel diode, and aware somebody's behind me. And I turn around. And there is John Fellows, with I believe it was the King of Sweden or something like that-- introduced me as Dr. Dill. And I could look beyond, and I could just see everybody's face suddenly--

Laws: So they had no idea?

Dill: They had no idea.

Laws: OK.

Dill: But it was great.

Laws: Good. And are you successful in building the tunnel diode?

Dill: I was successful in building tunnel diodes. And then in spite of my efforts to resign my commission, ROTC commission, because they didn't need me, it took them six months to finally make up their mind and say, get yourself in here now.

Laws: OK.

Dill: So I went down and spent six months at Fort Monmouth.

Laws: That's in New Jersey?

Dill: In New Jersey. While I was in grad school, I first got a letter, I say, from the president, promoting me to first lieutenant, because I'd been a second lieutenant for three years. And he's a busy man, and I didn't bother him to say, I didn't really need it. And then, by the time I went in, I had four years longevity. So I was clearly first lieutenant and senior, and four years longevity in the officer training school for three months. Yes, I was the class commander.

Laws: Mhm.

Dill: It was fun. We walked everywhere as a mob. I didn't particularly like to fall people in, particularly officers, and ask them to march. And they were happy. We got thrown out one Christmas holiday for being too noisy, out of the officer's club. They were good times. So I went to school for three months. And then they said, well, you ought to be in the Signal Corps Lab, and so I went over and looked. And they wanted me to rebuild some little shielded box that some previous lieutenant had not done. And I told them about this interesting device I was working on, and I knew how to make it.

Oh, well. They finally settled on, well, you can go do a library search on something for us.

Laws: Mhm.

Dill: That was on Friday. On Monday, I showed up for the job. And somebody had just come back from a visit to GE and heard about this new device. And they said “Can you build this?” And I said, yes. And it'll oscillate at over 200 megahertz.

Laws: Mhm.

Dill: So they set me up with a little lab, and I built everything I needed. They gave me a technician, who I mostly sent off to get out of my way. He wasn't very helpful. But I made tunnel diodes.

Laws: This is for the Signal Corps?

Dill: For the Signal Corps. And then the electronics guys would invariably burn them out immediately, which didn't surprise me. So I'd make more. And finally, one afternoon, I went, and I scrounged up an old communications receiver. And I took a tunnel diode and connected it up simply do a battery that was oscillating between it and the capacitor on the leads, and I simply cut the leads, and cut the leads, and cut the leads. Each time the frequency went up.

And when I got it well over 200 megahertz, I called everybody in and said, look. After that, I did nothing else of use in the army. I had done it. I had achieved it. And interestingly, for some time, they were looking for an officer like me to go to the Signal Corps lab.

Laws: Mhm.

Dill: They eventually got it. One of my year-behind Carnegie colleagues, Jim Meindl, Again, good friend, who not only was in the army for two years, but he also married the daughter of the lab director.

Laws: Gave him access, huh? And so how long were you in the army for?

Dill: Six months.

Laws: Six months. And then you returned to IBM?

Dill: I returned to IBM. And when I left the army, they said, on reserve, don't call us. We'll call you. And they never called, and I finally got a letter saying I was too dumb to be promoted to captain. But if I would just go take this course, I could be promoted to captain. And I was sorry that I was so stupid, and I never became a captain. And after the seven years were up, I got an honorable discharge, which I saved.

Laws: OK. Good for you, Rick. What did you do when you went back to IBM?

Dill: I went back to the same group, did more tunnel diodes, migrated from germanium to 3-5's, gallium antimonide and gallium arsenide, which made much better tunnel diodes because of the direct band gap.

Laws: Mhm.

Dill: Also observed, however, that they were very short lived. And that's something that cropped up later, when we were doing semiconductor lasers. I'll talk to that then.

Laws:. And you did move on to LED laser diodes?

Dill: And then we moved from Poughkeepsie down to Yorktown, and I was playing a little bit with gallium arsenide diffused alloy transistors. Not very happily, not very successfully. And then light emitting diodes became the thing for the physicists. And well, I could make them, no problem. So I was making light emitting diodes, and then the team of four physicists, Marshall Nathan, Bill Dumke, Gordon Lasher, and Gerry Burns.

Dill: You can put it in the transcript, OK. They had the idea that if you just blasted these diodes hard enough with a pulse, they would become lasers. So I would make diodes, and they would get very short pulses, and burn them out until one day, they got ….

Laws: This was visible or infrared?

Dill: Infrared. Gallium arsenide, yes, is in the near infrared. Until one day, they got line width narrowing. (You got rather broadband radiation from the diodes as LEDs.)

Laws: Mhm.

Dill: And declared that we had a laser, and made a few more immediately, and another one did it. These were unstructured. But within a few days, I dropped enough gallium arsenide crystals to know that they broke on crystalline surfaces. And I was making diodes that were aligned, so those surfaces were perpendicular. The 1-1-1 planes were perpendicular, and cleaving them (to make the mirrors). And then wire sawing the sides of the die. And again, it had the diffused junction in it, so you put a contact on top and bottom, and you had a laser.

And now, all the light came out the ends. It took much less current. Within a few weeks, we had CW lasers at nitrogen temperatures, and only got better after that. And just being a dumb engineer, I'd always thought about optical communications. But all the ways to modulate light seemed very difficult to me. And if you had a light bulb you could switch on and off, which you can't do with incandescent or any of the common ones we know. So the question was how fast can you switch these on and off?

And I pondered it, and I was in contact with my friend, Karl Konnerth at Carnegie, and brought him out for a summer and said, you'd do this. We're engineers. Gave him all summer to do it. And he came up with the correct answer, faster than we can measure.

Laws: Fascinating.

Dill: And he went back, and taught another year, and then came to IBM.

Laws: OK.

Dill: And among other things, He set up optical communication links. Had them running out the doors, up along the corners of the wall and ceiling, and around corners to another lab.

Laws: So who else had been working on this? Bell was doing some optical work at that time?

[an aside .. Bell Labs wished they had been working on it enough that in their informational ads celebrating the 100th anniversary of the telephone, they claimed to have invented the semiconductor laser. That was some years after the invention. I cut the ad out and gave it to Gomory, director of research. He had a good time with it in peer discussions with top Bell Labs execs.]]

Dill: IBM demoed at Expo in Toronto, two optical links.

Laws: And that was what year?

Dill: It was '67. And they demoed two optical links with Karl, and an engineer, Musti Narasimham, in Fishkill put together. One of them, which was low speed, because it went to the stock market, so they had a readout from the stock market on a display. And the other one, which was a direct link from the top, down the open center of the building, top to bottom, was a high speed link between top and bottom.

Laws: Fascinating.

Dill: Not in Fiber.

Laws: Right.

Dill: But we knew about Fiber. We also knew some of the problems with Fiber at the time.

Laws: Sure. So this was '67. But I understand you were also involved on the Compact Committee that helped decide SLT. So that must've been quite a few years before this. Is that right?

Dill: It was probably '59 or '60. IBM formed a Compact Committee.

Laws: Meaning making smaller?

Dill: Well, Compact was the name. It was basically, what do we want to build our next generation computers with? Not the architecture. But we had the guys, the architects. We had the circuit guys. We had the device guys all sitting down, with at least weekly meetings. We looked, what kind of logic do you want? Everybody was saying, well, can we build just one thing?

Well, that the answer to that is the NOR gate. So we settled back and got off that. But in doing that, we looked at do you want to do crude integrated circuits? Do you want to use the full-adder transistor? And the answer was they couldn't make up their minds. And finally, at what in my mind, was the climax meeting, was one where Bill Harding-- and I know Bill Harding well.

He can be a little brash. He stood up and said, damn it! “I'll give you transistors for a nickel.” We'll solder them down and onto a ceramic substrate with thin film resistors, and that's what you get. And that's what won. And you have to look at what IBM was then.

We had incredible depth in a number of areas. For instance, you say, oh, these are transistor guys. They built this automated machine. No. We had electromechanical guys who could do automation to build the transistors. (for the 1401)

We had deep machining skills. We had crystal growth. We had the things needed, both in germanium, and as we moved to silicon. And this was the first silicon. There were some ground rules that came down from management.

Management, Bob Evans, had their own directives. They wanted the transistor to be hermetically sealed, so they insisted—[They also wanted components, transistors included, to be soldered down.]

Laws: These were planar transistors by then?

Dill: These were simply silicon planar transistors.

Laws: You were talking about mounting them on the ceramic?

Dill: And so on the top of the finished wafer, we essentially, put a low temperature powdered glass and fired it to hermetically seal it, the same as we did on the glass metal seal kinds of things, and assumed that that was what would protect the transistors. We etched holes in the glass down to the chrome copper gold overcoat we had on the aluminum contacts to the silicon. Then we evaporated a thick solder dot over each contact using a metal shadow mask in the evaporator. Copper balls then placed on the contacts using a plate with holes and solder melted to make three copper plated contacts on each chip.

Laws: So you're attaching--

Dill: So now, you go back to our transistor making machine. You have the syntron sonic system spirals that bring transistor chips up, so that at the top, you pick them up, transfer them to where you're holding them from the back, test them electrically and place them on the substrate held by flux until they are soldered down

Laws: OK.

Dill: The resistors were [developed by] one of my colleagues. In undergraduate school, he was president in the student council, and I was vice president. Ed Davis was a PhD from Stanford. Eventually, his aim was to be an executive, to be vice president of IBM for the components division. I had two colleagues with that aim, and both of them did it, Ed Davis, and then Paul Low. And Ed Davis basically did the resistor technology, which was to silkscreen, something we knew how to do from various other things we'd done. Palladium oxide resistors. And these were not very precise resistors.

But having worked with the circuit guys, I knew that in digital circuits, they wanted as precise a resistor as they could get, because this let them get higher performance, because the levels were all better defined. And so the module, before it had the transistors mounted on it, went into an automated machine that could access each resistor electrically, and then with a sand blaster, cut a groove into it until it was a 1% resistor.

Laws: A way to get precision resistors on a piece of ceramic.

Dill: And so this was not a Mickey Mouse technology, but it was not something anybody else in the industry would have done. The early ICs had pretty bad resistor tolerance.

Laws: Right.

Dill: It was as different as the Philco surface-barrier technology was for germanium, which still in my mind is one of the very innovative ways to make transistors, even if they were not very rugged mechanically.

Laws: But It took unique advantage of the technologies that IBM were able to bring to bear on it.

Dill: Yes.

Laws: Not everybody else had access to that.

Dill: And not everybody else had the same business experience. IBM didn't sell its machines. It rented them. When they broke, they had to fix them.

Laws: Yep.

Dill: The soldering was so that you could replace components right down of the transistor. Forget that it's only a nickel.

Laws: Right.

Dill: But in fact, if you did, and you tested the circuit, and it showed a bad transistor, you could replace it. No big deal.

Laws: Sure.

Dill: They also had the flexibility-- they developed multi-level circuit boards for soldering the modules into, including having to work on getting what everybody does trivially today. They plated through holes, et cetera.

Laws: Sure.

Dill: Had all of that together, together with plugging those into our back plane, which was I believe, for the 360, still wire wrapped, but automatically.

Laws: Mhm.

Dill: And now, this gave you the incredible flexibility they wanted, because you're selling these machines for a lot of money to customers, a few of which have ideas about something they want on their computer that nobody else has.

Laws: Right.

Dill: When you saw a mainframe being built in the factory, it was on a maple floor, industrial maple. It had a sign overhead naming the customer. They brought the customer in to see the computer being built.

Laws: Mhm.

Dill: This was not 500 million PCs or iPhones.

Laws: Sure. And they had a unique ability to customize the machines for the customers.

Dill: The customization was there, and that continued out through the 370 line. I'll cover some of that later.

Laws: Now, this would be in what, this 1963, '64 time frame? Well, they announced the 360 in '64, wasn't it?

Dill: Yeah. The Compact meeting was about 1960.

Laws: Right.

Dill: The process went. We literally set up first in the main plant and then built Fishkill. So yes. The product was announced in '64. A month after we started shipping, we had some interesting technical problems in that all of a sudden, the transistors were testing as leaky. And like many things, life doesn't go without major traumas. But this was an interesting one to me, because what I have drawn from it is the inference that it helped IBM much inadvertently by solving it.

They had a phosphorus diffusion for the emitter which was done from a phosphorus silicate class, just evaporated over the SiO2, down to the silicon, where you wanted the diffusion done. And so that glass remained on top. But it didn't have as good an adherence for the metallization as they liked, so it went through a brief etch to take off the surface layer. Well, eventually, it took the most of a month, because everybody said, they're doing exactly what they're told.

They're standing behind this guy. And he picks up a wafer, and he looks at it. It's fresh. He dips it in the etch for the 15 seconds, or whatever it is, takes it out, washes it off, looks at it again. Etches it again, picks it up, washes it off, looks at it, etched it three times. That took off the phosphorus silicate glass. And I asked him, what he did. And he described, I etched this for 15 seconds.

Laws: He forget the three times.

Dill: Three times. That, which we didn't know then, was your wafers, which were handled by people, were handled by water that wasn't as clean as we learned to use in later years. All had sodium on the surface. And when you heated them up for any thermal process, the sodium is in the oxide, migrates freely.

Laws: Yep.

Dill: Even at room temperature, under field. And what happens is like many things that pervade in semiconductors. If something is far more soluble elsewhere, and is able to migrate, it will get there.

Laws: Right.

Dill: So the sodium all ended up in the phososilicate glass and couldn't get near the surface. [The passivation of the semiconductors was really the psg and not the frit glass, but no need to eliminate the glass at that point.]

Laws: So that was protecting it from sodium contamination?

Dill: That was protecting you from getting inversion layers, which made the transistor leaky. End of story on that. The 360 was a success. It worked well. You could put other components on your modules, up to four contacts. Beyond that, because the copper ball of the copper balls, it wasn't a reliable contact system for more than four. But that let IBM build the 360 family, let them build the 360 family with a variety of circuits, with a variety of performance.

And it was kind of an interesting experiment, to build something that big, that had a single operating architecture, and the only thing that actually executed the architecture was the top of the line machine.

Laws: Now, were you involved in the next generation of SLT architecture Rick?

Dill: No. But was I involved in watching the technology? Did I interact with my friends in development? The answer was yes. I had a pretty good window on the whole world, because I was not the isolated researcher off doing things. I was trying to do things that would be useful to mankind. SLT became MST with IBM invented solder bumps (C4-contacts) and integrated circuits going to MLC and VLSI chips soldered to multi-layer boards for the 370 and water cooling of the chips. I did stay active in the arena of automation concepts for manufacturing.

Laws: How did you get into this position? You must have been working for someone who gave you direction.

Dill: No. I never worked for--

Laws: Nobody gave you direction?

Dill: I was considered by some of my managers as very delightful to manage, because I didn't require a lot of direction. And there were others that at points would have fired me, if they could.

Laws: Yeah. OK. So you're able to gravitate to things that you felt you could contribute to?

Dill: You see these people in the cafeteria, because lots of researchers in microelectronics never went to Fishkill.

Laws: Mhm.

Dill: But didn't have a social thing. I had social contacts with the magnetics people, with a wide range of people. The thing about IBM Research is the only thing today that I can see that remotely resembles that environment, where people can have a large amount of self direction is Google. It's a very different company

Laws: Right.

Dill: IBM had very strict business directions, much of it from the top. But their wealth of smart people was just amazing.

Laws: I think you mentioned you used to talk with John Cocke, and Fran Allen, and other people.

Dill: Yeah. Fran Allen was just one of the other singles interested in lots of things. And I was interested in what she was doing, and never did get her to tell me very much about what she did on running the team that programmed Harvest, other than a few things like it was fortunate for the wealth of instructions, because you could make the machine run with few enough of them that mortal programmers could actually do it.

Laws: And John Cocke's work, were you familiar with what he was doing?

Dill: Oh, yeah. Well, John Cocke, again, was part of the social group. And we skied weekends together. We drank beer together. I remember periods when we had a group that got together. We called it the Thursday night club, at the Little Brauhaus in Poughkeepsie. It met any night [that] more than one member was there. But we read poetry. We discussed all sorts of things, cars, and computers.

If John was there, it was [an occasional. Likely as not, I'd end up in the parking lot at 2:00 in the morning, after the bar had closed, talking to him about his computer. And he would come to me, because he was interested in what I was doing. It was a fascinating world to be in. And that, for me, continued, because I had the research environment. Even when I went and spent seven years in manufacturing later, it was with smart people. They weren't all PhD's.

But that's not how you judge people.

Laws: Right.

Dill: And then the IBM Academy was again, a really neat gathering.

Laws: That was at the research facility?

Dill: No. We'll get to that.

Laws: OK. That was later on in your career. So this was during the '60's?

Dill: It was during the '60's.

Laws: And at some point, you took a sabbatical and came out to Berkeley

Dill: Well, no. What happened after the semiconductor laser was again, I was talking to John Cocke. I knew I knew Jack Bertram. And Jack pulled me aside and said he needed to build high-speed circuits for Project Y.

Laws: Mhm.

Dill: And how would I approach it? And so I thought about it. And I said, all right. I would like to use a high mobility semiconductor. Silicon distinctly set you back on mobility from germanium. And I had already written off gallium arsenide as hard to work with. And not that it shouldn't have been worked with, but I didn't want to work with it. And it had only one mobility that was high. The hole mobility was tanked.

So I suggested we should try to build planar transistors in germanium.

Laws: Mhm.

Dill: And he got me the ability to form a group to do that. I brought in a bunch of people. We had a circuit group, Arnie Farber, and Gene Schlig who did some of the first RAM [cells].

Laws: Right.

Dill: And we had a materials group under Arnie Reisman,I probably should have been manager of the project but he certainly outweighed me in the time with the company and apparent leadership. So I was there. And then there was a third group added, which came to me when Holly Caswell came off the cryotron project.

He wanted to organize a semiconductor group. And he set out to compete with me. Holly was a very good guy. I worked for Holly later. This didn't end us up as enemies. But I ended up winning and having two small labs that could build transistors, with slightly different technologies, which was actually neat. We adopted an interesting fabrication technology that was used a number of places. But in particular, TI was using it to make low noise transistors for the federal government.

Basically, you just diffused a base layer on a lightly doped epitaxial layer, with a low resistance collector contact in the back, because for low noise, you want to keep the resistance low. And then this is oriented on the crystallographic 110 plane, so that the 111 surfaces are coming down and intersecting on it. And you put down an aluminum stripe in the direction of the V intersection that contains arsenic. Go through an alloy process, and it melts down into a "v," and the arsenic diffuses forward.

And that's the active base. It can be very thin. You do the alloying. And that is also your diffusion time, and you're at 700 degrees for a few minutes.

Laws: And because you couldn't use oxide masking--

Dill: Oh, yes we did. We used deposited SiO2.

Laws: So you deposited silicon on the germanium?

Dill: Yes. And we deposited the aluminum on the silicon oxide with openings, and so we were essentially planar on the surface. And one of the things of having the two groups working, because we were working at 2 and 1/2 microns. And one of the things that we found was that the group that came from Caswell was using positive resist, which turned out to be-- we were using the Kodak KMER negative resist. And we were defining our aluminum in the KMER process by depositing the aluminum on the resist, and then heating the wafer to about 100 degrees, and spraying it with solvent, at which point, the resist would blister all off, and leave just the aluminum stripe.

There was something involved in that resist process that passivated the SiO2 from the aluminum attacking it so that on the other process where we were etching the aluminum, we still had to put down the negative resist and blister-peel it off. That's just the nuances you discover and never will quite understand why.

Laws: Sure.

Dill: But we were able to make transistors. The project worked in open direct competition, everybody helping everybody, with a group of silicon under Dave Dewitt. And they had their modeling guy. I had my modeling guy. It would take them about three or four weeks after coming up with modeling, how to improve what we'd last done, which was about the time I had for running wafers through the line and doing the seat of the pants. What do I think I should do next? And it was interesting, because our cycle times really matched pretty well. In 1967, we recorded 150 picoseconds raw circuit delay for our single transistors in a circuit on a sapphire substrate, with nichrome resistors. We also build some IC's that were a little slower. The silicon wasn't far behind us.

Now, they had a little more sophisticated technologys than we had, but not a lot.

Laws: Mhm.

Dill: But I figure we achieved our aim. But I also recognize that there's a big hit if you're going to go back to germanium.

Laws: Right.

Dill: And one day, Dick Joy and Gary Hachtel, the two modeling guys walked into my office and said, Dill, you missed something. And it was sobering, because I was hoping for a 2 and 1/2 to 4 advantage. And they said, well, in germanium, when you speed the electrons up at high field at 10 to the fourth volts per centimeter, they stop going any faster. That doesn't happen in silicon. That happens to be the speed of sound in germanium. This also relates to how Gunn diodes work.

Laws: Uh-huh.

Dill: And so I was down to 1 and 1/2 to 2. I'm an engineer. My boss is a chemist. He believes in what we're doing, even though it wasn't his originally, like it's a religion. I could not go up management through him. I had a good relationship with his boss. But I couldn't do that. So I went to Art Anderson, then the director of research, and basically said, the gig is up. I said, you've been telling us we should transfer or kill the project.

Laws: Right.

Dill: And the answer is plain. We should declare a success and kill the project. My boss would have fired me if he could have. This was really bad. For me, it said, wait a minute. This means we could think what to do next. I've never felt the change was bad. It turned out I managed to find that Berkeley wanted somebody to cover for a faculty member on sabbatical. And I took two quarters. And Dave Dewitt, who led the silicon project that we worked and competed with, came in, and took the third quarter. So we covered the year.

He actually moved into our apartment when we moved out.

Laws: And this was 1968?

Dill: 1968.

Laws: Interesting time to be at Berkeley.

Dill: Oh, yes. It was also an interesting time, because it was the year I got married.

Laws: OK.

Dill: And so I had a new wife. We were in Berkeley.

Laws: Where did you meet your wife?

Dill: I met my wife at IBM.

Laws: OK. And she was doing?

Dill: She had a master's in experimental psychology and was doing a number of interesting things. Things like Flicker, This was the early days of TSS. Things like writing programs to look privately, not at what people were doing at keyboards. How often did they hit the keys, not what instructions were they running.

Laws: I should ask, her name was-- is?

Dill: Was Amanda Brown. You can find Amanda Brown on papers on Flicker, if you look back.

Laws: OK.

Dill: Later, when I managed display technology, people would bring me this paper they discovered, written by Amanda Brown

Laws: Fascinating.

Dill: But we did our own Flicker studies later.

Laws: OK. And so she came to Berkeley with you?

Dill: She came to Berkeley. She took a year off, took the time off, and got to go take courses and walk across campus when they were protesting. And they would invite her into the protest lines. It was a good time.

Laws: So I arrived in California, and I used to wander around the Stanford campus at this summer.

Dill: Well, we lived just off Telegraph Avenue, a few blocks north of campus. It was a great fall and winter.

Laws: Interesting time. Did you learn to fly gliders that summer?

Dill: Yes. Lloyd Hunter, who had left IBM for Rochester, I'd seen him at the device research conference before we came out. And I was thinking about maybe learning to fly. And he said, oh, well. You've got to do it in gliders. He was a very good glider pilot, and loved to teach.

Laws: Mhm.

Dill: Well, as I went home and told my wife, and it basically scared her shitless. However, when we came out to Berkeley. It was the month before we got our car. As soon as I got the car, I went down to IBM.

Laws: IBM down here in San Jose?

Dill: At Cottle Road. I'm walking out of the cafeteria. And who I meet but Lloyd Hunter, who's out on sabbatical. The next weekend we went to Yosemite, and hiked, and lay on our backs, looking at the sky, and watching the hawks soar. And she was agreeable to it. And we both took lessons almost every Saturday.

You went down to the basement of Cory Hall at Berkeley, and you found a tech who was part of the glider group. And he got you signed up for the Northern California Soaring Association and the Ames club which owned the gliders.

Laws: And where was the flying from?

Dill: It was Livermore. Hummingbird Haven. And we'd show up there just about every weekend and fly, Saturday or Sunday. And didn't solo, but we got a lot of training. Went up in a super cub and did two turn spins as our first power training. And it was good.

Laws: Something else you discovered at Berkeley, I understand, was photolithography?

Dill: No. What I did at Berkeley, I was very frustrated by photolithography, because it was the one process - and I love photography - but it was the one process I didn't have a good understanding of how it worked. Yes, I know. You shine light here, and it either stays or goes away. But that's not a good enough thing for understanding how to make it work for you.

So I spent a lot of spare time just pondering this and talking to anybody who would lend me an ear. But what I did was first quarter, I taught the undergraduate solid state course. And the second quarter, I taught the graduate course. And I brought a very different flavor to each of them, because here's a guy who actually does this stuff in industry. And it's fun.

Laws: Was Andy Grove teaching there then?

Dill: No. He had taught there. [But it was Grove’s undergraduate course]

Laws: Interesting.

Dill: From his book. Yes, it was stuff that wasn't in the literature when I was in school.

Laws: Right.

Dill: But it's always a challenge. But it was fun. And I tended in the graduate course to try each week to have real world problems, including one where the solution wasn't known, because that's what you run into. And by the way, you aren't expected to be able to answer those. So it was a good time. I arrived as an unknown.

Ernie Ku was the department chair. There were a bunch of young faculty that we got to be friends with. I have had a very special relationship with Berkeley ever since. Respect both ways.

Laws: Sure.

Dill: It wasn't clear it was going to work that way, but it did.

Laws: Right.

Dill: There was one night we went out to dinner with Tom Everhart and his wife. As my wife says, she didn't think I understood what he was asking. He was more or less asking me, would I stay and be on the faculty? And the answer was no. That's not me. But it would've been a very different career.

Laws: Sure. Back to photolithography then. So I wanted to understand more about the process.

Dill: Well, when I went back to IBM, I was offered my old job back. And I said, no. I left it in good hands. And I talked to a bunch of people. I spent some time visiting our development, and manufacturing, Fishkill, and Burlington. And we got looking at measurements. And much of the metrology was a little bit like a sophomore physics lab. Very manual. Very tedious.

And Karl Konnerth was around and he and I talked about it. And we decided it would be fun to do computer controlled measurements. Thin film thickness is the first thing to work on. And made a proposal. And I was given probably the best opportunity anybody ever gets, which was not only the right to build a group, but the right to really invite people to join my group without first asking their managers.

And so I built a group, and it really had two threads. One was computer controlled measurements, and the other one was I had enough spare energy to get a few people to work about and think about lithography. Well, on the measurement side, we got an IBM 1130. We got a tech who'd been on the IBM computer assisted education thing who was just good at connecting things to computers. Mitch Phillips, Karl Konnerth was the lead guy in the software and computer side.

And I sort of managed it. We acquired some other people. We built an automated spectrophotometer, with just a rotating filter wheel indexed. Fiber optics to get the light to the wafer and collect the reflection normally back off it. And proceeded to analyze it. And we made a tool that in a few seconds, could measure a thickness.

There were some interesting things. Karl and I had a good relationship. I said, all of these curves are going to lie between the two asymptotes of a minimum and a maximum. And he went and calculated it first, and plotted it out as a graph, which showed all the curves lying between two asymptotes, which he put up on the wall. It was a graph plotted to prove I was wrong, which of course, proved I was right.

We went from having to go through this as a DP (Data Processing) machine. And then once a little later, being challenged because we were only using it 44% of the time. And my friend, Janusz Wilczynski, who was designing lenses, was using his 40% of the time. Couldn't we share? We adapted. Every program ended in a loop that waited for the stop button to start the next program.

Laws: I see.

Dill: A few years later, I didn't know how many computers we had.

Laws: Mhm.

Dill: We had a communications controller, which was a very interesting architecture, because IBM formed IBM Instruments, and their first product was to be our film thickness analyzer. Doing that, and also doing color matching for paint. The color matching had been written for the 1800 before, and this was going to package it [the tool ended up being aimed at fabric dying and not paint color.]

Laws: OK.

Dill: And we were going to put a Series One in it. But IBM's politics said we had to pay list price for the Series One and I could buy this three board computer, which I saw first as a prototype, actually got one of the prototypes, which had an obscene value that the bookkeepers would have had trouble with if they'd known. But it was a communications controller which was very good at switching tasks. A 16-bit, three card computer.

Laws: Mhm.

Dill: However, we had to write our own basically start up system. We put an IGAR, that is an 8 inch floppy disk drive on it as our storage, and used that for our IPL. Had to write the code for that. And I looked around the skills of the group, and everybody knew FORTRAN. A few people, like Karl, were adept at writing the other code. So I decided we should have a FORTRAN compiler.

Fran Allen and told me I couldn't do it. Correctly, probably. Peter Capek told me if it took me more than two weeks, I was incompetent. I hired a graduate student, Jim Sneeringer for the summer, who was studying with Fred Brooks. And he, Karl, and a technician, who simply volunteered that he wanted to be part of the project and wrote all the math routines, in six months-- took more than three-- in six months, put together a rock solid adaptation of Fortran H, which was written in Fortran, so it was relatively easy, which we gave to other users in IBM to use, and never had a service call.

Laws: Solid, like you said.

Dill: But the answer is I shouldn't have had the competence to do it.

Laws: And meanwhile, the photolithographic work?

Dill: OK. On the lithography side, I had, by then, worked through a set of assumptions, which was we really had to look at inside the photo resist at how the light behaved. And having worked in thin films, you know that it's wiggly inside. And I got this reinforced with SEM images, which showed fringes on the edges of images of resist patterns on cleaved wafers. So you had to calculate the degree of exposure at every point within the resist.

That's OK. But it was complicated by the fact that the resist was changing its absorption as it got exposed. And so I assumed that there's a final absorption level of a fully exposed resist. Here's the changing absorption, which is that plus the changing absorption. And then there's essentially, a time constant for the change. So those were named A, B, and C as my constants, and we then proceeded to develop the full modeling, and to measure the resists, measure their absorption.

Again, we've got our own computer controlled tools. Why not? Put resist on a non-reflecting substrate so that you don't have standing waves. It's almost the same thing. But you still get a little bit of standing wave you can calculate the thickness as it changes. If it's on silicon, you can watch it step down as it develops and derive A, B, and C.

Laws: Mhm.

Dill: So we could characterize the resist. We could measure the resist. And then you say, all right. There then is a relationship between the rate of dissolution and the amount of exposure. And that parameter was m, which was just the fraction of complete exposure. And lo and behold, a sugar cube-like dissolution model. Others models have happened since. They do as well. Maybe slightly better, but not much.

We had a complete model, no free parameters for positive photo resist. I was pretty comfortable, because nobody else was doing this. And so we took our time and published five papers in 1975. I was author or co-author on all of them.

Laws: And they were published where?

Dill: Electron Devices Transactions. My loyalty.

Laws: This was the IEEE?

Dill: Yeah. I was later president of IEEE, Electron Devices. But we published them all there. - the complete picture. And that's probably the finest piece of technical work in my life, put together as a working manager. But as this happens, opportunity comes along. After some time of this, things were running fairly stabley. We did an automated ellipsometer, where based on lunchtime conversations of Fourier analysis in optics, I decided, you ought to be able to apply Fourier analysis to rotating components in an ellipsometer, instead of trying to find a null, which you can do, but it's tedious.

Laws: And what is the function of an ellipsometer?

Dill: The ellipsometer measures film thickness-- index and thickness of a film. And it will measure it down to literally, a fraction of a monolayer. It is a fun tool, more tedious. But we automated that. And that's been again, a very extensively used tool. And as a matter of fact, the spectral version of that ellipsometer, that is, you put a measure as a function of wavelength, has been used by Costas Spanos at Berkeley and his students.

And it is the only way to make profile measurements of test gratings on wafers with visible light at 15 nanometers today. (within the clean FAB)

Laws: And this was in the late '70's?

Dill: No. The ellipsometer was the late '70s. The scatterometry by Spanos completely blindsided me. But I have to praise it. It came out in the late '90s.

Laws: OK.

Dill: And it's used in every high tech fab today, because there's no other nondestructive way. It's even used on the lithography tools. You can see not only the image size, but the profile. You do it by taking the measurement, and then matching in, scattering computations of what light you're expecting, and nearby.

Laws: Mhm. Interesting.

Dill: Yes. A very critical and interesting tool. I didn't invent it.

Laws: Now, you were also involved in display technology.

Dill: Well, from there, we migrated our computer control work to doing an electrocardiogram machine, because IBM had a computer analysis of electrocardiograms that was very good. It was third generation. And we put that together with data acquisition by one of our U C processors.

We formed IBM Instruments, which didn't last in IBM's world, with the spectrometer.

We formed IBM Bio-med with the EKG, and even sent the key people over with it. It didn't survive either. Mainframes were just too damn profitable and every internal start-up was expected to be as good..

Laws: Right.

Dill: You couldn't compete against putting your investments in something that makes ordinary profits. But we did that. At about that time we were doing that, I got invited to join Gomory on his research staff as just a staffy. But again, not really directed. I got a chance to just look at things, including Gomory getting a little upset with me, because I would help his secretaries with word processors. And he thought, that was secretarial work, which turned around a few years later when I did have the display labs.

And we now have a display on his desk. And he was over at our labs with Carol Thompson then Karl Konnerth -- because those were the people that could show him what he could do with this, that he related to. But I did that. And then I was invited to take over display technology, which was just coming off of gas panel.

Laws: Mhm.

Dill: And I had to do a major reorientation. IBM had put out a gas panel display, which didn't go well. It was hard to see how you could get IBM deep into any new flat panel display technology. And we investigated electroluminescence. I looked at the limits of CRTs, which is if you're trying to get very high resolution, then you lose brightness. And well, the way around that, to me, was a cluster of beams all deflected together.

A rectangle, which is tilted, so they interlace. And I went backward in time and built vacuum tubes-- set up to build vacuum tubes, and we built some with an integrated cathode grid. Ceramic, with the cathode material in cavities, and the grid on the front face. Operated at logic [voltages]. Turned the beams on and off at logic voltages-- very nice and swept commonly. And after I was all the way gone from displays, they built a 7 megapixel display with all the electronic corrections to keep the beams looking nice. You could read full page of The New York Times on that.

Yeah, it was 7 megapixel. It didn't make it. We did some other interesting stuff.

Laws: Because it was competing with liquid crystal?

Dill: Because the only technology that would take it to color was Sony, and they were not an interested partner. ([LCD wasn't a good candidate because it really needed something like TFT to make it work. That came later. Paul Alt who was part of my team had written the definitive paper on limits of matrix display, particularly LCD. The problem was lack of non-linearity limited x-y selectivity.])

Laws: Right.

Dill: This was not their business.

Laws: Right.

Dill: I acquired more and more pieces of the display world. When the PC came out and we hadn't even seen one, I was sitting with my small management group Friday afternoon in my office. And one of the guys bragged he was getting a PC for the weekend to show to his schoolteachers. And I just raised the question of, gee, "What would it take to turn that into a computer terminal?"

And we had the right guys in the room, and we agreed that it would be interesting to try if they had it for a few days. So a phone call said we could have it through Wednesday, when I happened to have a show and tell to the technical brass from the division building displays. And they got the machine Saturday afternoon. Wednesday afternoon, they had up and running, a full 3270 emulation running basically on a dumb terminal-- not a 3270, but already, the emulator was written.

But they had it running from the PC with the PC communicating, which we also had to write the code for.

Laws: Busy few days there?

Dill: Busy few days. And we'd done the terminal. No, we hadn't done the terminal. That's when we did the terminal. We just took the terminal emulation and ran it in the PC. That was easy. But we wrote the communications thing from guys who'd never seen the communications protocols before Saturday or Friday afternoon. There was 12 hour days in pairs, completed, up and running, and didn't crash in the demo.

I invented the video RAM, bringing in a few others to fill out the concept who joined the patent, and set up a group to try to prototype it in Research. This was unusual since Research didn't do chip design. Eventually, got that picked up by Burlington, but not before other companies found the paper. But that was in the era when you were competing with refreshing your display and updating your display. That, now, is a past problem. But we built the first video RAM. And I've always been a little bit disappointed that nobody ever figured out many of the other uses you could've put the secondary high speed output port to. Because in some sense, it was very interesting dual port memory.

Laws: And that was manufactured then as a product by Burlington?

Dill: And I think others in the industry built them actually [got to market] before we had our product out. We had the patent.

Laws: Good. So where did you go from there Rick?

Dill: Well, I then acquired a very old research project on signature verification.

Laws: This is a signature in a person's handwriting?

Dill: Yes, a person's handwriting with a sensored pen. It measured acceleration and pressure. It was a great idea, far oversold for the degree of engineering done. But I was asked if I would take it on as a project and get it ready for manufacture. And I said, if I got a manager to handle it, and we did it. We built a group.

And they did a superb job. I look at-- because signature verification comes up frequently. And I can look at it. And I can say, well, I know what the false positives and range of things is. And it isn't perfect. You wouldn't want to use it as your sole authentication. On the other hand, when it was demoed to the FBI by one of the team, they brought in this scruffy guy in a mismatching coat. And Tom, who was running the demo, signed his name very nicely. And forger sat down and did a beautiful forgery.

But of course, the rhythm and everything wasn't there.

Laws: Right.

Dill: But we did run field tests, where we were paying for lunch if you could defeat the system. And we did pay some [people]. You could set parameters and change either the rejection of your signature, or the rejection of other people's signatures.

Laws: Mhm.

Dill: Down in the low 1% and around that level.

Laws: OK.

Dill: And I'm impulsive. My manager, who was on Gomory's staff when he'd asked me to take it on, was now my manager, sat down at lunch one day when I had a new employee in the signature verification sitting with me. And he told me what a dumb project it was. Well, it had been oversold. It was hard to sell, because of funny rules of how IBM charges things.

If it had just been said, “This'll help sell PCs”, it would've been OK. But whoever takes it on first has to pay the whole development cost. And that wasn't going to happen.

Laws: OK.

Dill: So we had a very simple, very inexpensive pen with ceramic phono sensors as xy accelerometers. Stereo is xy orthogonal, very nice, and just a piezo pressure transducer. Very simple pen, very cheap.

Worked well. I had it in my home set up so I didn't have to use the callback we were using for security. I could sign my name.

But it didn't fly. My manager (who asked me to take on the project earlier) sat down in lunch one day in front of a new employee, ranted about what a stupid project it was. And I was two hours later in his office saying, I'm leaving. I'm not leaving the company. And I went up to Fishkill for seven years, took part in putting in the last two bipolar factories that IBM put in. Very small team. Again, complete freedom, open.

I got to investigate, to work with people on the control systems. I got my friend Karl Konnerth up, because we talked about things and looked at the line. And it was clear that we needed to make the line paperless. It had never been done. Took PCs, took communicating PCs, and a mainframe, and worked and made a system that had a dedicated mainframefor each line, had a terminal at each workstation. No sign on protocols. It's (the cleanroom) a closed environment.

Had the instructions for running the tools. That was one of the documents that was at every workstation. The biggest document at every workstation was the “how to use a terminal document”. All the things you could do on it. All of that was gone. All of the instructions were in. The tool instructions were locally stored. Last in, first out. So you could query multiple tools.

But whenever you went on, it looked to the mainframe, which looked up to the database system to see if that was the current document.

Laws: Mhm.

Dill: And we did that. Took on the testers, which wafers would come in to be tested. And you had to wait (up to many hours) until the results came back from a (busy) database mainframe, which would take an unknown amount of time, depending on the load, before you could pass the job on. And some sweet, young thing had gone to the new lab director, who I knew, and said, why don't we do it on a PC?

Which sort of brings me back to The Beatles, "Why Don't We Do It In The Road?" And I took that on, and I've challenged Mark Donner, who I'd hired some years ago, and then gotten him supported when he went back to CMU for his PhD and offered him the challenge of coming up and doing it. And he came up and took the PC, took the unique test language, which turned out to be two separate languages, converted them using LEX & YACC, two languages you could actually work with on any computer, run on any computer, and got it up and running.

Transferred it to somebody who could maintain it, and literally, we could disposition the jobs as soon as they were off the tool.

Laws: That’s important. So all this was at Fishkill?

Dill: All this was Fishkill. And I wrote a few apps myself that ran on the line.

Laws: Did those get picked up by Burlington, or any of the other facilities?

Dill: No. These were two new factories that were-- Fishkill was running-- not common with Burlington.

Laws: Sure.

Dill: They (Burlington) did those strange things with field effect [transistors].

Laws: MOS and other things like that?

Dill: Got involved in some of the things related to the electron beam, and to understand some of the nuances of the lithography there, which was pretty amazing. But literally, I wrote one of the documents in the line that was critical, [That] was what mask to use with what wafer. It might trigger your curiosity to know it was called the Exception Sheet. It had to be updated by specific people when its content changed and stamped with the right stamp by somebody who dressed up in a bunny suit, who came out, and did it.

And it was to be something like 30 or 40 man years to replace that, software wise (according to the IT people). I got a bright, undergraduate summer kid from MIT. He essentially wrote code using REXX to act like a user when a job was released, and to get the exception sheet. And then I wrote the code that the production control people used to update it, which by the way, kept track of all the updates so that I could go in, and I could see that they made a change here.

15 minutes later, they changed it back. I can see the activity. I could also see that one person was doing all the work of the four, which their manager was not smart enough to see, and I never snitched on. But it was good times. And then one day, Jim McGroddy came in and asked me to come back down to Yorktown and take over managing TCAD modeling.

Laws: OK.

Dill: And that was like herding a bunch of cats. It wasn't really very fun. And I'm always a little taken back when somebody thinks I'm a computer scientist, because I'm really, a very painful programmer. Not a very good programmer. I can write stuff. I have written stuff. But I did that for a while. Just in a department that was doing manufacturing related things

And I was comfortable in there, so that was good. And I went off, spent a lot of time in that era for both IEEE and for the IBM Academy. [I was 4th president of the IBM Academy and served two years on IEEE's Board of Directors, each with a lot of follow-on responsibility]

Laws: OK.

Dill: By the way, Fran Allen, a few years after me, was president of the Academy.

Laws: What was the role of the Academy?

Dill: Well, the Academy was started in something like '89 by top management, corporate technical committee,[John] Armstrong and the technical guys at the top, modeled after the National Academy as a means to get a peer elected group, a mostly peer elected group. In other words, IBM Fellows automatically were Academy members. So there was a management route in.

But beyond the initial selection of about 70, of which I was one, it was very good people who'd done things in IBM.

Laws: So this was to recognize the people that had made major contributions?

Dill: Well, to recognize them, and to get them to do things.

Laws: OK.

Dill: We have an annual meeting. We had organized groups who did studies and wrote white papers. The first white paper, and by far, the most influential was on patents. IBM was dropping down in patent productivity. And it looked thoroughly at the whole system. And IBM has turned around and is number one in the world ever since. And they went from not making really much money off patent licenses to where significant portions of research are now paid by patent license, which gives it a little more independence than it might otherwise have. And I was about the fourth president.

Not because I was elected, but because Ed Lasseter, or who was supposed to be president the year ahead of when I was, had some medical problems. And so they put the vice president in, and they searched around for somebody who would say, yes. So I'm the only unelected president. But I didn't feel I was not entitled.

Laws: What year was that? Do you remember?

Dill: It was 1992.

Laws: OK. So we're up to the '90s with your career.

Dill: And in my usual bouncing around and talking to people, I'd been out to the West Coast. Way back, when we were still building. And I guess way back, I forgot one thing. There was a secret weapon in IBM's SLT transistor. It was the mask maker. And it was one reason why they could build significantly higher performance circuits with discretes than you could build with IC's.

IC's initially enlarged the lithography rather than shrank it, because of all the lateral dimension, and overlay, and other things. IBM took a copper disk, dented it with a ball bearing in an array, then put it in a mold and pressed a plastic replica of what the surface looked like. And that became the fly's eye lens.

The lens, you could make the aperture to put on the front of the lens to limit its aperture. It was 500x, cut in Rubylith. They got SLT features down to 2 microns when IC's were at 10.

Laws: Yep.

Dill: There's a difference.

Laws: A lot of differences.

Dill: There is no overlay error, as long as your photo lab or your litho lab is temperature controlled, which it has to be. So it is a wonderful device. I was able to build IC's. Not at the same resolution level, because once you got off axis, you get spherical aberration. But that was the key thing. Back toward the end of my time in the silicon program. I got curious about thin-film recording heads.

And I talked to my friend, Dave Thompson. And he said, well, they'd been thinking about it, gave me a few instructions. And you could say, I designed IBM's first [thin film] recording head, because I basically took that verbal description, the limitations of my tool, and laid out the patterns for the poles, for the coils. And that's what they built. He and Lubomyr Romankiw became IBM Fellows, and I did it after hours. It wasn't my job.

Laws: So this was the first thin film recording head?

Dill: Yes.

Dill: Inductive, yes. Well, back in the early '90s, I was out here and ran into some problems, and taught in how they were building then magnetoresistive heads. In particular, they were trying to build the top pole after they put the coils down on a very non-planar structure. [I referred to it as a “mountain”]

Laws: Mhm.

Dill: And that was hard to get resolution. They were using the one to one Perkin Elmer system, and they were trying to make three micron structures in 12 microns of resist. And so I went home. And being dumb, I modeled it, because after all, what else would I do? And it turned out it was not nearly as hard as I thought to make the three micron patterns, but very hard to tell if you'd done it right, because as you changed focus, the sidewall angles changed more than the bottom.

And I looked around and what we were doing in silicon, and I wrote a white paper saying that we should use alumina fill and planarization, CMP. [Chemical Mechanical Polishing] And I also suggested a few ways to build heads by multiple layers, and went out to San Jose, and walked into every office that they'd let me in. Promptly got thrown out until I met Bob Fontana, who was key to getting IBM's success in MR, which was very complicated. It took four or five years before the industry, even with our MR heads, could figure out how to make them.

Laws: OK.

Dill: And he listened to me. And he said, look. If I make some samples for you, will you do your magic process on them? And I said, yes. Now, here am I saying, yes. And I haven't been in the lab for 25 years. Well, he sent me samples. I found an unused, old CMP machine. Did them. Within a few months, we had really nice looking stuff. And we had a project going.

But if I didn't come west at least once a month, it stalled. It didn't take long to get a lab running out in San Jose with its own CMP machine. It was my lab, and I got a tech in it, even though I was still back east. And I got a couple of guys down in development working with me, and we got a CMP machine onto the factory floor.

Laws: And this was in San Jose now?

Dill: In San Jose. And couldn't get any traction. Couldn't get wafers to process in the factory until one day, the head of the project there-- I have a blank on his name, but it's probably just as well. He was a very dominant manager. I met with him once, and I realized that either I worked for him, or I was the enemy. So I knew who I was. But one day, I wasn't notified. But everybody else was notified that he needed CMP, and they needed it running in the factory in three weeks or six weeks.

It took six months. But it was key to reducing dimensions. And eventually, many of the multilayer things I'd thought of happened.

Laws: So did you move out from the east?

Dill: No. My wife was working. I had family. I had my wife's mother. I had a developmentally disabled daughter all back east. I did, after a few years of this-- we had 10 years of commuting.

Laws: Wow.

Dill: And I did, after a few years of this, invest in real estate here, and bought a house that was nominally on the National Historic Registry and about to fall down. That's where I live now.

Laws: That was the place in New Almaden?

Dill: In New Almaden. It took me seven years to get permits. By that time, I'd bought and fixed up the brick house next door. So I have two houses in New Almaden.

But we were basically, doing our coils by plating copper into photoresist patterns. And it looked to me like we could use the [IBM semiconductor chip] copper conductor process, and I suggested it out here.

And immediately, people started inventing new ways to do it. Well, having watched the copper conductor work in Fishkill and Yorktown, it was clear to me it was a very hard thing. And so I organized a pair of teams. And we video conferenced every week, and managed to get the technology transferred out so that it is known how to do out here. It still hasn't been adopted, because they figured out that they can still plate in to photo resist.

I'm OK with that. But at least, we didn't try to invent a different way of doing it.

And I was still in a going back and forth mode. I found again, we had trouble. We were doing the sensors for the recording heads, as was everybody, with a lift-off process, lithographic process, which it's really hard to build mushrooms with sort of process fudging when you're down below 200 nanometers. And so I conceived of a scheme which basically [deposits the sensor film on the bottom pole surface and uses resist and ion mill to pattern the sensor, followed by deposition of the magnetic bias films over the resist covered sensor and then using CMP to remove the resist assisted by then polish resistant films.] This sounds complicated, but it allows you to define sensors much more precisely.

So at 100 microns, just where we were when Hitachi came, this process went very quickly from first experiments to production in well under a year.

Laws: This was about the time that Hitachi purchased the IBM disk drive operation.

Dill: It was just entering production when Hitachi took over.

Laws: Mhm.

Dill: Now, as soon as you've delivered your first drive to a customer, the competition knows what your heads look like.

Laws: Right.

Dill: The thing was there were no vestiges of how we made ourpolel pieces. They were literally textbook. It was probably steeper than they should've been. But don't bother me. People were so happy, because they looked textbook rectangular. And no trouble. We had an electron beam machine available. Actually, exercised the structure down to 20 nanometers.

Laws: Wow.

Dill: So that process will work for as long as we're doing magnetic recording, which makes me feel happy, because we won't have to do it again.

Laws: At least not in our lifetime probably. Fascinating. A lot of work. So you stayed then with Hitachi for--so you were with IBM, I think, with total, was it 44 years?

Dill: I was with IBM. And actually, I wasn't part of the Hitachi package. And they gave me a very good offer to come. I was still part of Yorktown, and I became part of Hitachi. And we did a number of things that were just fun. I moved to CA permanently and spent five years with Hitachi before retiring

Laws: Your family had moved out now?

Dill: Well, yeah. About 10 years ago, I got my daughter moved. And then we figured out how to move my mother-in-law from Connecticut to a California, nursing home to nursing home in a day, and that enabled my wife to come out.

Laws: Sure.

Dill: And she's still working. She went to med school when my daughter, who's the middle kid, was 10. As a physician with Kaiser.

Laws: OK. Now, you did a lot of work with your daughter, I understand, in terms of helping her overcome the challenges that she faced.

Dill: Well, clearly, if your wife goes to med school when your kids are 10, you do have some family responsibilities. I quit traveling for 10 years. Almost quit, not 100%. But I've been participative with my kids, but particularly, with my daughter, who needed more. Before going to public school, she went to Montessori, I had two kids in the Montessori, Janet and her younger brother Steve. And a mother there wanted somebody to carpool to gymnastics. Well, I had made my job flexible enough. I could do that.

[So I] did this very early kid gymnastics thing. It was good for everybody, but particularly, good for her. So I kept her in gymnastics. And when she was eight, she went to Special Olympics and was clearly pretty interesting. And she was in gymnastics. They got a program about then that she was in, and I just drove her to and drove her home. And then the bank that was sponsoring the program decided to spend their charity elsewhere, and it went away. I took over as coach.

Not of the whole program, but of my daughter, in a very small program. And I have no skills in this, no experience in this other than I had taken a couple one hour sessions for coaches, which were basically, how do you keep your kid from banging their head or breaking their back? It's spotting.

Laws: Sure.

Dill: We had a small program. I would talk my way into a commercial gym or use the YMCA room with a matted floor, and got to where I had, in some years, the best gymnasts in the state.

Laws: Really?

Dill: And when she graduated from high school and was going to a post-high school program in New Haven, they had World Games there. And she got a gold medal.

Laws: Wow.

Dill: And she's still, in spite of a rough decade healthwise, is a pretty good athlete to be said for. She's climbed Half Dome. She has lived by herself in Mountain View, is moving to a new setting, which will be more people like herself, so she'll have easier access to friends that she can relate to.

Laws: Now, you have some executive involvement in this development, right?

Dill: Well, I had her signed up for housing out here, because I had a family of what I regard as great computer people. Hal Van Zoeren, who was one of the key people of the IT compiler and his wife, knew Janet before. They had a daughter with Downs and so they were my guide here. They guided me to this small agency that does housing for developmentally disabled. Is by far the most productive in the whole state.

Over 200 people in apartments that are affordable, safe, and appropriate, and many more than that in the standard inventory of housing, both families of with people with disabilities and individuals.

Laws: OK.

Dill: And so after Janet was placed, I got lured onto the board, and I am now president of the board.

Laws: And the name of the organization is?

Dill: Housing Choices Coalition.

Laws: And they're based in?

Dill: They're based in San Jose. They service Santa Clara, Santa Cruz, and Monterey counties. But most of the action is in Santa Clara where as we say, we're opening up 26 new apartments.

Laws: Big achievement. What else do you do with your time Rick? You've always got your fingers in some pie or other.

Dill: Well, I've had a lot to do with hands-on in this house restoration. I didn't do the major carpentry construction. And it's never done. I have just finished final grading of the backyard. You ask what an old man does with his first tractor, and the answer is you sometimes are out there running it on your small plot, civilizing it. And we acquired a cottage in the mountains, which we have again restored, and when we can get away, we get up there, summer and winter. I still ski. I still hike. I haven't been up Half Dome for five or so years.

Laws: Now, you went up the face of Half Dome?

Dill: No.

Laws: The chain walk on the back?

Dill: Just up the cables.

Laws: Yeah, sure. Even, that's an achievement.

Dill: I trashed my leg once in my '40s, and so I have a stiff knee. But I still hike. I do a little bicycling. I row, I keep active.

Laws: It's plenty for man half your age Rick. Well, this has been a fascinating conversation. Is there anything else you'd like to add on at the end here? Perhaps something you'd pass on to young people who are considering going into technology?

Dill: Well, I feel that the most wonderful thing you can have in life is a passion for what you do. I've watched my kids. My oldest, who got exposed to computers early by me, through some machinations we did at IBM, got hooked on computer games. After grad school, went to work. Didn't get his PhD, dropped out went to work in the game industry, is well established in the world of AI for computer games, but now, working for Lockheed Martin, doing it for everything from teaching kids algebra, which seems to be working well. It's in beta test, to all sorts of other applications, and is involved both with the academics. And my youngest got a master's in EE from Stanford, and to my surprise, ended up at IBM. And he was there for 11 years. He did lots of things. He was involved in relational database stuff, searches on the web for the government for a while. Had a very successful project which IBM didn't keep being successful after he left. Two years ago his team in a hackathon was best of 130 projects in the company. But he wasn't getting the satisfaction or passion from it that I got, and he has quit, and is now doing small business.

And as he says, right now, he's learning faster than he was at IBM, and that's all he cares about.

Laws: Right.

Dill: So it's trying to get things that you can be really interested and care about. And if you're lucky, it's something that pays you a living and gives you a remarkable opening. If I were a kid today, I probably would be pretty similar, except I'd probably be interested in the instrumentation part of the bio-med industry. I haven't had a peek into that for a few years. But I had a conference for young engineers that we held for the National Academy out here, and in fact, had our dinner at this museum.

I unfortunately, didn't make that dinner. The theme of what we did was the ultra productive technologies of which the first is integrated circuits.

[Here I messed up and merged two things I did for the National Academy of Engineering. The one on ultra-productive technologies was a one-day thing for NAE members and the public. The one for young engineers was a multi-day one when they presented much of their work and looked at challenge topics together. It was the one which had its final dinner at CHM. This probably isn’t worth trying to fix. Memory is a challenge, but I’ve often mis-spoken .. I would probably have been diagnosed dyslexic except that they didn’t ever label people much when I was a kid]

Laws: Mhm.

Dill: But there is Storage. There is following that, Communication. These are things that have all improved by 10 to the ninth times in productivity, something mankind has never ever seen anywhere.

Laws: Right.

Dill: And the fourth one is the gene sequencing. And there'll be some more in the bio. I had Gene Myers down from Berkeley, explaining gene sequencing, and what the hell? A computer scientist was doing it. And very frankly, it's a puzzle matching, immense puzzle matching.

I guess that brings me to something that was sort of the climax of my lectures back in '74, which was way before Moore's Law ran out.

But being an engineer, I know that a straight line exponential curve, it's not going to go on forever. And I've been taking part and watched with fascination as we've kept it going pretty well. But now, people, are beginning to round off. And eventually, when productivity improvement is smaller than the cost increase, we'll just build more, not improve the productivity. But I mentioned this in my last lecture at MIT, because people think that when Moore's Law runs out, there is going to be a great problem. And I just have looked at this. And it's very simple to me.

When Moore's Law runs out, we’ll have a Golden Age in design. I used the numbers, probably something like 10 million transistors back in '74, with a question of “What could you design that would be useful to mankind with 10 million transistors?”

Laws: Right. We've moved it by several zeros.

Dill: Now, I think the number is 10 billion. And the challenge is still there. At that time, I was thinking, how do we get designs beyond what we can build {beyond] the standard Von Neumann computer? Well, we now have to finally, some more computer architectures. We have more things coming that we're building. If there are large, they're still very hard to build. We hardly exhausted what can be designed.

The one disruptive technology I would like to see eventually happen-- now, I'm sure it will happen sometime. It was first proposed in the '90s, was taking the current scanner, which may or may not be the last lithographic generation. We'll see, and not giving it a mask, but giving it essentially, a mirror array as a mask. And by the way, you can do everything with the mirror array and the mask, including phase that you can do with the mask. So I come to the place of thinking that we really need that tool so that we can try ideas that are often small perturbations on what we're doing.

Laws: Mhm.

Dill: Because if you change the mask set, that's somewhere on the order of $50 million. Now, we burn through multiple masks sets to make a product.

Laws: Right.

Dill: That's OK if we're going to build 200 million [units] of our product. But if we could make wafers in which we wrote from data, then on a single wafer, we could express multiple ideas.

Laws: Mhm.

Dill: So that's one of the things I feel a passion for. And yes, if you can do it, better with multiple electron beams. I have some skepticism. But what I did see in IBM when I was in Fishkill, and this was the end of the bipolar era, when IBM chose not to build custom integrated circuits, but gate arrays, and to wire them, and to have a great deal of automation and design support end to end.

Laws: Right.

Dill: If a customer wanted to feature on their mainframe, and an engineer seeing that request knew how to solve it, that engineer could modify a chip to include that feature, maybe add it with unused gates, whatever, simulate it, generate test patterns, and generate the very complex corrections needed for the e-beam writing tool we had, generate everything, and release it to manufacturing. And the only person who had to touch it after that was the person in production control that decided what wafers the chips went on so they didn't all go on the same wafer, and how many to make.

It was an incredible time. It was an incredible capability. We could still have it.

Laws: At multiples of complexity.

Dill: Oh, yes. At today's complexity.

Laws: Right. Fascinating Rick. I appreciate you taking the time to talk with us. Any last things you want to say before we sign off here?

Dill: Then I think I will say, “Thank you David.” I have enjoyed it. I hope it's not too scattered.

Laws: It sees into so many different aspects of IBM over a 40 year period. A lot of people haven't had the opportunity to see, let alone talk about.

Dill: Well, my impression is that many people who write the history haven't been there, haven't had the interaction. Not that I have been everywhere. It's been amazing to see. There were little things, like when Paul Low, who started early on, as he got to be an executive, interacting with people, places like Intel and Motorola, to seeing things like SRC and the Roadmap develop, and to look at the many, many things we've done.

Laws: Sure.

Dill: I look at Moore's law. And I say, it's a wonderful contribution. But what's made it happen are thousands and thousands of individuals. Here I am. I'm proudly talking about some of mine. But that doesn't do deep trenches filling them up. It doesn't do oxide isolation that led us shrink things. It doesn't do stressing the semiconductor. It doesn't do the modeling simulation.

The whole thing, it has been a wonderful ride. You're on it. What you're living for is change. Not fear of change. And so that, I think, is my wrap up.

Laws: OK. Thank you very much Rick.

END OF INTERVIEW

