Oral History of Steven R. Hofstein

Interviewed by:
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Laws: Good morning. I'm David Laws, semiconductor curator at the Computer History Museum in Mountain View, California. It's October 27, 2010, and we're here today to record an oral history of Steven Hofstein, Steven was a pioneer in MOS technology at RCA and went on to have many other interesting adventures in his career. Good morning, Steven. Thank you for joining us today.

Hofstein: Thank you for having me, Dave.

Laws: Could you tell us a little bit about your childhood, when you were born, where you went to school, something about the family?

Hofstein: I was born in the Bronx, New York, in 1938, and lived in the South Bronx until I was 16. Then my parents and I moved to the West Bronx. We used to live in the East Bronx, or South Bronx it used to be called, on 174th Street. We moved to the West Bronx on 174th Street so it was kind of interesting. We didn't do a north-south migration. I stayed in New York. I went to Bronx High School of Science. After I graduated high school, I went to Cooper Union for the Advancement of Science and Art in New York. It was a school established in 1859 by Peter Cooper who liked to call himself a mechanic. He created a school which was unique in many respects, the first being that it is a full scholarship school. All students there are on full scholarship. There is no tuition. The only thing you have to pay is your expenses, your books and such like. I graduated from Cooper Union in 1959.

Laws: Why did you go to that particular college and study that subject?

Hofstein: I always loved electronics and my dad worked for the U.S. Post Office. We were not wealthy people by any means. We had a three-room apartment in East Bronx that I grew up in and I loved the mystery of technology. Well, chemistry of course is always interesting. You make things blow up and that was a lot of fun but as I got a little bit older and began to worry about losing my fingers I kind of decided to do electronics instead. It was a wonderful era because the war had ended and tons and tons of war surplus electronic material made its way down to an area in Cortlandt Street in Lower Manhattan. You would go down there and walk the streets and they had all of these stores selling boxes and boxes of receiving tubes, all the stuff left over from the war that now was war surplus. You could buy a 6AU6. I don't know why I remember that tube. I liked it. It was a good one. They don't make receiving tubes anymore. I guess they called them an acorn-size tube and you got it for five cents. I didn't know what to do with it but I had it, and I was very excited. I used to take it out and look at it all the time. So I began to play with circuits and I really fell in love with electronics and electricity and all the miracles that were associated with that. So I was kind of hooked on electronics and by the time I came to the Cooper Union, of course it was my desire to become an electrical engineer. Although it was interesting, they gave us an orientation session and I was sitting in this big lecture hall and we were all filling out the form, and one question caught me by surprise: If you couldn't be an electrical engineer, what trade would you want?

And I thought about it and thought to myself music. That was the only thing that interested me was music and I often wonder the close connection that people have found over the years in terms of structure of music and science and imaging. Most of the great inventions came from people who saw a picture. They did not come necessarily from a mathematical equation. The equations followed the invention. For example, people knew about superconductivity before Bardeen, Cooper, and Schrieffer came up with the theory, not vice versa. And so I was at Cooper Union, enjoying it very much. I was there for four years, graduated in 1959, and had the option of going to one of two places that I really liked, Bell Telephone Laboratories or RCA Laboratories. I had worked for RCA the previous summer and I liked the people and I liked the company. But that was down in their military division in Camden, New Jersey, and of course the laboratories were considerably different. One of the things that attracted me, and I guess most of the people I graduated with were looking for some type of graduate study program. I think a great deal of the people that came out in technology or in engineering looked towards graduate school as a necessity if they wanted to do really advanced work. Bell Telephone had a graduate study program in collaboration with New York University, NYU, which is a very fine, very lovely school, and RCA had one with Princeton, which doesn't need any further explanation. Both of them made me a great job offer. And I was waiting to hear from the universities and NYU did send me a nice acceptance letter and I got a letter from Princeton University that said "We want to thank you so much for applying. You have a fantastic resume but we are somewhat limited in space so we wish you the best of luck". I figured that's it so I went down to Bell Telephone and I told them I would be joining them. I still have the very nice acceptance letter. I was ready to report for duty and I got a phone call from Paul Cuomo who was the HR person at RCA Laboratories asking when are they going to hear from me. , I said, "Well, Paul, when we spoke I had mentioned to you that the graduate study program was important." And he said, "Yes, of course we know that, we notified Princeton University." I said, "But I got a rejection letter." He said, "You got what?" <laughs> I said, "I got a rejection letter." He says, "Don't go away. I'll call you back tomorrow." He didn't call tomorrow. I got a letter by messenger. They had made a mistake. There was room after all. So now I had the problem that the good news was I that was going to get to go to Princeton University. The bad news was I had already accepted a job at Bell Telephone. Much to their credit they were very gracious about it. I sent them a letter. I explained the whole thing to them and I got a very lovely letter back saying they absolutely understood, they wished me the best of luck, and should anything ever change again come call them. So I had very good feelings about Bell Telephone.

Laws: Where were the RCA labs at this point in time?

Hofstein: The laboratories were in Princeton, where they are today. Okay. Yeah. I'm thinking there's Princeton, Princeton Borough, Princeton Junction so it's confusing, but I do think they actually were physically within Princeton. They may not have been. Of course, the names change as you move further out. But I'll tell you the Princeton when I went there in 1959 [and today] are, two different places. It is astonishing the development that has taken place over the period. When I went there people were bemoaning about the fact that they built a bridge across the lake. Many of the scientists at laboratories were Europeans and loved boating and so they bought homes along Carnegie Lake on the side away from RCA Laboratories, whereas the Americans bought the stuff on the other side. And the reason for it was that the Europeans had no problem getting in a canoe in the morning and canoeing right across the lake. They parked the canoe and walked to the laboratories, for real. So when they built the bridge, which everyone said was modernization, it was totally untenable.

Laws: What did you do initially at the labs? What was your role?

Hofstein: The laboratories had an orientation, a one-year trial period. , When you came in you had the choice of going to three tours to different sections of the laboratories. It actually truly is RCA Laboratories, plural, because I think there were seven individual laboratories each with its own laboratory director, and I believe they reported directly to the vice president, which was Jim Hillier. The first one I went into was a circuits laboratory. The big push at that time was in memories. Computers were becoming important and memory was everything. There was a group doing superconductivity, and Dick Ahrons came into that group just as I left it. He followed on my heels as it were. Everyone was arguing over the best way to make memory. Anything that could hold a memory was being investigated because the need to use something other than iron cores was becoming very dramatic. And so the second of the two training assignments was in the Electron Devices Laboratory headed by Bill Webster. That's when I had my first contact with the group that were making the attempts to do integrated logic nets. They didn't call them integrated circuits at that time.

Laws: That was Torkel Wallmark's group?

Hofstein: Yes. Wallmark's group was investigating the unipolar transistor. They were made by gouging out little channels [in the silicon]. The theory was that you would take a rod of these things [unipolar transistors] in series and you would wire them up and put them on a substrate and get them to work. It was a good idea, and other than getting the processing under control, it did perform. So I had the four months there, loved the work, went down to the Superconductivity Group. After those four months were up, I made the decision to go back to the Electron Devices Laboratory.

Laws: Was there a specific project that you wanted to work on?

Hofstein: I wanted to work on those transistor integrated logic nets. So I sat down in Tom's office the first day I went back to the laboratory—

Laws: Tom was Tom Stanley?

Hofstein: Tom Stanley. Tom was an absolutely marvelous man. I was delighted to see his [CHM Oral History] interview. He's sharp and is wonderful. If he's watching this, Tom, I miss you. You're a great guy. I still have the original book online you gave me by Schumacher. I live with the thing. I won't give it to anybody else. Thank you. We were talking about where I would go and Tom said, "Would you be interested in working on metal oxide semiconductor transistors." And I remember the first thought that came to mind was metal oxide. I pictured iron rust. —"How do you make a transistor out of iron rust and oxide?" I don't know how iron rust will make a transistor but I didn't say anything because I thought it's obviously something, and I said, "Well, that's very interesting." I said, "Why that?" "Why myself? "Nobody else is working on it" he said "and there's a story that goes with that." He said, "The [metal oxide] transistor, or the concept for it, has been around for a long time. A lot of people have tried to make it work and have not succeeded, and in every case that they've tried and failed it was kind of a career killer." He said, "And so nobody here will touch it with a ten-foot pole because it's going to be death". And he said, "You on the other hand have no career to kill. Why not?" I'll never forget that. You have no career to kill. That was very true. Thank you again, Tom.

Laws: This was 1960--

Hofstein: Yes, that would have been I guess the fall 1960.

Laws: Dawon Kahng had already read his paper by then?

Hofstein: Yeah, [Kahng's paper described the first demonstration of a working MOS device]. Everyone had worked on it. It was a great concept. You could demonstrate the effect. Karl Zaininger [at RCA] in fact took a little bar of silicon, put a gold dot on it, and then reproduced what Dawon Kahng had done.

Laws: An MOS diode?

Hofstein: Actually, it was a triode. He took a small bar of silicon and he welded wires to each end and then he put a gold dot on the oxide and was able to show some modulation of current, which kind of reproduced what Kahng had done. It showed the fact that, there was an effect and it could be made to work. I'm hesitating whether to tell the story that Karl told me. I'll let Karl tell the story. Where was I?

Laws: I was trying to establish the year when you talked with Tom Stanley.

Hofstein: That would have been August of 1960 because the training program was one year long and I came back right after that so it would have been the fall. So they set me up and I began to try and create the MOS transistor. It was fascinating because I built the first few of them and indeed like everyone else saw, it was an effect but it wouldn't work. It took a great deal of experimentation until we finally got it to work. We tried everything that everyone else was trying. Cleaning it, then polishing, but whatever you did it just seemed that the [surface] states would appear. We tried wet oxidation, dry oxidation. I think the breakthrough came when I remembered metals being annealed. You would anneal things. You would forge them and then hammer them. You create them. Then you would anneal them to get the strength and so on, and so the thought occurred why not try after the oxidation period to see about annealing it. What was a common thing was when you annealed it either in an inert gas and something like hydrogen and particularly if you had had a oxidation process if there was leftover oxygen in there causing a disruption at the interface hydrogen would certainly act as a getter if you will and suck it right out. And so we heated it up, and this- I'm condensing it but Lord knows when you do these experiments there is so much of them similar to Edison. There was the Edisonian approach, which is to try a million things. And the other one is, you have to theoretically focus and then when you have the solution you test it. It's a compromise. You try and come up with even a thought, “Is this something that might work?”, and you try that so it's Edisonian and theory at the same time melded together. If you Edisonian, you'll be working forever. If you combine the two, you can cut it down to a limited number of tests and trials and so on. But still it took a year until we finally got the hydrogen anneal [process] to work.

Laws: You're saying "we." You were working with Fred Heiman?

Hofstein: Fred Heiman joined I guess just around nine to ten months into the project. I would be going on for my doctoral degree, which required a period of nine months where I'd be mainly away from the laboratories to get my residence requirement at the university. And so they began to plan- Tom planned in advance to try and get somebody in the group so that when I left and wasn't available for the full-time work somebody else would be there to continue it and that's how Fred joined the group. Fred was a very, very, very bright guy. I worked with him for many years, not just at RCA, but when I left in 1968 he came with me into the new company that we formed called Princeton Electronics. Subsequently, he went on to the Mars Company on vending machines. That's another story. It involves the Susan B. Anthony dollar.

Laws: We'll save that story for another time.

Hofstein: Fred and I were working on it and we got it [the MOS transistor] to work and then discovered the horror of instability. It just wasn't stable and so I focused on instability. We got the transistor to work but if you turned it on it stayed on. If you turned it off it stayed off. It had hysteresis. The curves instead of just going up and down went up and came back in a loop so you had your hysteresis loop like just magnetism and iron but the transistor doesn't make it workable. And so the question was “what was happening?” We finally figured of course something was moving charges through the oxide. What this charge was and how it went we really didn't know. We had some theories about it and we set about the problem of solving instabilities which went on for almost a year and we were able to make them stable. We found that by doping the oxide with phosphorus we could block whatever it was that was moving. It was sort of a Band-Aid in the sense that you weren't eliminating what caused it, and the thing that was frustrating was that periodically you'd make a batch of them and they were absolutely stable but you couldn't reproduce. At that time Fairchild was also working on it. The group, I think, was headed by Gordon Moore with C.T. Sah and Andy Grove and Ed Snow. It was a very, very, very good group. Our little group at RCA Laboratories could make them [the MOS transistors] and they worked very nicely but they weren't commercial because they weren't stable. And this was just before we did the phosphorous by the way. Fairchild had solved the stability problem but they didn't solve the surface state problem. At least they were having some difficulties with it. We were sitting in the lunchroom at RCA one day, a group of us, Clare Thornton from Philco was there and a couple people from Bell Laboratories, and I said, "Why don't we start a small invitation only conference?" There were only about 60 of us in the United States working actively on silicon and its use in transistors, which is really amazing when you think about Silicon Valley now. Only 60 people in the entire United States working on that. And so I said, "Why don't we have a conference that's invitation only? Everybody who comes to the conference has to submit a paper. There are no free rides, no free lunch here. Anyone who comes has to contribute. Maybe if we all get together for the benefit of everybody we can interchange and you'll give me some information and I'll give you some information, and overall we'll do better as a group instead of guarding our own little territories." And they thought it was a great idea so the IEEE approved it and because I suggested it I got to choose the venue. When they asked where I'd like to go. I said I thought Las Vegas would be good, which produced a lot of raised eyebrows because I will tell you nobody but the Elks --- and that's the higher level, it went down from there--were using Las Vegas for any kind of convention. I don't know who gave me the lead to the Stardust Hotel but they were fascinated. A real genuine convention with real scientists was going to come to Las Vegas. They comped the entire group. They swept the floors. They were so excited having a real technical conference come. We all know where that went. <laughs>

Laws: Did you have a name for the conference?

Hofstein: Yes. It was called the Silicon Interface Specialists Conference.

Laws: The year was--

Hofstein: Was 1965. That was the first one. Interestingly, I came across the notes and the technical information on the conference. (It was on the web and the IEEE has it.) I made the program schedule and the invitations. I was invitations chairman for the first conference, became the general chairman for the second one, but it was very successful. People in the field came out and a lot of information was exchanged, and I think the development of commercial integrated circuits was greatly benefited by this conference. I was fascinated too to find out it's still in existence. I Googled it the other day and found out that it's still being run but not in Las Vegas.

Laws: There are still a few problems left to solve.

Hofstein: Interface problems are so dominant half a century later – it is fascinating. Just they get more and more arcane. So anyway, we're getting ready for the conference and I get a call from Bill Webster who invites me into his office—

Laws: Bill at this time was?

Hofstein: Bill is the director of the Electronics Research Laboratory.

Laws: Stanley worked for him?

Hofstein: Tom Stanley worked for Bill and I worked for Tom. And I'm trying to remember how the conversation began. He said, "You're going to be going out there and we need some guidelines in terms of things you can disclose and not disclose." And to take it back just a little bit, when we got the transistor to work Fred and I were very excited and so we authored a paper called “The Silicon MOS Field Effect Transistor.” And we were going to submit it to the I EEE Proceedings. I think it was called the IRE Proceedings about then [the name] had just had switched over, and what we were told was "Listen. It's a fantastic device, everyone's looking forward to the paper. What you must not discuss, because legal will never approve, it is how you did it. You can talk about the curves, how it works, how it does this, make a circuit. Stay away from the fabrication." And so we did and we submitted the paper to the legal department at RCA and it was rejected and they called me down and I said, "Why?" They said, "Well, it's too sensitive." And I said, "But there's nothing in there at all about how we made it work" and they said, "Steve, you have to understand something. It's not how you made it work; it- that you proved it can work. Right now everyone out there doesn't believe this thing is going to work. No one else is working on it. We haven't even announced it yet. The moment we announce it can be done -- there are a lot of smart people out there - they'll reproduce what you did". And they were absolutely right. I just happened to be the first because I'm very tenacious and I just didn't believe it would not work. But once you tell somebody else it can work they say, "Well, okay, let me go back to it. It's going to work." And so it was fascinating to me because it leads up to something that my whole life is very puzzling, Patents. When you invent something do you patent it? Well, the problem is that to file for a patent you must disclose how you got it to work and that ran right into that concept, which is that the damage is telling people it does work. And so trade secrets to me have always been far more powerful than a patent. Even if you get the patent, which is very iffy, you've already disclosed the fact that it can work and at least one way to make it work. That's by regulation or you can't file for it. And then even if you do get the patent you're going to have to prosecute it, and so the net result is commercially a lot of damage can be done before you ever recoup it through your patent in a lawsuit. So the best thing is just keep it a secret. So now we're up to the Silicon Interface Specialists Conference and Bill Webster is saying, "All right. Steve, don't talk about how you did it, what the secrets are. Everyone's going to want to know how you got rid of the surface states." And he said, "And there's also a problem we have about stability, which we know Fairchild has solved." And he said, "You have to understand something, Steve. We can't selectively give secret information to another company." RCA--and I don't know the details of this but--had some big suit with Honeywell I believe it was back in the '30s or '40s and part of it was an antitrust thing, had to do with some Honeywell patents, and truly I'm ignorant on this but I know the net result was that RCA had to be very careful about disclosing things preferentially. And the legal reasons are beyond my--what do you call it—pay grade. So they said, "On the other hand, we'd really like to know how Fairchild got this thing to be stable and they'd really like to know how we got this thing to work. So if you happen to be talking to Andy [Grove] and you mention something about how to get it to work, we wouldn't be too upset and he might just bring something up about how you get rid of the instability. These things happen." So I found myself in Las Vegas and the first lunch break we're out in the pool and Andy is staring at me and I'm staring at him and so we kind of chitchat a little bit and I don't know who the first person was to say it. Perhaps it was me saying, "Do you have something you want to tell me?" and he said, "Do you have something you want to tell me?" and I said, "Hydrogen" and he said, "Sodium." I tell that story to people who tell you that when you get someone to consult, for example you pay them a million dollars because you came up with an idea. That's a lot of money for just a few minutes' work. Those two words took millions of dollars of effort by teams. I try and tell people you cannot make a judgment on the worth of an idea in terms of how long did it take you, how difficult was it to do, how many hours did you spend on it. It's what it achieves. So that's how things began to move along. Indeed it was sodium [that caused instability]. One of the things that also turned out that does move was hydrogen. For the longest time I did some experiments. I thought originally it was hydrogen, sodium in the same class if you will, but I wasn't thinking sodium. I was thinking hydrogen because of all the water we were using and the hydrogen anneal, and so I did some experiments with tritium and then got to write a paper for the Physical Letters, <laughs> the most technical paper I ever wrote. We did tritium radiotracer experiments and in fact we were able to see the fact that protons would move through the oxide. It was an interesting experiment because that material is extremely dangerous but at the time there was a reactor about five miles outside of the RCA Laboratories. It was in Grover Mills, where the flying saucers landed in H.G. Wells. That's where the reactor was that might have been built by aliens. Except I don't know the true story, but we were able to prove that tritium moves and that kind of disappeared. I came across some articles recently. They're still working on it. It was rediscovered about 30 years later in the late 1990s so it was nice. It does move and in fact they're using it for some type of advanced fabrication techniques now.

Laws: You used it to prove--

Hofstein: I used it to prove that protons were moving but indeed sodium, which is next in the family, was the more dominant element. Both move, both will have the effect, but sodium was the thing causing the very, very large effect. It's astonishing because you would think of oxide as being glass, which it is. How does sodium move through glass at room temperature? In itself it's counterintuitive but it does. When you really think about it it's amazing. The oxide is also interesting. In some experiments that were conducted--I've never seen this published--it's also extraordinarily sensitive to low energy x-rays. At Princeton Electronics we were making a device which depended upon storage on the oxide to get an image, and what we found was the image would fade and we thought that was due to gas in the tubes. And we pumped them and we pumped them and we pumped them and no matter how well we got it down it didn't make a difference, and then somebody at Bell Laboratories said, "Steve, take a look at the pattern. It's very diffuse. If it were a gas migration, it would have sharp boundaries. If you look, the boundaries are very diffuse. It's x-rays." And to this day to me- I've never heard of anyone following up on the fact that something like silicon dioxide is x-ray sensitive down to 500 electron volts, which is astonishingly low. For x-rays that's virtually nonexistent. So anyway--

Laws: Fairchild learned how to fix surface states. RCA learned how to fix stability. How long did it take the two companies to come up with commercial products that took advantage of this knowledge?

Hofstein: Well, products began to appear almost immediately. Even at the time we were talking they were making individual devices. RCA was big into analog and so the first use of MOS was not in integrated circuits. The first commercial units were individual transistors and the success of MOS was elusive. Again it goes back to Andy's endurance formula. If you think about it, it was- in 1970 there was an article which I have a copy of that came out in one of the technical magazines saying "Is this the year that MOS finally makes it?" I'll send you the article. Total sales in 1970 were $14 million and it was not integrated circuits. It was all analog devices.

Laws: Phil Ferguson sat in that chair a few months ago. Phil was the reluctant second CEO at General Microelectronics [who made the first commercial ICs in 1964] so I heard a lot of stories about the problems that they had with stability..

Hofstein: Oh, I'd love to hear them really. That'd be fantastic. It's nice to be able to tell everyone the stories here but it'd be so much more fun to read the oral histories of the other fellows that I worked with. I came across Paul Weimer's, which was done some years ago. A very, very bright- very brilliant man. If you look at the iPhone display screen, that whole thing came out of a small group at RCA. You had Paul Weimer who developed the TFT [Thin Film Transistor], which is absolutely critical to lighting up the little cells on the screen. You had George Heilmeyer who of course discovered the nematic phase in liquid crystals that it could do it. You had myself and Freddie working on the MOS digital chip. Between those three groups you had the basic core of what you see today as a flat panel TV display.

Laws: You worked on an LCD watch--

Hofstein: Yeah. It was--

Laws: I'd like to get to that but first let’s back up a few years here. You talked about the paper that you were not allowed to give for the IEEE. When was that?

Hofstein: I believe it was in '62, '63 at the Electron Devices meeting. By that time RCA had an LCD device. In other words, RCA had come out in 1963 I believe with the first IC announcement. I could be off by the one year. I believe it was mid '63, there was a column by Athelstan Spilhaus [author of a popular educational science strip, "Our New Age", syndicated in many Sunday newspapers]. He had a one-pager and one of the things in that particular month's issue starts off "The tiny disk that Tom Stanley held in his hands may prove yet to be the next revolution in computers" and it did turn out to be so., There were releases going out. RCA had made the transistor available and then we gave the technical paper that year.

Laws: In that technical paper you talked about the 16 transistor experimental chip?

Hofstein: I believe we did. Remember this is the devices meeting and it's kind of interesting because there was a very definite pattern to how these things come along. First it was the materials war back in the early '50s. This is going to be germanium; this is going to be silicon; it's going to be thin films. Then once you began to home in on the materials and moved up one level you went from materials to devices, and the MOS even though it looked very promising it was one of many. Shockley now had a new kind of four-layered diode. Other people kept searching. It wasn't clear to everyone "Oh, we have the device; so let's stop". So you had the device wars where everyone- knew what the material was going to be now everyone is arguing over what device is going to be the best device for the industry to pursue. And finally we began to home in on the MOS or on transistors and then it became the integrated circuit. It keeps going up by levels. Then came the integrated circuit technology war. Was it going to be little chips being put on little metal balls like IBM was doing? Was it going to be something carved out mechanically? Was it going to be something on silicon? So the methodology of integrating it, how are the bonds going to be made, and then it went up to large packages so as anything it grows. It grew first in materials and then it was a fight over what device, then how to integrate the devices. There was a lot of interesting work going on during that year.

Laws: So you made the 16 transistor chip--

Hofstein: It's a 16 transistor NOR gate- exclusive NOR gate, I believe, and it was functional.

Laws: Why 16? Why not 8? Why not 100?

Hofstein: Well, 16 for the- is about the largest I believe that we could do. It was a number that produced an actual functional circuit that wasn't just a demo. It actually did something useful if you will and it had a moderate number-- It was funny because we would have loved to have put more transistors on it but the failure rate was very high and this was something that always fascinated me. We would sit there, all of us around the table at lunch and at the conferences, and say, "How many of these things do you think we'll ever be able to make on a chip?" And people would think it would be a hundred and there might be some redundancy, maybe some way to make two hundred and use one hundred. That original chip that we did was a quarter of an inch by a quarter of an inch and now I understand they get several million on them. How they do that boggles my mind, really amazing.

Laws: Did you appreciate that this was essentially the first MOS integrated circuit?

Hofstein: Yes, it was. We were very excited and happy. I think with the advent of that circuit that's what I believe triggered the shutdown of Torkel's group doing work on the unipolar transistor.

Laws: These were p-channel transistors?.

Hofstein: Torkel's were, I believe, n-channel. But I'm not sure.

Laws: What were yours?

Hofstein: Ours were also n-channel. We made both. We made n-channel and p-channel but we stayed with n-channel. The complementary pair [for CMOS] was to come later. That was actually a takeover of the complementary pair Paul had done way back with his thin film transistors. We took that structure and ported it over. Remember when the first transistors were made and sold they were depletion devices. They were meant to be analog. In other words, they were normally on and you could shut them off and the concept of turning them on as a switch and doing this in a complementary way was just a short time later. But your question was—

Laws: Because p-channel were much easier to build than n-channel, at least here in the Valley, for many years. I was wondering what it was you started with.

Hofstein: Well, we started I believe with n-channel back in those days. But I'd have to go back and check but pretty sure all the diffusions we did were phosphorus n-channel where I go back all those years. It could have been p-channel. But I think it was n-channel.

Laws: I've seen a page from your notebook that was signed by Wallmark and Zaininger of a new device-

Hofstein: That was the era of is there a better version of MOS. That device was basically a reverse biased diode with a gate on top of it to control. If you look at it carefully, the source and drain with two different materials, n plus and p plus or n and p whereas in a regular MOS transistor they are the same material and they're bridged by the channel. And this device was looked at as something to reverse bias and it controlled the breakdown and it looked very promising when we built them and I gave a paper out in Boulder, Colorado, and it was very interesting. This was-- Oh, gosh. I think it was '65. I could be wrong but it was the Electron Devices meeting being held in Boulder. And it was an exciting announcement. I gave the paper on the device. Harvey Nathanson also had looked at it, and he gave a paper. I had gotten them to work. And I had all the characteristic curves. Harvey was pretty close behind me on that. And we were talking about our experiences.

Laws: And Harvey was from?

Hofstein: Harvey Nathanson of Westinghouse. A fellow who invented the DOP [Digital Optical Processor] chip that would be used half a century later by Texas Instruments.

Laws: You were in Boulder, Colorado.

Hofstein: We're in Boulder, Colorado. And the chairman got up to say that "A very exciting announcement for those of you here. Tomorrow at the end of the conference for those of you who are interested, Bill Shockley has a great new revolution he's going to be announcing. He's going to be flying in. And, you know, obviously, we normally don't accept papers at the last minute like this. But it is Dr. Shockley, and it is a whole new device. And so those of you who want to stick around, he's very guarded about it, but I'm sure you'll enjoy. It'll be great." It turned out to be the same device.

Laws: Is that right?

Hofstein: He was really sweet. He got up, and he said, "Well, I was going talk about my new device. But already there have been two of papers on it. And it's a little more than I have. So I just want to congratulate the people that did that. And it's wonderful." Nicest guy. That was really it. It just goes to the same thing, things happen in parallel. It's only a question of timing.

Laws: Was this the time in Colorado, where you went out with Grove and Longo and __________...

Hofstein: No. Actually, that was-- the driver was Bob Noyce.

Laws: Okay.

Hofstein: I'm sorry. Bill Webster was driving. Bob Noyce was sitting next to him. I was in the back with Bill-- they brought me along because we were all very happy. We just had lots of happy hour stuff. And they wanted young blood in the car. So you can imagine how long ago it is that I was considered young blood. So they stuffed me in back of the car. And Tom Longo was next to me, and this other fellow. So now, there were five of us. And Bill looked around and Bob said "Does anyone know who this fellow is? " The guy was just sitting there happy. Nobody knew who he was. So he opened the door and pushed him out. And then, we closed the door, and we took off. We wanted to go for egg rolls. Everyone decided on egg rolls at 1:00 in the morning and near Boulder, Colorado was a wonderful thing to do. So we skoodled up and down the highways and made a couple of U-turns, couldn't find the egg rolls. We did, at one point, stop off, because somebody had to go to the bathroom. I'm not going to name a name. But I can say it wasn't me. He went in, didn't show up. We finally went in, and he was passed out on the potty. Bill Webster crawled underneath [the door] and unlatched it so we could open the door to get the fellow out. So I thought to myself, "This is a wonderful field. I love science."

Laws: Okay. So now, we're up to about '66 or so, I think.

Hofstein: Yeah, '66.

Laws: And by this time, you had your meeting with Grove?

Hofstein: Oh, things were moving along. The MOS devices pretty had much gone into [production] Somerville, New Jersey, the semiconductor division.

Laws: Were you involved in the transfer of the technology?

Hofstein: We were very close, physically. We were out at Somerville at all times. So yeah, we were involved. They came to the labs. We went out there. And very bright people. I think the fellow named Jack Omstead was the fellow that we originally worked with out there. And was our, kind of, interface on that device. For myself, back in the labs, I've always loved watches. And do you remember the Bulova Acutron, with the little tuning fork?

Laws: Yes.

Hofstein: I was fascinated. I bought the one with the transparent face. I loved to watch that thing and listen to it, and so on. And one day, I think it was Tom, called me in the office and said, "You know George Heilmeier? I said, "I've seen him and say hello." He said, "George has discovered something very remarkable that's top secret." He said, "There are five people in the labs. You're now the sixth one that even knows that it exists." And he said, "I want you to go down and take a look at it. Only a limited number of people are being allowed to see this thing because of its impact. And they are people that we think might be creative in finding a way to get it to go." And so I went down to George. His was the only laboratory kept locked. It would be the doors to his particular lab, they were kept locked at all times. And so they invited me in. And George said, "I'll show you something." He had this microscope. And he had these two glass slides on it and a little battery sitting next to it. And he said, "Take a look through the microscope." So I looked through the microscope, and I'm looking at a glass slide. And I can see something's faint on it. But I don't know what it is. And he touches the battery. And, all of a sudden, "boink," there's a house, a little tiny house. And he says, "Now watch." And he takes it away, and it disappears. And that was my first introduction to the first liquid crystal display ever made in the history of the world. And it was fascinating. Just an image of a little house on a slide. And the problems, of course, at the time, were that-- it's always the same thing. There are always defects until you perfect it. In the case of the MOS transistor, it was sodium, for example. In the case of this, we still don't know-- at least, I don't know, what the contaminant was. But the liquid crystal would fail. I mean, to switch modes like that is very physically aggressive to do to material. And whatever else was in there didn't like it. And after a few days, it would turn brown. And so that was the problem they were looking at, also, the response time. RCA, I had started to mention before, had built its fortune on television. And even though they encouraged investigation in all these other areas, television was still their major interest. And flat panel displays-- once color came out, and that was a massive undertaking. I don't know if anyone's ever written a story of the RCA one-year crash project to get color television, compatible color television. For a period of one year, they had cots. The scientists slept at the laboratories. They worked around the clock. The families would bring food in and back and forth. The kitchen was kept open. It was a crash project. Because the FCC had given us one year-- us being RCA-- one year to prove that they could compete with CBS, If so, the method, would get the FCC sanction and be allowed to work. And so they had to create, come up with the idea of a shadow mask. To take something from just raw ideas, how to do the materials, how to do the shadow mask, everything was done in a period of one year. When you look back upon it, it was an astonishing period. I mean, to do that much in one year, It’s like building an atomic bomb in two months from dead scratch.

Laws: We'll cover some more of this topic this afternoon. But just now you were describing the challenges involved in developing liquid crystal technology.

Hofstein: And what occurred to me, when I saw it, was that I asked George, I said, "How much power does this take?" And George said, "I don't know. We've never measured it." I said, "Does anyone have a meter here?" And he said, "Well, yeah." And so we got a meter. And when he connected the battery up this time, we took a measurement. And it was a couple of microamperes, which also was interesting, but not a great significance. And I thought to myself, "You know, I had taken the battery out of my little Acutron. And it drew 10 microamperes."

Laws: Ten? Okay.

Hofstein: So now, we had a display that was in range of that kind of support from a tiny battery. And the MOS transistor, particularly in the CMOS configuration, took almost no power at all. We could build a watch. And so I did some research for a week or two. And I got a whole bunch of financial reports about the watch industry. Presented it to Tom Stanley. It was a 500 million dollar a year industry. And we can do it. And after about three or four weeks, the word came back from headquarters that RCA was not in the watch business. And by that time, I had built the first counter. George made me an eight-segment display. And I built a little decoder on it and ran it off of a crystal. And the numbers would change. Unfortunately, nobody took a picture of it. But that was the first liquid crystal digital clock.

Laws: So this was in...

Hofstein: '65, '66.

Laws: Okay.

Hofstein: We filed for it and we did get a patent. And, you know, it's so funny. That patent is so old it expired in 1987, which is really something. That's, like, 25 years ago, it expired. So I was very delighted to see that eventually it did take off. Watches began to appear. I'm not allowed to wear one. My wife thinks it's ugly. Parenthood doesn't count for anything when it comes to wearing a watch.

Laws: And RCA, also, was pretty heavily involved with the LED watch. Didn't they build the chips for the Pulsar?

Hofstein: Yeah, they did. But we were reminiscing. First time I saw it, we had heard about the LED. I'm not sure who had done the first ones, you know, IBM or GM. I'm not sure. The fact that light could be emitted from a diode, we'd all had a tunnel diode. So we knew people could do things with diodes and play with them. But this is the first time we heard about light being emitted. And so we got an excited call to that labs that they think they had reproduced it out in Somerville. And so we all rushed out to Somerville. And they had this thing under a microscope. And, in truth, it lit up red. It turned out later it was a piece of phosphorus that was stuck on it that was luminescent. But they didn't know it at the time. But it was good, because it gave them this energy to go ahead.

Laws: To go find out.

Hofstein: And before they actually produced a real light - before they found out that the other one was a fake. They didn't know it. So anyway, it's just astonishing how far that's come.

Laws: Okay. So now, we're up to '66 or so, anything else after the watch at RCA before you moved on?

Hofstein: No. I actually left in '68.

Laws: '68, okay.

Hofstein: And so we continued to do additional work on MOS and work on the watch and so on. But the watch was the last active project before I left.

Laws: Okay. And what did you do in '68?

Hofstein: Well, '68 came, and I decided to form my own company. I really loved the laboratories. It was a difficult decision. Because, I mean, I enjoyed what I was doing. But it had been ten years. And I, kind of, thought it might be fun to just try and start up a little company to see what I could do. And I had all of the naivety that's necessarily when you're in your 20's to make you think you can lick the world kind of thing. And so I submitted notice of resignation and left in 1968 and formed a company. And before I did, I'll take you back again. This was now 19-- it was either '68 or-- yes, it was the '68 meeting in Washington, the Electronic Devices meeting. And Andy Grove came up and said, "Steve, what are you doing for lunch? Gordon and I would like to have lunch with you if you have time." I said, "Sure." And so we sat down at lunch. And Andy said, "Listen," after usual pleasantries. He said, "I want to tell you something." And he said, "What I want to tell you, I can only tell you because you've already told RCA that you're leaving. Otherwise, I would not even speak of this. Separate and aside from that, we'd really appreciate it if you could keep it just confidential for the moment. There are very few people that know about it." And I said, "Well, okay. What?" And Andy said, "Well, Gordon and I will be leaving Fairchild to form a new company. And Bob is coming with us. We're going to be financed by Arthur Rock." I don't know if he mentioned the name, Arthur Rock, at the time. "We have financing. And it's a brand new idea. There are only about six or seven of us right now. And we're not sure of the timing. And we don't even know what we're going to call the company. [It was, of course, Intel] But we'd like you to think about joining us." And my initial reaction was, "Well, I'm very flattered. Thank you, Andy. But I was, kind of, thinking of, you know, running my own thing." And Andy gave me, once again, a wonderful piece of advice. He said, "Let me tell you something. I know you're excited. You're young. I'm a little older than you are. You're going to go out there. You're going to run your own team and so on. He said, "Steve, there is nothing more powerful than being a member of a small team and working together as a team. You can do infinitely more than working by yourself. Do you want to think about that? We've worked as a team for many years. You've seen what we've done. We'd like to have you join that team. I think you'll find it very exciting." And I said, "You know, it actually does sound very interesting. Let me think about it a bit." They said, "What's the schedule?" And I said, "Well, the conference is over tomorrow. I'm flying back to Princeton." And they said, "Well, that's coincidental. We're going up to Bell Telephone Laboratories. What we can do, we fly in and stop off in Princeton at your house." I gave him the address and everything. "And we can talk about this some more." And I said, "Sure. That's a great idea." Well, the next morning came. And my wife decided-- first wife had decided-- not current wife, first wife, decided she wanted to stay in town to do shopping. So we did, we stayed one more day, flew back. And when we got home, there was a business card. Gordon's card was in the door of the house. And a little note on the back that said, "Steve, give us a call. We want to talk to you." And I didn't return that call. And so here I am now. I went somewhere else...

Laws: The rest is history.

Hofstein: Marvelous people.

Laws: Do you have any other contact with Andy or Gordon over the years after that?

Hofstein: No. I think that we may have had telephone contact several times during the period after that. But no, not really. I followed his career with great interest. He's a remarkable-- he's a great man.

Laws: Certainly is. And so you went on with your original plan to form your own company?

Hofstein: Yes, we did. We formed Princeton Electronics. Actually, when we first formed the company, the first thing we were going to try and build was something that was a radical idea. It was a device called an aeroptics. It would generate a pinpoint of light. This is, you've got to remember, before laser diodes were well known and were used. I think they had light emitting diodes. But I think it was a while before there were laser diodes. And so the light beam itself was so small. Let me back up and give the introduction to it. One of the other projects at RCA that I did consult on, and very powerful, was the videodisc and the whole concept of how to do a videodisc. There were two different thoughts in industry. Actually, RCA labs itself-- and it relates. If I get off subject, just stop me. But RCA, again, back in the video world, was trying to find some way of doing video more than just a high-speed tape. And I demonstrated videotape by just taking audiotape and running it at about 300 feet a second. And to produce video, you could do any show up to 90 seconds. It was wonderful. But that was, kind of, a limiting format. So they were working on it. And there were two different approaches. One fellow was working on using holograms. And his name escapes me right now. But what he was basically doing was he would shine a laser. And they were able to record video as a series of holograms on a rotating disc, which is interesting. But in order for that thing to be practical, you had to have a color camera tube. The whole thing had to be built for $400. That was the magic number. And there was no way, at that time that a 400-dollar camera tube in color was going to be developed. The other hand, there was something called-- and this is Tom Stanley's invention. Tom came up with the idea of using RCA's advanced technology. They had technology knowhow in pressing vinyl discs. We had an enormous record pressing plant in Bloomington, I believe it was, Indiana. And Tom had come up with the idea of, basically, going the route that they did when they went from the 70 rpm to what was called a micro groove. That's how you got-- that's where you made a disc to be a one-hour disc. Tom was looking at the next generation of that. Where you'd be able to put 25 grooves in a single groove [of a conventional record]. That's how tiny it would be. And it was fascinating, because if they could be made to work, RCA had the tremendous facilities to make them. And pressing a disc is cheap. Everything else would've been more expensive at the time. And so a lot of work went into developing these videodiscs. Which, in fact, ultimately, did get on the market for some period of years. But there were tremendous challenges. The biggest one was how to get a needle that was fine enough to get in the groove. And then, keep it from touching the walls of the groove. Because if it ever touched the walls the way it did on an audio disc, it would destroy it. The grooves are too fragile. And they actually created a tone arm. To me, it's just amazing. They used a feedback circuit. The needle itself never touched the walls of the groove. It was held exactly in the middle by two little magnets. And there were correcting currents, little electromagnets. And if the needle started to veer towards one wall, it would be pulled gently back to the center. And that got to be working. So that was a huge feat. They could actually get a needle, keep it in there, and it was nowhere on the grooves. What fascinated me was why they didn't take this and apply it backwards to long-playing records. Instead of wearing them out and wearing out the needles. To me, I always thought it would've been a great idea to have used that piece of technology just for long-playing discs, in terms of maintaining their quality. But anyway, didn't happen. So the next problem was the disc had to be conductive. The surface had to be conductive. The needle didn't actually wiggle. It went up and down.

Laws: Okay.

Hofstein: And so the guide didn't go up and down. The needle could not be allowed to move. Because a signal was being embedded by an undulation in the base of the track. And so the needle was kept perfectly centered if it started to move, whereas, the signal was in the undulations. And, again, this too was necessary, because on a standard record, it's lateral. So they flipped it. Instead of the variance being horizontal, it was made vertical. The problem they needed now was to get the surface of the disc conductive. Because it was the variation in the capacity that would cause the signal to be generated and create the video image. And after a lot of experimentation, they did this, I believe, with a very light flashing of copper. And it looked good. And it played. They tested it. It was fine. They put it into production. And actually began to sell the discs. And then, something funny happened. All the copper started to fall off the discs. So they had themselves a product, literally something out in the marketplace that had light problems. And they did, kind of, resolve that one. But, meanwhile, the laser disc, I think 3M popularized it. But the laser disc, which went the next step further, became the dominant source. And, eventually, to be made into the little CD-ROMs and DVDs. And all of this is a prelude to what I thought I wanted to do when I formed Princeton Electronics. At that time, I knew about the audio disc, or rather the methodology they were using to do the videodisc, with the mechanical thing. And I'd come across this very fine optical needle, if you will. It was a device made by a company in Long Island, called Aeroptics [spelling?] And it wasn't coherent light, but it would focus a very tiny-- I think it was a 4-micron beam, on the surface. And my great thought was that some how, I would use that to make a really small audio record. Which turned out not to be what I did. About a month into that, when we realized the problems, I had another idea, which came to me about using these...

Laws: Now, you had founded Princeton by this time?

Hofstein: Yeah, Princeton Electronics existed. We were about a month into trying to do-- at that time, the company was two people; myself and Bob Persing, a technician who had worked with me, operating in my garage. Which is always the place you must start. I was offered a lab, which was a 25,000 square foot building. But I said I have to start in my garage, or I don't have a story to tell later on.

Laws: Right.

Hofstein: So anyway, we were working on it. And I was, kind of, sitting there, and there's this thing called the silicon Vidicon that everyone was working on. This is before George Smith came up with the bubble technology that allows you to actually make a camera out of just the chip of silicon. So what you had was a disc of silicon being used as the light sensitive target. But we didn't have the wiring capability to get in and interrogate the individual cells. So it was a hybrid technology. An electron beam was being used to scan the disc. One of the problems that they had was on the surface of the disc where the diodes had been created, it was oxide. And the oxide would pick up a charge and would block the beam so the images would fade. And the camera tube didn't work so well. And I thought to myself, after-- it was, gosh, about two or three months after we left, "You know, you can put an image on the oxide. You don't need the diodes. You could store an image. And so I sat down. We filed the patent on it, which we ultimately got, on using a silicon target to store the information for an image. And, again, it comes down to memory. And it fascinates me. The tube was very successful. We created a whole bunch of stuff. We did the first airport x-ray systems for Picatinny Arsenal. The lithocon. which it was also called, would store one frame of high-resolution black and white TV. That's it, just one frame.

Laws: And the image was stored in analog form?

Hofstein: No. It was-- yes. You would say it was stored as a charge pattern. If you picture the target, it was a very simple one. It was a silicon layer. And we etched into that a grid. And so you had a grid. Now, when you brought the target up to a voltage, the beam would penetrate and you get your signal. If you charge the oxide, which was-- in effect, that was inadvertent in the vidicon. The charge would repel the beam. And so if you charged this part of the oxide, the beam couldn't get through. And that'd be black. And if you didn't charge the other part of the oxide, the beam could get through. In other words, you were storing an image. And so we wrote the image as a charge pattern on top of the oxide. And as long as that charge pattern was intact, you had the image stored. Things like gas and other things we talked about, x-rays, would make it fade. But, at least, you had it for many minutes.

Laws: And you had to read it out some how?

Hofstein: Yes. It reads out just the way a silicon vidicon would read out. You're scanning the surface. And the signal comes out of the target as a variation in the signal. In a vidicon you're recharging the diodes. In the image tube, you're just looking at the charge that's on the oxide. And so you literally get a high-resolution image.

Laws: And the benefit of this over the previous methods? Lower power or...

Hofstein: The biggest thing was the relative inexpensive, the quality of the image, and the fact that it could do grayscale.

Laws: I see.

Hofstein: There were storage scopes at the time, for example, but they were binary. I think Hughes Corporation made a number of storage tubes that were primarily binary. And they were being made for things like radar retention and so on and so forth. This tube had grayscale. And it had high resolution. It was the equivalent-- I remember thinking at the time that "Wow. It effectively is storing something like-- including the grayscale, something like 10 million bits of information." Which is phenomenal. It'd be a long time before we saw 10 million bits of memory in semiconductors. Nothing stands still. So we came out with the tube, which we put in a device called a scan converter. And the scan converter was a box that said, basically, you can paint a pattern any way you want on this image. And then read it out as a TV signal. So it's a scan converter. It converts something, any kind of any kind of signal into an image. And as they often say, it was a fantastic solution to non-existent problems.

Laws: So who used this tube?

Hofstein: Well, the first breakthrough came in ultrasound medicine We advertised. We began to send them out. We got calls from various companies interested in the fact that we're using storage tubes or interested in using it. And this was, like, a whole next generation. One of the customers who purchased it was Picatenny Arsenal. They liked it. And they gave us a contract to produce with a portable low dosage x-ray system. The original purpose was for battlefield injuries. A medic going out onto the battlefield did not have any means of telling if someone's bone is fractured or not fractured. What they needed was a portable x-ray unit that was not dangerous, and would allow the guy to see, is this a fracture or not a fracture? And the technology itself, or the system itself, was very simple. They had already developed the flash x-ray tube. This is a tube that just goes "pop." It develops one blast of x-ray. The total dosage is very low. It's very intense, but it's low. So it's harmless, if you will. They would get a photo luminescent screen. And so if you put an object in front of the screen, and you popped the x-ray, the screen would flash up. And then, the image would disappear. So now the challenge became one of how do you maintain this image?

Laws: Store it.

Hofstein: And that's where the storage came in. They took a sensitive camera-- so you pop the flash that made the image. The camera picked up the image, put it into the lithocon tube where it stayed. So the illusion, if you will, you popped it. And then, you could see an image and study it.

Laws: And how long did it remain?

Hofstein: Oh, the image would last for many minutes. More than adequate for actual practical use. And so that was very successful. We were not allowed up at the demonstration, interestingly. Because there are a whole bunch of government agencies up there that we weren't allowed to be with, like NSA. Everyone was there to look at the tube. But out of that one meeting, came a lot of opportunity. For example, the FAA purchased a unit-- well, actually, they didn't purchase. They sent out an RFP to three customers that were using it, using our stuff. I think Philips was one of them and American Science and Engineering, and Bendix. And they decided they wanted to try to see if this little flash x-ray unit, could be used for security purposes at airports. And so the first airport-- you want to talk about irony, the first airport, the first test ever, was at the airport in Oklahoma City, later to be that huge horrible bombing. And

I have the original report, which I think, back in the day was confidential. But it's long since been declassified. And it was very fascinating. Some of the stories that went along with the tests were very funny. They were told at the gate that there would be-- what do you call? What's the word? Not stooges. There would be people secretly being set up to be bomb makers; old ladies. You would never know who they are. And they'd hide a dummy bomb in their clothes. And the question was, "Can you pick them up? Can you find them?" And so everyone was on hair's edge, because the value of the system. And all of them want to get these phantoms, people coming through. They wouldn't know who it was. Don't even judge them by how they look. Because they're not going to be picked for looks. They may be carrying a bomb. And so this little old lady comes up to the Bendix system and hands a package. And they put it on there. Holy smokes. On the screen, there are the sticks, the logs, the sticks of dynamite. Wires are running all over the place. Batteries and gears. And they grab the old lady, who was obviously a plant. They hustle her into a room, and they grab this thing. And following protocol, they take it, and they bump it in a bucket of oil. You don't use water. You use oil. And this woman is crying and crying and crying. Turns out, when they opened it up, they've managed to destroy a toy truck. It was a logging truck. And it had the little logs on it that look just like sticks of dynamite. And it had the batteries that ran the motor. It had all the wires. This was just a grandson's gift. That's one of the more humorous stories that came out. It also was used by the Library of Congress. They have a tremendous problem with book theft. And they tried-- of course, these days, you have all the things you can put in books. But the problem with that was, there are 10 million books. And the thought of pulling 10 million books off the shelf and putting a sticker on them. So they did purchase a unit. We also sold a unit, which turned out, ended up in Jordan in King Hussein's personal security. And it was interesting. We found out about this only because the unit failed. And so we got a phone call. "I can't tell you who I am. But we need to bring a unit back that you sold." We had sold this to some non-descript government company or something. We didn't know what it was. And we said, "Okay. Well, how do we reach you?" "Well, you can't reach me. I'll call you. Someone will call you and give you a phone number, and you call back." So we make an arrangement. The unit appears at our door, along with two very burley, swarthy men. "They will be with this unit at all times. That's their job." They did tell us that this unit was being used in the Middle East. We found out later, it was Hussein. These were his personal bodyguards. And their instruction was that unit was never out of their sight. We couldn't keep it overnight. They had to make sure nobody was sticking a bomb in the darn thing, I guess. And so we worked on it the first day, and found out where the problem was, in the supply. And we started to get the parts together. Then, they had to take the unit back to their motel. And they brought it back the next morning. And we fixed it. And we waved goodbye. And they took it back. And I guess it worked, because King Hussein was never assassinated.

Laws: So how big did Princeton grow?

Hofstein: I think at our peak, we were bringing revenue of about three or four million dollars.

Laws: How many people?

Hofstein: At that time, it was about 30 people. And, like anything else, our technology was-- we didn't have the kind of revenue …. Part of the problem was we were an OEM. This is something that I've always, kind of, taken as a lesson to be learned. When you're in OEM, the power of it is you're making this device and selling it to everybody. Okay. Anyone can buy the device. That's great. Because now you have a big market. Whereas, if you are lined up with a particular client, or you then, follow it through to its actual use, you're a more limited market. The problem with being an OEM is that you're really selling technology. And as we've all found out, even back in those days, technology moves along. What was laughable when we formed the company in 1968, it's, like, "Oh, God, there'll never be a 10 million bit semiconductor memory." Oh, yeah. We went ten years later, after that, 1978, I went through Zurich, Switzerland. They still had one of our scan converters in operation on one of the x-ray systems there. So they had a good lifetime. And, eventually, the MOS came and bit me in the tush, as they say. They started to make big memories. And, of course, you didn't need the lithocon tube anymore. But it was fascinating. Do you remember, Super Bowl 1969?

Laws: Um-hum.

Hofstein: 1969, 1970, During the middle break of the Super Bowl, the first pictures from Mars, it was Mariner 9, I think, were coming back. They were being assembled on a lithocon tube out in California in a trailer and then, beamed out over the networks. So it was just a tube, but it's good to know that our tube was the link between Mars and the vast audience we had here.

Laws: Sure.

Hofstein: Oh, last one, but not least, ultrasound medicine. The first grayscale ultrasound medicine was done by the University of Chicago. They had been working for a long time, using scopes and they had switched over to use our tube and were finally being able to get diagnostic quality images. The problem was the mode that we're using it in took a lot of care in how you scanned it. And then, a fellow I had gone to school with, back at Cooper Union, a fellow named Ralph Rinaldi called me from California. He was working for a company called Roje [Roche?] Scientific. And they wanted to get into the ultrasound business. And he thought the tube would be wonderful. Ralph had a great idea about how to paint the picture that made it easy. In other words, it was done by target modulation. Without getting technical, it allowed the picture to be scanned in. And then, it would be stable. If you rescanned it, it stayed. Whereas, the other way, as you were scanning it, it got brighter and brighter. And so you had to be very careful how you scanned it. This way, it gave you almost like a real photograph. And so we began to sell these units. And Roje Scientific came out and began to sell one of the first of the medical ultrasound systems. They were followed by a company called Unirad out of Colorado, again, using our stuff. So our main revenue during that period was actually ultrasound medicine. We created the first units. They went into the field. And they were enormously successful. Our competition there ultimately ended up being Hughes Corporation, who some several years later, began to make storage tubes, as well. And they were a very effective competitor, unfortunately. But between Hughes and between the fact that our technology was stagnant I began to appreciate Andy's advice. The company was very definitely sustainable. But it was built on a technology. And we didn't have the resources to move the technology forward into the next level. And so eventually, you know, we got superseded. But by that time, I had sold the company and moved on from there.

Laws: What did you move on to?

Hofstein: A premature retirement,. I thought that that was really wonderful. I came up with some fellows, and we did some very interesting stuff with Hahnemann Medical School and University, down in Philadelphia. And so I got involved for a while with some people in continuing medical education. And about, I guess it was 1989, moved down to Florida. I formed a company called Ascot Technologies, Inc. and came up with the idea of applying expert system technology into some business applications. And doing some advanced work into OCR and so on. And that's the company that I was with, right up until 2009, when it was purchased.

Laws: Where did your background in expert systems come from?

Hofstein: Books, learned it. You know, it's like anything else, you take what exists and then, you modify and advance it to take it to the next level. I didn't invent, by any means, expert systems. They're a part of artificial intelligence. They're very different from a rules engine, because they infer. Let me take a second to tell you. A rules engine does rules. It always does the same thing. An inference engine, which is the core of an expert system, makes inferences. It's never 100 percent right. But it's good enough to mimic an expert. Which, if you're right 98 percent of the time or 99 percent of the time, it's very, very commercial and very feasible. And so the first area we went into was that of insurance tracking. And that was in 1999. We had already put a whole bunch of systems out in healthcare. Do you remember the HCFA [Health Care Financing Administration] form?

Laws: No.

Hofstein: It's the bill the physician sends to the government or the insurance company for payment. It's a standardized form that was being made with dropout, meaning it was made with red ink. And so the form was very suitable for OCR. And OCR, which is very interesting, it all comes back to computers. OCR back in 1980's, like the '80s and '90, was done on something called a line scanner. In other words, you had special fonts. You would run it through a very complicated machine that would look at the font and identify what it is. The problem with that technology was that if there was an error, even one error on that entire form, the paper had to be pulled and worked manually. And so the judgment of a good OCR machine, then, was how many documents remained untouched? What people didn't anticipate was imaging. Imaging came along and changed the whole game. Because now, for the first time, you could actually generate an image of the document. And then, electronically, work on that image, rather than try and pass it through a line scanner. And it would work in anything. The problem was there was no open architecture software available, until I think, 91. A company called Symbus [ph?] up in New England came out for the first time. And remember, computers were still just developing. And personal computers were just coming on the market. They came up with open architecture software that would run on any computer. Okay. And would allow you to do OCR on an image. And that company, too, became, I guess, a casualty of technology over the years. I got involved with it, in terms of building systems. And we did a lot of them for the medical field, Blue Cross Blue Shield of Memphis, for example, and United Healthcare down in Florida, in Coral Gables. United Healthcare, at the time, was called CAC Ramsay. It's a company founded by a very brilliant Cuban immigrant. And when United Healthcare bought it, they didn't like the way it was organized. I'll explain what I mean. Culturally, most of the people working in healthcare at the time were women. And so you had this open room filled with women who were just chatting away with each other. While they were working, chatting away, chatting away, and chatting away. And United Healthcare said, "This is not good. You know, we have to stop it." So they passed the word stop it. But you don't tell a bunch of happy women in that ethnic group not to chitchat. They're going to chitchat all day long. They do their work, by the way. But United Healthcare is a big organization. And there are standards, and there are models and so on. So they put in barriers, which was a disaster, because now, the woman stood up to talk. And when they stood up, then, they couldn't work. At least without the barriers, they were sitting and talking and working; now they were just standing up and talking. So that barriers came back down again.

Laws: And physically what was your product?

Hofstein: The product was software and just take it a little bit further; 1999 comes around and we have done something a little unusual; OCR in the form at that time required that you have a template, you know where everything is, in other words, up here is a policy number for example, and here is a doctor’s name. You know exactly where to go on the form to get the information. Well we had begun to develop a technique where you didn't have to know where it was and in fact, you could do it on any form, which meant if you wanted to go for a policy number you would, you would look at a form you'd say, well how does a person do it? Well you look and see there’s a word, policy number and numbers to the right, or sometimes it’s underneath so what we’re going to do is we’re going to look for the label, then we’re going to scour the area and find something that looks like a policy number and that's probably it and so that was the beginning. The concept here was now you're beginning to build software that thinks like a person and you emulate what a person does and so we’re starting to capture these elements. Now something even more interesting came along. We didn't know it was an expert system yet, it was now just a better OCR system; it was using a more advanced technique to locate the position of the element, but other than that it was still pretty much just simplistic; find a label look for something it’s on. Which is not trivial, because for every time you think you have it knocked down another form comes out and it ain't where you think it’s going to be. So we’re contacted by a company called American Security Systems, later to become Assurant, which is a giant in insurance in the United States and this was back in ’99 and they’d heard about the fact that we were doing something with title forms with attorneys at Title Insurance up in Florida. They, being American Security Group, was one of the top three tier trackers of insurance. Have you heard of insurance tracking?

Laws: No

Hofstein: When you take a loan out on a house or a car, okay you have to get an insurance package on it, and you'll notice whenever you get a renewal from your insurance company or a cancellation or a reinstatement, a copy of it went to your lender, but it doesn't go to your lender; it goes to a company that's tracking the insurance for the lender and if you examine a lot of the forms that come out they're all going into Springfield, Ohio which is where Assurant or that's where American Security Group had a tracking facility and so we went out to visit it and it was fascinating. They're in the top three tier of insurance trackers which means they write their own insurance. The other two are Balboa and a company called ZC Sterling. The three of them counted for 90 percent of the insurance tracking on mortgages in United States and the problem they had at Assurant or American Security Group is they were losing market share and the reason they were losing market share is because the other companies claimed to have a better technology. They had imaging and the clients who came in who were very non-technical looked at this imaging facility and said well that's advanced. And then they looked at Assurant and all they had were these women in front of these old Unix terminals on a green screen typing away, looking at paper and typing away and naturally they assumed that the advanced technology was better. And Assurant said, actually it's not better, it slows them down but it gives the illusion of being better and we need something that is better and we're not going to put imaging in, we need real OCR automation and they said well why a little company like us? Well it turned out to be interesting. They being the IT department, a very large IT department, had apparently been trying to do this for several years, had spent about three and a half, four million dollars and it failed and so when they found us, the IT people said listen it's not going to work, you being the marketing people, you want to pay for it, that's fine, keep these people away for us, don't even ask us for any help and it was interesting because that was a lucky break. Typically when you go out and you offer a solution to a large company, their IT group blocks you because their job is to generate a solution, your job is to give them tools.

Laws: They're the gatekeepers.

Hofstein: That's right, they're the gatekeepers and in this particular case, they had tried it and failed and were convinced it couldn't be done so they didn't care. It took us a year and it really started to work but the first thing about it that was interesting, you talk about expert systems were when I stood there watching the operators, I realized, this is not data entry. These operators, I said, "How long does it take to train them?" "Well you see this is a certain form from a certain company, now that policy number means a certain thing; if you see that policy number then you have to go here and get that, because that language doesn't say replacement cost, but it means the same thing." So the training for these people, it took an operator like 6 months of training to begin to understand the form enough to make the knowledge based decisions about what to do with the data, what data to take, where did you find the data. Maybe it didn't say policy number, maybe this carrier it says account number and so we realized, this is not so much data capture, this is knowledge work and we started to build a knowledge base with an inference engine and that's an expert system. When people would ask us, "What can it do?" The answer is very simple: Anything that a trained operator can do. What it can't do is artwork and I'll explain a standard story I would tell. The things that it can do, can't do are as follows, you have a submarine sonar system, you've seen them these hair screens with everything dribbling down, just like in the matrix and you have these unique people who can look at that screen and say that's a submarine and that's a whale and you don't see anything. And another guy sitting next to him says, "Well I see two shapes on there, but I can't tell the difference." and the third guy's sitting there saying, "What, I don't see anything." That part of the brain you can't do with an expert system. That kind of recognition is, it's like music, it's on a different side of the brain; it's on the right half side of the brain, it's an imaging, you can't touch it. The other side of the brain that's analytical, you can. So the rule is if you have a trained operator and you train them on a manual, you can put in a manual, you can build an expert system to remember everything and what's more powerful about it is it combines the knowledge of all the operators and it gets better and better and better so anyway, Assurant came out with it in 2000; went from 15,000 documents a day back up to 120,000 documents a day; today they do 350,000 a day through that software. In 2003, they acquired-- 2003 was interesting. We had been working with them for four years, and that paid us some very large figures in licensing fees for the software.

Laws: And we by this time, how big was your company?

Hofstein: ATI Systems at that time was 8 people.

Laws: Eight people billing roughly...?

Hofstein: In the millions, nice. I'll tell you my problem later as to why I never got to lead a big company. I can never get away from the bench. I've been criticized-- rightly so. Princeton Electronics was financed by Roussel Uclaf among others. Roussel Uclaf was the largest French pharmaceutical maker and they became interested because our imaging tube technology enabled people to see fragments and injectables. I know going back and you can edit this out later if you want, but one of the customers that we had was Schering-Plough. Schering had a problem, they make injectables and one of the things that's dangerous in injectables are particles because a particle gets into your bloodstream, it could cause a clot, and so these are being examined for particles and the way they examine them is operators sit in front of a table that has an illuminated plate and they take each individual vial and they spin it and they look at it and it passes; spin it, nope, doesn't pass and every single one is 100 percent examined by a human being and Shearing wanted some way to automate it and make it less subjective. Well we developed a way with the tube operated in dynamic mode which basically showed only moving objects. It would look at a scene and if something moved you would see it moving but if it was stationary it wasn't there and so we'd spin the bottle and boy the thing lit up; you could see all these fantastic particles swirling around and that was the problem, it was too good; every single vial failed, it was too much better and so the bottom line was, it was never put into production because everything would have failed. The other interesting thing is I would tell you that realistically it's all show. I said, you know let's assume you have a glass vial with nothing in it. Now you snap the neck off. What do you think just happened to all the little pieces of glass you created? Do you think some of it may have fallen into the liquid? Of course they do, but it was cosmetic. So we were financed by Roussel Uclaf, the pharmaceutical company, to develop the machine for them, which we did. They ran into a similar problem but one time, their expert, the fellow who had taken us over there and introduced us to the two brothers who ran the company came over and visited us in Princeton and I was sitting in the laboratory working on a problem we had in the lab area, working a problem we had and getting the tube to focus in the corners and he came over to me and he said, "What are you doing?" I said, "I'm working." "What work?" I said, "I'm working on the board." He says, "You're the President of the company, you shouldn't be in this lab; it's ridiculous, you need to be in your office and organize the company." He was absolutely right, but that was my problem; I could never get away from the bench. Even the company I had now, which met with success was because I never got out of the technical part of it. I'm not a great businessman but I had a lot of fun with technology and overall I'm a lot happier, because I've always loved the stuff for all these years, so I'm doomed; Andy was right, I would have been so much better with those guys' help.

Laws: The team at Intel.

Hofstein: Absolutely.

Laws: And I interrupted you when you were telling me about the number of documents that were being read.

Hofstein: Right they had gone up to about 120,000 so now they had-- an interesting point; they came to me, they being Gene Mergelmeyer who at that time was the Vice President of Marketing for the company and who had sponsored the project and said look we need to be independent of you; we'd like you to think about giving us a source code license because up to now, they had the object code, but we always had the source code and they had no rights to the source code. It was kind of interesting, well a second, turned out what their problem was is they wanted to go public and the underwriters told them, "Hey, the software that has made all the difference in the world that you're using and showing everybody and it's on record is being made for you is being made by a tiny company that you don't own, have no control over, we're going to have to put that into prospectus and that ain't going to fly." And so they came and they said well look we'd like a source code license; we gave them a license, or sold them a license, again it was expensive for them, but it allowed them to maintain the software. We also kept the right to audit them once a year to make sure everything was in order and basically they just used it as is and have for many years; it's very powerful stuff. But once we had done that, we were locked out of doing mortgage, because part of paying us for the source code which was a lot of money was that they had exclusivity for five years and so we turned around and said, well what other than mortgage can we do and it is automotive and so in 2004, we began to develop the same expert technology for automobile tracking, which is similar but somewhat different. We're very successful with this; partnered with a company, introduced us to some of the big titans and in 2009, we had the same problem all over again. The company we were working with, a company called Southwest Business Corporation is a company out of Texas and they were doing automotive tracking and were getting ready to get into the mortgage business and suddenly had the awakening of once again, this little company controls the technology; what are we going to do? Do we take the giant step? Do we cut ties with them? Well, I sat and I talked with them, and I think they made the right decision, they purchased our company.

Laws: I see.

Hofstein: And so on that fateful day in 2009 after 40 years of being an entrepreneur and a businessman, I became an employee. I had been an employee for a long time under my wife, Karen, but this was officially for a big company.

Laws: <Laughs>

Hofstein: It’s amazing; when you're employed by your wife, you pay for the privilege, that's even more fascinating.

Laws: And the company, you changed the name?

Hofstein: The company at the time, once-- we reformulated back in 2004, for the automotive industry and we changed the name to Cognisys. And Cognisys was then purchased by SWBC, so we’re now a division of SWBC, which is a fantastic company; unbelievably great.

Laws: And you're still going into work every day and running the company?

Hofstein: Yep.

Laws: How big is it now?

Hofstein: -- They kept the company core in Florida. We’ve expanded to be six people, which is really a joke because we were eight people, now we’re six people. Well we have the support of a huge company, so a lot of the more I don’t call it medium, but a lot of the more basic stuff is ported over to Texas and stuff like that and we concentrate on the core development. it’s fascinating what’s available out there, now that-- and again, remember I told you the problem I had all these years with Princeton Electronics were you're running your own little company, you don’t have the resources to expand and get into markets and so you've had this technological breakthrough and you live on it and you live on it and you live on it and truthfully what we’re doing in the field of data capturing if you will, or expert system technology still has not been surpassed and it’s been a long run. I mean we started doing it successfully, commercially in 1998-99 and we’re still doing it. So it’s moved along but on the other hand, what excites me so much about and for the first time being part of a time and Andy yes, you were right, is that there are a lot of smart people in the company going out and opening up marketplaces so somewhat belatedly I am now an employee of a very smart team.

Laws: Are there new areas that you're looking into apply the technology that you can talk about.

Hofstein: I can't; that's one of the things that happens. <Laughs>

Laws: That's fine.

Hofstein: I'm back to the, I can't say.

Laws: How about do you have any life outside of the fun at work?

Hofstein: Oh we had great fun; we had great fun. We had a lot to of fun when, I'm trying to think of the best way to describe this. One of the fun times for example was back when we were financed by Roussel Uclaf in France, we were traveling over there, and Karen, my lovely young wife at the time, went with us and we were sitting at dinner and the Tour de Gall still there, it's the oldest restaurant in Paris; I think it started in the 1500s and a very lovely man named Claude Torai [ph?] runs the restaurant and we were upstairs and we had this very lovely table because we had four or five top executives who were French so we were being treated very very nicely and Karen's very lovely and sitting there and there are two or three of us from the company and I don't know what the whim caught me but with my limited high school French called the waiter over, or the Maitre d' actually and told him that mademoiselle is Karen Carter, the niece of the President of the United States and that I am a security agent and please would he be aware of anything, and I got, "Oh yes." I sat down, I thought that was kind of funny; we get nice treatment, the Maitre d' was very hospitable. Next thing I know Mr. Claude Torai has appeared and he has this card, and if you look at the walls of the Tour de Gall are filled with cards signed by notables, so Karen signed as Karen Carter, niece of the President of the United States, which ultimately went up on the wall and was there for many many years, but now this became interesting. The French men who were with us were getting a kick out of this; they're just sitting there nodding and giving it credibility and now at one point, they had this great wine cellar and so the Maitre d' had come over and said, "Anything that Mademoiselle would like to do?" I said, "Yes, she would like to tour the wine cellar, but it's a security matter, we cannot have anyone else down there." "No problem;" they went downstairs, threw everyone out of the wine cellar or the catacombs of Paris that many years ago they sealed off and they kept literally half a million, a million cases of wine in there. Cases, not bottles and so we the security agents went downstairs, very sternly, we checked the corridors, we sent a message back up; Mademoiselle Karen came down and now everyone is guiding her and showing her and everyone's standing there looking very serious and finally they seat us down and they serve us some Armengot [ph?] from 1876 and they say anything Mademoiselle would like to do in Paris this evening? Well Regine's if you recall Regine's was the disco at the time, you're talking way back when and the disco is the place to be. There was a Regine's in New York. Not a problem and so they call up a limousine, they put us in a limousine, they drive us to Regine's; we get out. The security people are holding the mobs back. They escort us in and they have reserved a corner area that's now been roped off, the royalty area and that's where we get to sit and every time Karen gets up to dance, we all march out onto the dance floor like security people we have a cord around her blocking anyone. This went on for about four or five hours; and it was wonderful. We paid the bill and gave lavish tips because that's what you do when you're quote, royalty even though Carter's family wasn't quite royalty, it's close enough and we get up to leave and they come rushing over, they'd been trying to reach Regine and they just got her on the phone, she's down in Monte Carlo but wants to talk to Karen Carter so my poor wife had to hand the phone with Regine, told her she loved the restaurant and said next time I'm back in Paris we'll talk about a few suggestions I might have. Now we marched out, we walk down the street, turn the corner and collapsed. You had 8 dignified French people and us all rolling around the grass laughing so it was a great deal of fun.

Laws: You have kids?

Hofstein: Yes we do. I have two by the first marriage, one here in California and one in Florida, and two with Karen.

Laws: Any of them going in a scientific direction or entrepreneur direction?

Hofstein: Yeah my doctor actually is becoming a doctor of physical therapy. She's now 27, very beautiful, has had some career changes. Started out by loving horses, doing a fantastic job, but it's difficult to earn a living in horses; the trainers earn a living, the contestants earn ribbons, the most expensive ribbons you ever had in your life and so after that she decided to be a photographer, went to photography school for two years; superb photographer but there isn't that much business, but she's had her work with the horses and photography oddly enough propelled her into the area of physical therapy and now she's getting her Doctorate; she's got her Master's and going on her Doctorate, which she'll complete next year and Daddy's little girl now gives him massages and when my back hurts, it's call the daughter, back hurts.

Laws: Do you have any advice for kids going into science these days?

Hofstein: That's an interesting question. Let me recount one thing that may pertain to that. When I first went to RCA, their practice was to take their new coming people coming in from school and send them out in the field as recruiters; the concept being that they bridge both worlds. In other words, going out there to say, hey I was in your shoes two years ago and here's what you need to think about and also get a better feel of who will be successful and the key question I always asked was why do you want to go into research and the answer I would hear too often was, I want to be creative. Research doesn't make you creative; it's an innate ability. If you are creative, I don't care if you're a ditch digger, you're going to figure out a better way to dig the ditch. If you're going to build a house, there's a better way to build a house. You're always inventing and creating. So to those people that think going into research will be great because it will make them creative; it's the flip side. If you feel creative and have been creative, then go into research, okay? In other words, try and judge what you enjoy doing and are good at doing and happy and try and follow that path. Now it's specious advice because I went to a scholarship school and all of us never had to pay tuition, we were okay for very middle class, lower middle class families and now I read out there about these kids that are coming out of college with a degree that have debts of thirty, forty, fifty thousand dollars hanging over them and a need to start repaying it on an immediate basis. I can't imagine that burden. In all the years that I went to school and all the people that I knew, we made it through one way or another, we either worked, or we got a scholarship, or we worked and got scholarships and that's where the money came from. Student loans, at least as I remember back in those days didn't exist. You may have come out with a degree, but you didn't have a debt. It may have taken longer to get the degree and you didn't have debt but and I'm not pointing fingers, the concept of easy debt for a student, everyone took advantage of, why not, it's crazy, everything is wonderful, I'll get a great job, I'll pay it down. They come out in the middle of a recession, they have this enormous debt and they can't pay it off and they can't get a job. I've never seen anything like it so I have to say any advice I might give them I'm afraid would be tinged by what was and ain't. If you go back in time 40 years I have some good advice for you, but other than that, no.

Laws: What do you think about museums? Are museums important in terms of teaching people about what has gone on before and how you may take advantage of that knowledge?

Hofstein: I believe so but I believe it's a question of the tail and the dog. You can take-- it's almost like that business the three men in front of that hair screen in the submarine. You get one person that'll come to the museum and say, "Oh wow; that's really fantastic; that reminds me, yeah I have an idea." You'll have another person come in and look at the same exhibit and say, "Huh?" It's the person. Are the museums important? Yes they are; they're extraordinarily important because seeing the stuff sparks people, the right people. There are people out there that will benefit tremendously from the museum; there are people out there that will not. We had a moon rock exhibition; this is 1973. By that time, I was now chairman of the Physics-- Reliability Physics Symposium it's called and in 1973 it was, we managed to get a moon rock out of NASA and on display at the show, at the conference and it was interesting. We had 25,000 people come past to see that by count, over a weekend. It was the first time a moon rock was never let out of government custody for any kind of show -- they had not done this because every politician wanted one; every government wanted one, we were very fortunate, NASA was able to get this for us, or at least loan it to us for that short period of time and so people had not had a chance to look at a moon rock and you had 25,000 people come past it and I know that because it was-- the guards on the moon rock had counters and they counted for every time a person came past and they fell into three categories, you talk about how people respond, is a museum important. What is important about seeing a moon rock? You see it in a newspaper, whatever and you have three reactions. One reaction was, "It looks like a piece of gravel in a driveway." Other reaction was, "I could wear that on a ring." And the third reaction was, "Wow!" And I'll tell you, every guy, the men, ugh what's the fuss, it's a rock? The women, "I can put it on a ring." The kids, "Wow!" So when you say is a museum important; you betcha. Every kid that walked past that moon rock never forgot it and it got them excited, it got them excited about science. It's the wonder that kids have. That can be nurtured and a museum can do it. I used to love to go to museum. It was the same thing; it would give me ideas and it was fascinating. So yeah you take away the museum, you take away an enormous stimulus factor that I think has shaped a lot of kids over the centuries so I think the effort you're doing out here is phenomenal. I'm hoping that the work that's going in-- even the oral history that's gone in, hopefully, somewhere, somehow, somebody's going to see this and it will make a difference. I'm sure it will. And I'm sure you're sure it will.

Laws: I wouldn't be spending my time if I didn't think it was important.

Hofstein: You know there are people out there that are pragmatic and say, well no it is a waste of money when you've got to cut this, cut this, you're cutting off your future. You're cutting off your future. Sure, cut back educational programs; it doesn't affect the bottom line today, but boy is it going to ruin us in the future. It's hard to fight it; hard to fight that thought.

Laws: If you look back over your career Steve, what do you think were the two or three most significant influences that you think sparked something or changed a direction?

Hofstein: Oh. What epiphanies did I have?

Laws: Yeah, that's a better way to put it. Were there any that really stand out now in hindsight?

Hofstein: Yeah the-- when you say insights, I think some of the epiphanies that I've had have been mainly technical. The realization, oh my God, I can store and image in that tube. There were always in those days, helped along by a little bit of gin, I was always most creative after a martini. I keep telling my wife that that would make me more creative; she says, no you're down to wine these days. But you're talking about the A-ha moments. They've occurred; I'm trying to go back. You're talking about the giant A-ha moments?

Laws: One you mentioned that may or may not qualify is the annealing process and its role in eliminating surface states.

Hofstein: Yeah there have been many, yeah. As a jump, it was no bigger than many others that I've done. As the consequence of that jump was enormous. In other words, was it one brilliant idea that then had other, no it's just one idea at the right place, right time. I got this thought; we followed through with the thought and the same thing with the insurance tracking and doing, how to do something, use and expert something in a series, you know they're incremental but the impact that they have depends upon where they're applied. In the case of the insurance tracking it was tremendous because that's a big business. In the case of the liquid crystal digital wristwatch, I haven't made any money out of that in my life, nor did RCA, or anyone else really, because by the time the watches became popular, the patent was dead.

Laws: But the world benefitted.

Hofstein: Yes, I wrote a paper once called "Dollars and Signs'" which actually got published and *Vital Speeches of our Day,*

Laws: Anything else you'd like to say, Steve? We're going to cover RCA Labs, the influence on you and the industry this afternoon.

Hofstein: I just want to thank you very very much; it's been a fantastic experience coming out here. I look around; I'm delighted. You know, one of the things about a museum is that so traditionally they contain ancient things. You go to Metropolitan Museum of Art and you look at mummies and you look at great old paintings. The very fact that the computers that I did are in a museum makes me feel so old is beyond belief. You know I'm like a dinosaur touring the Museum of Natural History and seeing himself there, you know oh my God, am I that old?

Laws: The challenge in a museum like this is when is something become important? And we generally have the rule that well it should have been around at least 10 years before we accession something in, but it's changing so fast now, we accepted the Google server after just 6 years.

Hofstein: What you're pointing out is really-- people pay lip service to it but I'm really seeing it as a real problem; the rate at which technology is moving now is a serious problem; I'll tell you why. Because the amount of money necessary to create the technology is counting on a payback over a certain period of time and that period of time is getting lesser and lesser and lesser. One of the things that fascinates me, let's take a good example of the old times. The color television tube; the color CRT was born in 1955-56 okay at that company that I knew. The last of them were probably manufactured about 8 or 9 years ago, you could still get color CRT monitors for your computer; they're gone now. So I've lived through the entire lifecycle of the shadow mask CRT which was created in the period of a year okay and lasted for half a century and you look at other technologies, small technology a few years ago they put in automated telesystems throughout the country. Florida has one called Sunpass and they came out with these transponders and the transponders are wonderful; you put two batteries in them, you clipped them on your dashboard and fantastic. It only took two years before they were replaced with a semiconductor chip that was being read-- a passive chip that was being read by a monitor above. Now the people who built those transponders put a lot of money into it; the cases, the mechanisms, all gone, no return. And so it becomes a little frightening because in a sense that it advances so quickly, it then begins to destroy the things that cause it to be funded, if you will.

Laws: And causes the decline of the big R and D establishment; Bell Labs, RCA, places like that don't exist anymore.

Hofstein: Oh absolutely. It's really amazing. I've been in business for 48 years, we've been successful and every customer we've ever had would look at us and say, we worry about the survival of your little company. Yet now they're all gone. We did stuff for Texaco, Lala [ph?] with Latin America, West Africa. They disappeared. It's just amazing; RCA is gone, like you said. It's just astonishing how you could be big; that doesn't guarantee security anymore. The thought that you would graduate school, go to work for IBM and then you could think about your 401K. When I went out recruiting, the people that would tell me "I want to be creative" were only superseded in terms of getting me disappointed by somebody who would say, "What are the retirement benefits?" That really happened.

Laws: The world has changed.

Hofstein: Take a look at video; go back to video again. In video records and take a look at the media. I think it was '75, '76 was the advent of the first of the home video tape capabilities. It was Betamax and it was VHS and it was a political struggle; Betamax was a Sony product and the rest was a consortium in Japan into VHS and marketing wise, VHS killed Betamax, which is a shame because Betamax was actually a better technology it was better resolution but that's neither here nor there. And videotape lasted a long time but some where. I would guess in the mid '90s, mid '90s. you began to see the DVD come out .So when you went to Blockbuster you would see 80 percent of it was still videotapes but there was now these little DVDs and the videotapes vanished over a period of 3 or 4 years, 5 years and now you have all DVDs and the DVDs began to become ordinary so they went to Blu-ray which is just tremendous innovation; tremendous amount of money and it's now being killed by streaming. For my son's birthday, I got him a new Blu-ray DVD player. I researched it and this one by LG had this great advantage. It had built into it direct wireless connectivity, so not only could you play DVDs on it, not only could you play Blu-ray on it but you could latch into the streaming services, which if you really think about it destroys the whole need for the DVD. They had it built in. In order to stay alive they're building in the competitor that's killing them.

Laws: And the time it was useful for is shorter.

Hofstein: Yes, you're exactly right, sir. You know there was an interesting-- I think there's maybe-- off subject, but it was an interesting experience, this is back well the year had to be mid '60s and there was a conference; this is after the MOS had been announced and Cyril Hilsum who was head of the Royal Radar Establishment was hosting an international conference on electron devices, somewhat different than the domestic one we had here and invited people from around the world to come and give papers the MOS transistor was out and I was going to be one of the participants. . We still built our own diffusion furnaces; this is really funny; you couldn't buy them, you had to build them. Now it's an industry, but anyway, I got a call and they said you need to go over to building three and talk to some people over there. Now building three was the building that RCA did it's government confidential secret work in and in all the years I was at RCA Laboratories, I never had set foot in it and so I went over, I was curious and I was invited into the office and one of the managers over there who I knew introduced me to this fellow named John and John is with the government and we have a request to make of you. I said the government, and offered me a card. He said, "You're going over to a conference that's going to be internationally attended. Now we're really keenly interested and John is keenly interested, the government is keenly interested in understanding just how far the Russians have come in MOS technology we have no idea because that's really critical in terms of computing power and supercomputers and a whole bunch of things." And I'm really beginning to feel, "Yes and we explained to John that you're not an activist, you don't mind me asking you to do this." I said, "No, not politically, I said it's quite fine, I love you, I love this country, anything I can do to help, what is it?" They said, "Well look; don't be James Bond. Don't ask any questions, don't make any leading remarks. If you happen to hear something interesting, just make a note of it, maybe write it down to remind yourself, that's all. Let us know when you get back but please don't do anything. Don't be brilliant; you're not a secret agent, just keep your ears open." So I go over and the first night is a cocktail party and Cyril is a very graceful host and one of the people standing in a little group of us talking is this fellow from Bulgaria; I don't even remember his name, but which was at that time an Iron Curtain country and he's standing there talking and he's chatting and he says, "I go to Moscow last week and I want to see what they're doing, They don't even have a diffusion furnace yet; how are they going to make anything? They have nothing." Thank you [I thought].

Laws: Loose lips.

Hofstein: That's it; and I went back and I told them that and guess what, when they landed a MIG in England a couple years after that, there wasn't any MOS on it, just tubes. So remember that loose lips sink ships, you never know. That was my role as James Bond; I got to be 001; never made it up past that.

Laws: And I hope we saved a few stories for this afternoon and we can talk with the group more about your involvement with RCA Labs.

END OF INTERVIEW

