# Oral History of Joel Karp

Interviewed by:
Gardner Hendrie

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**Gardner Hendrie:** Alright. Well we have with us today Joel Karp, who has very graciously agreed to be interviewed for the Computer History Museum's oral history project.

**Joel Karp:** Oh, this is my pleasure.

**Hendrie:** Good, well I'm glad. What I might like to start, if I could Joel, is with some questions about your early life before you became an engineer. Could you just tell me where you grew up? Did you have brothers and sisters? Some things like that.

**Karp:** Sure. I grew up in a suburb of Boston called Chelsea, Massachusetts, which is just to the north of Boston. And it's basically a small working-class type town. My early life was I think quite normal. I went to school and had friends and played "War" and "Cowboys and Indians" and all that sort of stuff. I got into music I guess when I was in junior high school, but maybe even in elementary school. I started playing in the band. I was playing the sousaphone, which, you know, that huge tuba that wraps around your body. And it was ah.. you know, I had to carry that in parades and stuff like that. But it was- what- a few years after I started playing that, I asked my parents to get me a trombone, so that became my main instrument.

**Hendrie:** How did you get into music? Were either of your parents musically inclined people?

**Karp:** My mother had a lot of natural talent. She was one of these people that could sit down and just play any song that you could, you know, that you could hum to her. She could just play it with full two hands, chords and so forth. And she wrote some songs in the early 50s and actually she and my father produced a few records, which actually made it onto the Boston pop charts, but I don't think they really got much further than that. But they were the typical kind of 1950s type of pop music.

**Hendrie:** So this is a very musical family, definitely.

**Karp:** <Laughs>. Yeah well at least there was, you know, I knew where my interest came from. It certainly came from my mother's side. On my father's side, he didn't play anything.

**Hendrie:** Did you have brothers and sisters?

**Karp:** I have one sister a few years younger than me. She's currently living in Las Vegas.

**Hendrie:** What did you parents do? What did your father do? Did your mother stay at home? Did she have a job? A little bit about the environment which often gives hints as to why people ended up where they did.

**Karp:** Well, my mother stayed at home. She never worked. She didn't drive a car. My father took her everywhere. My father was kind of a businessman. He did a number of different things as I was growing up. He'd run his own business. I mean nothing really- nothing major, just kind of ah... mom and pop type stuff. And they were actually fairly simple people. Neither of them went to college. My mother graduated high school. She grew up in Providence, Rhode Island. My father came over from Russia at the age of thirteen and was thrown into the Chelsea school system without even being able to speak any English. So he basically- I don't even think he got through the first grade. <Laughs>. And so he was completely self-taught. And then during the war he did things like work on the ships in the Boston naval shipyard, painting and the whole- see he had really, really terrible jobs. He actually would have gone into the service, but he had a disability because of having had tuberculosis as a teenager. So uhm... they struggled. And they really struggled to put me through college. They had to take out an extra mortgage on their house and things like that. And it was a lot cheaper then than it is now, as you know. But they got me through MIT and, you know, that was I think what really got me going in this industry.

**Hendrie:** When you were growing up, do you remember what you thought you might want to do when you grew up?

**Karp:** There was a period when I wanted to be a musician. And that was my dream. And I would say that would have been in my early teens. But basically, I kind of hate to say this, but probably the reason I became an engineer was because I was lazy, because engineering, science, math, those things always came very easy to me. Music was hard. I mean sitting in a chair and putting your trombone in your face for eight to ten hours a day is really tough. <Laughs>. And I didn't have- I really lacked that kind of drive to actually become a truly, you know, a professional musician. And so somewhere in during the- somewhere in high school I kind of dropped the dreams to become a musician and basically started concentrating on the scientific subjects, which I did very well in math and science in high school. I did terrible in English and, you know, the typical engineer I guess.

**Hendrie:** Yes, exactly. I can relate to that. When you were thinking about going on to college, what sorts of places did you think you might want to go?

**Karp:** Well, when you grow up in Boston, MIT is the gold standard.

**Hendrie:** As an engineer, yes.

**Karp:** Every, every mother wants her son to go to MIT. And I remember, even as a kid, we'd be driving passing through Cambridge and my mother would point to that place and say, "Someday I want you to go there." <Laughs>.

**Hendrie:** Oh, so there was some subtle direction here.

**Karp:** Right. So in high school when it came time to decide where to go, I didn't apply to a whole bunch of places. I applied basically to three schools. And I covered the gamut. I applied to Northeastern in Boston, which was a slam dunk. So you knew, you know, there was no problem getting in there. I knew for sure I had a college to go to. The place I really wanted to go to was MIT, however what I do remember is that the high school guidance counselors actually tried to convince my parents not to waste the ten dollars to send in the application to MIT.

**Hendrie:** They were saying it's too hard to get into the competition school.

**Karp:** They said, "Your son is not MIT material." <Laughs>. And but they decided to blow the ten dollars anyway, and I'm glad they did. So other than MIT, the only other college that I applied to was Brown University. And I didn't technically get in to Brown. I got a letter from them which more or less said-- I had told them when I interviewed them that I really wanted to go to MIT. If I got in there that was gonna be first choice. The Ivy League schools, they never like to be turned down. So they wrote this letter that said, "If you don't get into MIT, let us know." <Laughs>. "But otherwise we're not going to accept you." <Laughs>.

**Hendrie:** So that makes their statistics look better.

**Karp:** Right. So actually since I got into MIT I never really had to let them know anything. But that was really my experience as far as, you know, applying to colleges.

**Hendrie:** So you went to MIT. There's a lot of engineering courses at MIT in all sorts of fields. What did you think you wanted to do when you got there? Did you know when you went in you wanted to do electrical engineering?

**Karp:** I think probably the seeds of the electrical engineering stuff were set in early. I did the usual crystal radio sets and I built Heathkits and things like that. And so I kind of had some interest in the electronics side, so I don't really remember ever giving it that much thought. I just kind of went there and said, "Yeah, I'll be an electronic engineer." It just seemed like the right thing to do.

**Hendrie:** Did you have any specialties or any particular things you focused on and took extra courses in?

**Karp:** **T**he thing that really clicked the most for me was the circuit design type of stuff, which I didn't really get into till senior year of college. But I really liked that. And I had an opportunity after my junior year I worked at a company that summer before my senior year and this was a company that was doing high-speed analog computers. And everything at that point in time was actually vacuum tubes. And it didn't take too much exper- it didn't take getting hit too many times by the three hundred volts in the back of those chassis for me to say, "I want to work- I want to work on solid-state." Solid-state was quite new in those days.

**Hendrie:** When was this?

  

**Karp:** I'm talking now in '61, where transistors are still quite expensive. You know, a little transistor in a little metal can was fifty, sixty dollars at that time. And I just didn't like that high voltage stuff. So I said, "I want to work on the low voltage stuff." <Laughs>.

**Hendrie:** What was the company you worked at in the summers?

**Karp:** The name of the company was GPS Instruments. And they were a small company in Newton, I believe. And their thing was that they had an analog computer, but it ran at three thousand times real time, so you- so you could solve all these complex problems, but you could solve 'em much faster than- typical analog computers, which ran in basically in real time. But to do that they needed very high bandwidth amplifiers, operational amplifiers, It's hard to remember some of this stuff, but, you know, in 1960 a typical operational amplifier in an analog computer might have had a ten kilohertz bandwidth or something like that. It was very precise, but very low bandwidth because they worked at very low frequencies. They worked at- it measured in cycles. So with their system where they had the three thousand to three thousand times compression of real time, they needed amplifiers that had megahertz type bandwidths which would give very low phase shift at the frequencies of interest. And so one of the things that I ended up doing was developing a- a transistorized operational amplifier as my senior thesis. And I ended up doing my senior thesis at MIT at this company. So while all the other people were struggling with their senior theses, I was getting paid a dollar seventy-five an hour. <Laughs>.

**Hendrie:** To do your thesis.

**Karp:** To do my thesis. And it actually turned out to be quite successful. I ended up building an amplifier that no one believed would work. In fact one night they brought consultants in, unknown to me, they brought consultants into the company and they fired up my amplifier and made their own measurements on it, 'cause they all said, "We don't believe his measurements." <Laughs>. And they verified them. I do recall that. So we ended with an op amp that used seven transistors and had just really outstanding characteristics. And one thing I should have mentioned was when I started this project, the first thing you do is you go and you get a thesis advisor. And so I got a thesis advisor and- who also turned out to be a consultant at this company. And that's- everything kind of works. That sort of was a connection. So they actually set me up with a thesis advisor. And he, you know, gave me a couple of ideas of who to go around at MIT that I might see to talk to and so forth. So I started going to various MIT labs and talking to people, what their experiences were. And when they found out that I was doing this for a bachelor's thesis, they said, "You're nuts." They said, "We've got people working on PhD theses that haven't been able to solve that problem." And in fact I remember going into one lab and them showing me-- they had this huge table, maybe an eight foot table just crammed in electronics. And this was some guy's idea of trying to build this amplifier that I was- that my goal was that I had to be able to do it for less than seventy dollars' worth of parts.

**Hendrie:** Right. He only had seven transistors.

**Karp:** Sothe thing was then, it was I was so naïve that I didn't know that I couldn't do it, so I did it. It was one of those kind of things. And it was actually quite successful. I was quite proud of that work and of course got an A.

**Hendrie:** Yes, of course.

**Karp:** In fact, it was one of the, you know, they would select a small number of bachelors' theses every year to put into the MIT library system. And that was one of the ones that they put in there. So I was happy with that.

**Hendrie:** Were there any particular teachers, professors at MIT that sort of influenced you or you really looked up to?

**Karp:** Well there were a number of really outstanding people there when I got there. People who were, you know, fairly famous people, that they ended up being my teachers. For example, Linus Pauling was a chemistry teacher there. And of course everybody used his book. Now I don't remember exactly whether he was actually teaching there at that time, but he was very- his book was actually developed there at MIT and became a standard college text all over. There was a guy by the name of Ernst Gilliman [ph?] who was the one who developed all the network theory in the 40s and 50s. And he was still lecturing in my first year of taking electronics courses, so I was quite lucky to have had him. The one who really stood out though was Paul Gray, who became the president of MIT several years after he was my professor. It was pretty incredible.

**Hendrie:** What did he teach?

**Karp:** He taught electronics. There was a famous set of notes that were developed under him. They were called the SEEC notes; S, E, E, C. And it was- it was kind of a group of professors from MIT, Stanford and other schools that developed this course. At the time, this was just really at the transition when the curriculum was changing over from vacuum tubes to solid-state. There wasn't that much solid-state stuff going on, and there was no integrated circuits. In fact, I introduced integrated circuits over there at MIT because after I graduated I took a graduate course under Gray and I would bring in stuff from my job and show the other students. We'd have these kind of seminar things. And I'd bring in little NOR gates and, you know, various things that I was working with, and really blew everybody away, because integrated circuits just weren't seen at all at the academic levels. Things are different now, I think, but back then what was going on in industry was far advanced than anything that was going on in the colleges.

**Hendrie:** You did your thesis. You graduated. You go get a job, right? Is that the next step here?

**Karp:** Right, the next step. So I ended up-- GPS wanted me to go to work there, but I got an offer from the MIT instrumentation lab, which is now the Charles Stark Draper lab. Back at that time it was- a lot of things changed in the 60s, but in the later 60s, over the protests with the Vietnam War and all that. But at this time it was still under the- the institute had several- they had the Lincoln labs, which I think they still have, and they had the instrumentation lab, which was doing mostly Navy and Air Force stuff, and also the Apollo project. They also had the guidance system for the Apollo. So I went to work with the group that was really doing all the guidance systems for all the strategic missiles as well as the Apollo systems.

  

**Hendrie:** Did they do the inertial platform?

**Karp:** They did the..

**Hendrie:** Or was that in another lab?

**Karp:** They designed the platforms there, and actually they were the prime contractor. So they would, for example, they were the prime contractor on the guidance for Lockheed on the fleet ballistic missiles that Polaris decided to do that- Trident, that whole series. And they were developing other inertial platforms that they developed for the Minuteman type of missiles. But the Apollo guidance- I don't know exactly- I know for sure they did the computers for the- for the lunar landing modules. And I'm not exactly sure what other parts of the Apollo that they actually were responsible for. But this is really where the hotbed of integrated circuits were developed, 'cause the Apollo was really the first major use of integrated circuits. And so I was kind of in the thick of it. So when I went to work there I had just come out of college, and everybody there was- was a vacuum tube engineer. These are all guys in their like 30s and 40s, so they'd all come up with vacuum tubes. And they'd learned something about point contact transistors. They had actually designed the first Polaris missiles were designed with point contact transistors. Point contact transistors. And they worked. The first systems, you know, were made with ah.. but when I got there, they were really interested in starting to miniaturize a lot of the stuff. So I got elected. As the young- as the new guy on the block, I got elected to start traveling around to various companies and trying to get people to support us in designing specialized analog components at the time. So I started- at this point in time, I really was an analog guy. And I was designing all sorts of, you know, I- as I mentioned, the operational amplifier. I was designing all sorts of weird stuff for these guidance systems. But what really got interesting was around 1963 when I was called into my boss' office and he said, "There's a really big problem that's just surfaced and we want you to go out to a two-week seminar out at Boeing in Seattle." And this was the beginning of all the radiation effect stuff. And they had discovered the effects of transient and ionizing and neutron type of radiation.

**Hendrie:** Neutron pulses.

**Karp:** So all these effects now are quite well known, but at that time, in '63, this was a very new field. So I went out there and learned all about hardening and all about radiation effects. I came back to Boston and I was told, "Don't unpack your bag. You're wanted in Washington tomorrow morning." I went down to a meeting the Navy Department in Washington, and they wanted a full briefing on this. These were very serious issues because at that point in time the missile systems were entirely vulnerable to any kind of radiation. So it didn't take much to knock these out of the..

**Hendrie:** You didn't have to blow them up to knock them out.

**Karp:** No, right. All you needed to do was set off some low yield weapon up in the upper atmosphere and the radiation effects would knock anything out of the sky that was up there because things were so sensitive. So it was going from that kind of a scenario where you had everything totally sensitive to where now you could actually fly through radiation clouds and the missiles would continue to fly. I actually invented something that allowed these missiles to fly through those clouds. And I was one of the named inventors on a very key patent that was issued to the U.S. Government. And it's a technique called circumvention, which basically says, "Okay, you can never really harden things because you can harden something to some level, but then the other side just makes it a little bigger." So..

**Hendrie:** Yes. Just increases the radiation, right?

**Karp:** Right. So hardening by itself was never going to be a perfect answer. The idea of circumvention, which really came out of this timeframe when I went Boeing and then, met with Navy people and worked on various strategies for how to make the integrated circuits, the idea was very simple. You detect the presence of a radiation event and you shut everything down and let things coast for a little while. And then, after a couple of milliseconds, you turn things back on. And it turns out that a ballistic missile doesn't do much in a couple of milliseconds. It's got a lot of momentum. And so the idea was you shut the system down, you let all the holes and electrons and the ionizing- and the gammas and you let that stuff all just bounce around for awhile and it settles down quite quickly. The entire event is a fraction of a nanosecond. So it doesn't take long for things to settle down. So a couple of milliseconds and everything's quiet again. You turn the system back on and you know how far- you know from your abi-ability to predict ballistic mechanics, you know how far the the missile should have traveled in those few milliseconds, so you just reload a bunch of constants into this computer and just start flying again. And that technique became known as circumvention. So that was probably the most exciting thing I did at that- and I was about twenty- I was about twenty-three or twenty-four years old when I was doing that. And actually I got to design a test of the concept, and build it and go out and put it in a hole in Nevada and blow an atomic bomb up on top of it. And uhm.. I didn't actually get to..

**Hendrie:** You didn't get to be out there when they pushed the button.

**Karp:** Well, I would have- I would have been out there when they pushed the button. I would have been in the instrumentation trailer ah.. you know, watching it. But just shortly before the event was scheduled to go off I actually left MIT and moved to the west coast, so that was just at that time.

**Hendrie:** What was the other technique? How did they harden circuits, transistorized circuits? Did they put shielding around them?

**Karp:** Well, you really couldn't because you really couldn't start adding lead shielding in these systems. It would be just too much stuff you had to shield. What they did was basically get- it turns out that you just get faster and faster transistors. So, for example, if you get an ionizing event in a big old slow power transistor, you generate a bunch of holes and electrons and then it just, decays after awhile. But if you push these things up into the gigahertz range then you actually have less hole electrons that get created by these type of events. So making the transistors faster was one thing they did and I guess things like killing lifetimes using gold doping and so forth. But now this all applied to bipolar transistors. MOS wasn't even in the picture at this point. But the concept in the Navy Department was that there were other effects that were actually scarier than just the upsets. You had these latch-up type effects. because if you look at a 1960's type of integrated circuit, you had a lot of different junctions. You had a lot of fairly large stack up of junctions. You had epitaxial materials and you had junctions on top of junctions on top of junctions. So it was very easy to make these kind of thyristor type switches out of an integrated circuit. And that was one of the real problems that I think the Air Force had with the Minuteman stuff that they were getting from TI back in the early 60s was they hit these things with radiation pulses and they'd just burn up. So the Navy didn't want that. So we actually started developing the dielectrically-isolated integrated circuits at that time. And that's when I got to go around to companies like Motorola and Texas Instruments and Fairchild and give them contracts to develop various chips for us. And I met people like Gordon Moore back in that timeframe. In fact, I remember handing him a contract for seventy-five thousand dollars to deliver us like a hundred chips of one of these dielectrically-isolated chips. And Fairchild did a good job on it at that time.

**Hendrie:** That's fascinating. So you did this for about how long? You graduated in?

**Karp:** I graduated in June of '62 and I left Boston for- that's funny. It's like an anniversary. I left Boston for California on March 1st 1966. So where are we now? This is let's see, thirty-four, thirty-seven years? Is that right? Did I do that right? Wow.

**Hendrie:** Yes, exactly. Thirty-seven.

**Karp:** Thirty-seven years to the day. And I had my wife, a three-year-old daughter and my wife was pregnant with our second child at that time. Not my current wife. This was my first wife.

**Hendrie:** Okay. This sounds like you're having a lot of fun here and you're doing good stuff.

**Karp:** Exactly. Well I loved that job. I loved the people there. There was only one problem. The money was terrible. I was making when I left MIT, I was making eight hundred dollars a month in '66. And I mean that's a lot- eight hundred dollars then was clearly a lot more than eight hundred dollars would be now, but it still wasn't- it still was..

**Hendrie:** It still wasn't a lot of money.

**Karp:** Right. And they really couldn't do anything for you there because it's a government, you know, it was all government funding and they had very strict rules on what kind of raises they could give you every year and so forth. And so..

**Hendrie:** They couldn't pay market rates. They just used their image.

**Karp:** They couldn't pay market rates, so actually what had happened was, since I was making all these trips out to the west coast and dealing with all these different companies, I became, I got to know a lot of people out here. And I just recall it was sometime in late '65 one of the guys that I'd been dealing with out here said, "Why don't you think about coming to work for us?" And I said, "That might be interesting." And I remember having an interview with a few people. And I can still remember, it was a Friday evening and the phone rang. It was about nine o'clock at night. And it was the people from, from California, and they said, "We'd like you to join us as a," I forget, some title, engineering whatever. And they offered me thirteen thousand dollars a year, which was a number that, by today's standards was clearly not that great, but in order to get that much money it would take me about probably another ten years at MIT to get to that point. And so the money thing was a really big influence about that time. But also there was something- this was like the Wild West or something out here. I mean it wasn't even called Silicon Valley yet, they still had orchards all over the place. And I think the timing was very good for me coming out here at that point. <Laughs>.

**Hendrie:** What company were you working with?

**Karp:** The company I had interviewed with was a company called General Micro Electronics. And this is history right here. This is some history right now. General Micro Electronics was a company that was- they didn't call them startups, they called them spin-offs in those days. And it was a company that came out of I guess mostly Fairchild. Everything came from Fairchild. <Laughs>. And they had developed the beginnings of- of P-channel MOS metal gate type technology at Fairchild. But Fairchild couldn't- they were known at that time for never being able to take something out of R&D and put it into production. And so they had lots of stuff that was done in R&D, but just never made it into the production world. So I think that a number of people decided to take that..

**Hendrie:** Now Gordon was running R&D.

**Karp:** Gordon- they did a great job in R&D. The only thing was that the guys across the street couldn't make any of it. They did it very well when it was in R&D. <Laughs>. And they had had a lot of tremendous advancements at- there. But- so GME started out basically to do the first MOS company. In fact the very first time I ever heard about it was a guy who had actually been a Fairchild salesman came in to see me at MIT. And he said, "Look, I'm working for this company called GME now." And I was struggling with putting like a triple three input NAND gate into a little metal can. I don't even think we were putting- maybe we had flat packs at that time, but, the- you know, DIP packages weren't even known. But we- but basically you allotted- most things were- had six or eight leads on them and they were, you know, they were in a little metal can.

**Hendrie:** I remember flat packs in about '64 or '65.

**Karp:** Yeah, flat packs were..

**Hendrie:** I think we made our first integrated circuit computer at Computer Control we started designing in '65 with rudimentary flat packs.

**Karp:** Right. And we had things going in both the TO-5 cans and in the flat packs. But the guy comes in and he pulls this TO-5 can out of his briefcase. And he says, this either a dual or a single 50 bit shift register. I said, "Get out of here." And he said, "There's a 50 bit shift register in this can." I said, "That's impossible." And of course they showed me how they-- at that time I didn't even know any MOS technology was. That was not very well known. So they told me a little bit about that and I was so impressed with that it just really, really blew me away. And so GME- when I'd come out to California, this guy, even though he wasn't working at Fairchild anymore, he was now working at GME, I, you know, we had become friends. So he was the one that really brought me into the fold there. And so GME hired me. In like, December of ’65 they made the offer. And I told them I would shoot for- to be out there in three months in terms of wrapping up everything and wrapping up my projects at MIT and so forth. By the time I got here, got out to California three months later, it wasn’t GME anymore. It was Philco Micro Electronics. So Philco had basically bought the company. And the interesting thing there is that when they came in to buy the company they bought out everybody’s shares at five hundred dollars a share. And these were shares that everybody had paid ten cents apiece for. So this was like the first big strike. Now, people didn’t have thousands of shares. My boss, who is actually still a very close friend of mine, had I think ten shares, or twenty shares. But, you know, five or ten thousand dollars at that point in time was an incredible..

**Hendrie:** That’s almost a year’s salary for you.

**Karp:** Well that was more than a- I mean you could put a down payment on a tremendous house in the Valley here at that time for that kind of money. So they had sold all their stock. Everybody had their five thousand dollars. And I think the top guy in the company ended up with about three hundred thousand dollars. And he went off and started a company called AMI at that time, which was here in the Valley for a long time. And I think it’s in Pocatello, Idaho now and it’s not a really well known company. It’s living dead now. But those kind of things were going on at that time and also General Instrument was starting up with MOS. So MOS was really starting to become important. Actually they built stuff . For years they really couldn’t get the stuff to work. It was very tweaky and the thresholds drifted all over the place and, MOS was far from a mature technology. But in the meantime, I believe the company existed by building these bipolar integrated circuits for NSA. NSA was using integrated circuits like crazy back at that time. And they kept the company going while they were developing all this MOS stuff. And they had one big project, which was a calculator chip. Not a calculator chip, but it was a calculator that took something like seventeen different integrated circuits. Each one ran at different voltages. I mean it was a real- this was- and actually they started shipping those calculators several years after I got there, and there were these huge boxes and it was nothing more than a calculator. It really wasn’t that, you know, special of a thing. It was ah.. I wish I could think of the company now that they built it for. Those kind of things were going on. One of the first things I got asked to do when I came out there was to build a clock generator that would run at the unheard of speed of- a four-phase clock generator that would run at the unheard of speed of ten megahertz. But these were very sharp clock pulses that were, you know, thirty volts. They weren’t like five volt things. They were thirty volt clock pulses where you could control the rise and fall time. And so we built this clock generator so that we could start building these four-phase circuits. And I actually wrote some papers in those days that were published. I don’t know if you’re interested in that kind of stuff. I have some copies of some of that stuff.

**Hendrie:** Oh, yeah. Sure.

**Karp:** Ah.. they might be interesting to you. I’ll get them before you leave today. But some very interesting things were discovered. Like the whole concept of bootstrapping using MOS was actually discovered in the work I was doing then. And no one even thought about filing patents on it at that point. I think at some point someone did get some basic patents on bootstrapping, but a lot of stuff got discovered just working with this stuff. At one point they came to me and said, “We’ve got this memory chip that we’re building for Bunker Ramo. It was a sixty-four bit memory. And it didn’t even have any decoding on it. It had basically eight wires going one way. It was an eight by eight matrix and so you energized the cells directly from the outside. And again, this was running at like thirty volts. They said, "We've been trying to make this chip and we just get zero yield. We just can't get them to work." So I took on that project and actually got those things- it turned out those things were working all along. It's one of those things where there's- there were so many kind of physical effects that were going on in MOS that people weren't understanding. In this case, it was you had these thirty volt circuits that were energizing these lines, and you were getting some overshoot because of inductance effects. And the overshoot was killing the device. I can't remember how I figured that out, but I figured that out at one point and I went out and I got these special diodes from Hew..

**Hendrie:** I was going to say, you take a low threshold diode and you plant the bloody thing.

**Karp:** Well these were- it turned out that you needed- you couldn't clamp them with- standard off the shelf computer diodes didn't work. They just weren't fast enough to- but HP had been making these ah.. I can't think of- they had made- been making these really exotic diodes. They were charging like fifty bucks apiece for them. And I remember going out and buying a handful of those, and they worked. And so within a matter of days, we ended up shipping five hundred of these chips to Bunker Ramo. And I remember the project manager coming in to thank us. I think we saved his job was what we did. They were putting some sort of a computer in a briefcase at that point. And without the semiconductor memory they wouldn't have been able to do it. Cores were just too bulky. So this was one of the very first semiconductor memories. So I'm now talking '67 timeframe with that.

**Hendrie:** That's fascinating. I think what we ought to do is take a break for a second and change tapes, okay?

**Karp:** Okay.

**Hendrie:** Let's see. You were at Philco, working on the Bunker Ramo contract. You were saying you were working on something else too. That was sort of just a quick project that you had to go solve a problem that they had no idea what was going on.

**Karp:** Right. Another project that we did was we did a dual two hundred bit shift register, a four phase shift register, and we went from masks- not even masks. We went from the design to finished parts, ready to ship to the customer, in something like five days. And we shipped parts to, this was for Wright Patterson Air Force Base.

**Hendrie:** For the military?

**Karp:** For the military.

**Hendrie:** Yes. Price was no object.

  

**Karp:** Right. Price was no object, but I can't remember why we got in that time thing, but I know they made a big deal of it and there was an article in Electronic News about this..

**Hendrie:** Oh, my goodness. About being able to do this?

**Karp:** Right. And and I remember that weekend, I don't think I slept at all that weekend. I was of course the project leader for that thing and dealing with everything from getting a call from the mask shop in the middle of the night that said, "Do you want mask two to be positive or negative?" <Laughs>. And so I remember that kind of stuff. I mean the processes were a lot simpler in those days. The MOS process..

**Hendrie:** Well you cut Rubies, right?

**Karp:** We cut Rubies, right. The MOS process only four masks back in that timeframe. So if you could process the stuff pretty quickly. Making the masks took most of the time. And I think we had kind of pioneered this technique for stepping and repeating on the masks themselves. So we would cut the Rubylith of a single cell and then basically make a whole bunch of copies and then just paste it together. So it was long before digitizing.

**Hendrie:** Yeah, before you did it on a screen.

**Karp:** Right, right. So I remember us doing the paper doll approach. Cutting out paper dolls to do those masks to putting them together.

**Hendrie:** Well that's very efficient, 'cause how else if you had to cut the Rubies for all two hundred bits?

**Karp:** Well I've got news for you. We did cut those Rubies for all those bits at Intel on that picture I showed you where we working on the 1102. That was all cut. There was nothing ah.. you know, every single transistor was cut on that thing.

**Hendrie:** Oh, my goodness. Well we'll get there in a minute. Fundamentally, you're an analog kind of guy and you're getting to understand MOS.

**Karp:** But actually I kind of skipped over that, but at one point I kind of switched into the digital world when I was at MIT at the instrumentation lab. When I got involved in all that circumvention stuff I had to become a computer expert at that point and understand memories; especially understanding, you know, memories, which at that time was all based on cores. So, by the time I came out to the west coast, I had all that analog background, but I didn't consider myself an analog guy anymore.

**Hendrie:** But you were faced with a circuit problem. You didn't have any problem going in and attacking it.

  

**Karp:** Right. I mean it turns out that when you look at the real key things that have been done in the semiconductor memories through the years, you need to know analog design. I mean you need to know how to design..

**Hendrie:** It is analog design.

**Karp:** Exactly, when you've got millivolts of signal and, you know, you've got differential amplifiers all over the place. So that background was actually essential for being a memory designer.

**Hendrie:** We're at '67. Is that where we are now?

**Karp:** We're in '67 and doing various projects there at around that time, I moved out of the R&D group at Philco and went into kind of an applications group. So I became more marketing and applications. I don't remember exactly why I made that move, but it seemed to me they were de-emphasizing the R&D things that were going on there. Although some very interesting things did happen during the time that I was there, including the very first invention of silicon gate was done in the group that I was in at Philco.

**Hendrie:** At Philco they did? Intel wants to say that it was invented, not at Intel, but at Fairchild, and then taken to Intel.

**Karp:** It turns out that Philco got a patent on silicon gate, and it was earlier than any of the work at Fairchild. But the patent was screwed up. The patent attorneys actually made some errors. And the patent was ultimately thrown out, but on technical grounds. There was some technicality with the patent itself. I don't remember all the details of it, and I don't know if this is something you want to get into with.. I can set you up with some more interviews if you want to <laughs> find out the real story of silicon gate. But there was that kind of stuff going on. I mean this was all stuff- there was no textbooks on any of this stuff yet. And even, through the first developments at Intel, none of these things existed in the colleges or in- the books hadn't been written yet. All the action was in the industry. People used to ask me, why didn't I go on and get an advanced degree. I said, "I did get an advanced degree, only not in a college." <Laughs>.

**Hendrie:** Well you worked on things that nobody's ever done before you're on your own.

**Karp:** So I kind of moved into somewhat of a more marketing applications role at Philco in '67. And in '68, I remember being asked to go to Japan to give marketing seminars in Japan. So that was my first chance to go there and that was in '68. But something major happened in '68 and Henry Ford, who was basically the head of Ford Motor Company which owned Philco. Philco had become assimilated by the Ford Motor Company and now it was Philco-Ford Micro Electronics, which to me, I thought I was going to work for this little startup and I ended up on the ground floor of the Ford Motor Company. <Laughs>. But it actually turned out to be a good deal, because even though I was only making thirteen thousand or fourteen thousand dollars a year by that point, I got a company car. And that was a really good deal with Ford that they actually gave company cars to thousands and thousands of people in their organization. So every year we got a brand new car. And you got to pick out what you wanted and all the extras you wanted on it and the colors and, you know, every year it was fun. You'd go into personnel and fill out this thing. And then the only thing you ever had to do was put gas in it. They did insurance. Maintenance was all taken care of by the company. That was a nice benny. I had to give that up when I left the company to go to Intel. <Laughs>. I had to buy my very first car when I joined Intel. So in '68 Henry Ford came out to have a walk through; look and see what his west coast division looked like. And I still remember to this day actually. Here's Henry Ford with like this whole coterie of vice-presidents with clipboards <laughs> and they were all wearing blue suits. <Laughs>. Blue suits and striped ties. And in fact I got in trouble because..

**Hendrie:** And California was even casual then, right?

**Karp:** I got in trouble, because I had come into work that day with a turtleneck on, and I was supposed to give a demonstration to Henry Ford. <Laughs>. And because I wasn't wearing a tie, they had somebody else come and do the demonstration. <Laughs>. I got yelled at. "How could you wear a turtleneck sweater for Henry Ford?" Well what happened that day was as they were walking around, he's the CEO of this huge company, right? And he's saying things like, "Well, gee, why do we have to have a separate division here on the west coast? Why don't we have it all- wouldn't we save money on Xerox machines or something if we had the, you know, if they were back east?" And people are furiously scribbling on their clipboards, you know, all these sorts of things. And within a few weeks of his visit, they said, "We're closing down the west coast, and we're moving everybody back east." Now they made that decision without checking with anybody as to whether anyone wanted to go. <Laughs>. As it turned out, out of the whole company, I think one guy went back. Everybody opted not to go. And at that time, they were telling me, "We'll give you a huge raise and you can have a second car." And I said, "Look, I just came out the west coast two years ago. I'm just not interested in going back to the east coast, and especially to a place called Bluebell, Pennsylvania." That just didn't..

**Hendrie:** Was that where they wanted you to go?

**Karp:** Right. It didn't interest me at all. So of course I had to start looking for a job. And so this was now early summer of '68 and I just started sending resumes out to various- and starting to have some interviews. Nothing really very exciting was happening until at one point, and this was in July, I picked up Electronic News, which at that time was the bible for the industry. Now it's nothing, but, you know, at that time it was the bible. And there was this little article that Gordon Moore and Bob Noyce have left Fairchild and they're starting a company. It didn't have a name yet, but they'd left and they were in the process of putting a company together. So of course I knew who Gordon Moore was, 'cause I'd met him. And Noyce was famous, you know. So, I made a note of that little article and kept my eyes open, and a week or so later there was another article. And it said they've now formed the company and it's called Intel and they're gonna be at 365 Middlefield Road in Mountain View. So I assembled my resume and all the various application notes that I'd written, papers I'd written, and I put it all in a big manila envelope and sent it off to them. And I don't know, I guess within a matter of a few days, I got a call from Les Valdez. And the message I got was that Leslie Valdez called. And so I thought it was a woman.

**Hendrie:** Yes, exactly. You didn't know Les.

**Karp:** Right. So anyway he calls and he tells me to come in for an interview. So I had an interview at Intel. It was the toughest interview I'd ever gone through in my life. It was incredibly tough. And I just thought I had done so horribly. I just couldn't believe that I would ever hear back from them again. I had to..

**Hendrie:** What did they make you do?

**Karp:** Well first of all, it went on for hours and, you know, and I had to interview with Ted Hoff and with Bob Noyce and with Andy Grove and, you know, I had interviews with all these people. And all these different questions. And I talked a lot like we're talking now, but then they'd give me problems, you know? "What do you do if you have this kind of a flip flop and this happens?" And so they started giving me tests. And I just I froze when they gave me these tests. And I just didn't think I'd done very well. So, weeks went by. I think the company was incorporated in the middle of July of '68. And so this this was within days that they were interviewing me. And I'm still basically going around, trying to-- I had a couple of potential offers at the time, but nothing really very exciting. And I had to go to Huntsville, Alabama, to teach a course, a one-week course, on MOS to a bunch of NASA scientists.

**Hendrie:** Okay.

**Karp:** It happened to be during the week -- of the Democratic Convention in 1968 in Chicago, which was the real big deal with the riots and police and, you know, the yippees and so forth. So, I remember very clearly being in this hotel room in Huntsville, Alabama watching all this stuff on TV on a nightly basis and then going in the next day and teaching these NASA scientists how to design MOS circuits. I get a call, actually, it was my wife that called me, and she said, "Les Valdez called and he wants you to call him at home." So I called him. And he said, "When are you coming back?" I said, "I'm going to be back on the weekend." He says, "Can you come over to see us on Monday?" He says, "We want to make you an offer." So I go over to Intel Monday morning, I meet him at this restaurant in Santa Clara. By the way, I should mention, at this point I have no idea what business they're in. They were so secretive they wouldn't say anything.

**Hendrie:** All you knew is that former general manager of Fairchild and the head of R&D at Fairchild were forming a company and you knew they were both very smart people. So, maybe they do something interesting.

**Karp:** So I just knew, you know, whatever they were going to be doing was probably going to be okay.

**Hendrie:** Exactly.

**Karp:** And I still really didn't know what they were doing. So, we meet at this restaurant. Now, remember earlier I told you about the Philco having the shares that got bought for $500.00 apiece, right?

**Hendrie:** Exactly.

**Karp:** Just this -- that's going to tie now back to this story. So that's the only thing I never know about -- that's the only thing I'd ever heard in my life about stock options was that. And my standard was 10 shares, 20 shares, something like that, right?

**Hendrie:** Right.

**Karp:** So, I go to lunch. So, I go to lunch with Vadasz, Andy Grove and Gordon Moore. The three of them take me out to lunch.

**Hendrie:** Oh, my goodness.

**Karp:** And, they make me this offer. They start off very apologetically on the offer. They said, "Our policy at Intel is that, we don't give raises. We know people will want to come here. So we don't give raises. So, we're going to just offer you your current salary", which was $16,000. And I said, "Okay." I really hadn't been expecting a raise at that point. They said, "But we're going to give you a stock option." And now I'm waiting now for them to tell me about the 10 shares. They said, "We're giving you a stock option of 1,000 shares." Well, I almost fell of the chair, of course.

**Hendrie:** Of course you did.

**Karp:** And I had a real hard time, you know, controlling my excitement, but I just kind of said, "Well, that sounds good. Let me think about that." And then about 10 seconds later, I said, "I thought about it. Okay." So, at that point, Vadasz said, "Well, if you have some time after lunch, I'd like to take you back to the office and show you what we're doing." He wouldn't even mention it in the restaurant. He wouldn't even tell me -- even at that point, he's hiring me as a engineer and I don't even know what I'm going to do. So, we go back to the office in Mountain View, which at that point in time, they weren't even occupying the building. They only had a suite of offices in the front of this building. And Union Carbide was still in the back of the building. They had some sort of semiconductor manufacturing thing going on back there. And, this building is still there in Mountain View. I don't know if you've ever actually seen it. It's one of the old style tilt-up buildings that were all over the valley in the '60s. And there's still activity going on in that building. But, not Intel. They sold the building 20 years ago or more. But they were in offices. And they had a conference room and maybe a half a dozen offices in the front of the building. And, at that time, there was Noyce and Moore, Grove, Vadasz, Ted Hoff. I don't even think Ted Hoff had started yet. I think he had been hired, but may have still been at Stanford. I know his employee number was number 12. Mine was number 20. So, there weren't that many people there. The day I started was actually their first real day of operations when they had- Just the weekend before I started, Union Carbide cleared out of the back of the building and allowing Intel to start moving in. So, they moved in with all 20 employees at that point. Me and another guy started, another guy that had also worked with me at Philco, and he was number 21, we started there on a Monday I remember.

**Hendrie:** On the same week, yes.

**Karp:** It was just after Labor Day in September. And so, at that point, the company had 21 people. And when he brought me back to the office, I kind of skipped over that. He brought me back to the office and he says, "What we're going to do is a 256-bit memory. And you'll be the designer on that." And I said, "Oh, that's cool." Because as to what I didn't know was during all this time, through the interviews, that was the thing that interested them the most of anything in my background was the fact that I'd done this 64 bit memory. I actually had had, you know, real memory experience. And, I think that was ended up really mostly --

**Hendrie:** It was a 64 bit -- it was bipolar.

**Karp:** Vadasz told me, uh.. no, that was MOS.

**Hendrie:** Oh, it was MOS? the 64 bit --

**Karp:** Yeah. That was the -- 1967 was MOS. Vadasz told me actually years later that he interviewed 300 people for that job, and I was one of the first people. I was one of the first ones that he interviewed. And, it was -- you know, everybody thinks of Intel now as this huge behemoth of a company. But, they weren't hiring lots of designers. I mean, it was a small company, but they were going to do everything. They had not just the design, but they had all the marketing and sales and manufacturing, the wafer manufacturing and the assembly and tests. All of it was all in this- this one little building.

**Hendrie:** Yeah, exactly.

**Karp:** And so, I was, as I said, number 20, and I was the first MOS designer. They also had a few people they'd hired to do bipolar design. But on the MOS side, I was the first one they hired. The second one who came in was number 200. So there were, between me and the second designer were 180 other people, various types of technicians and factory workers and process engineers.

**Hendrie:** Well, they clearly weren't betting their rear end totally on MOS yet.

**Karp:** Right.

**Hendrie:** Even though they knew that's where they were going. Because I remember they did bipolar circuits very early because -- I never knew why.

**Karp:** Well, when they started, they started both the bipolar and the MOS at the same time. They really started to go in both directions, although I think clearly the MOS was really where they saw the future. But they also knew they needed to get products out quicker on more established processes. And it was probably a good thing they did that because, otherwise, they wouldn't have had anything to sell for a long time because it took a long time to get that silicon gate process working. And that was the other thing when we went back to the office. He told me, "We're going to do this memory. And, oh, and we're also going to do it with this technology called silicon gate." And I said, "Oh, yeah. I know all about that." And he looked at me like, "You know about silicon gate? How would you know about silicon gate?" So I explained to him what I knew at that point. And that had never even come up during --

**Hendrie:** He probably didn't even know that Philco had --

**Karp:** Right. And that had never come up during the interview process because that was --

**Hendrie:** You weren't hired because you knew what silicon gate was.

**Karp:** Right. Right.

**Hendrie:** Oh, wow. Okay. Fascinating. So, the first thing you're going to do is? They're putting you right to work designing --

**Karp:** Well, the first thing I needed to do was hire people because, okay, they hired an engineer. But, you know, you need somebody to lay out the chip. So Vadasz is like, "Well, do you know anybody?" So, I ended up bringing in technicians, I brought in this woman that I knew that came in to do the chip layout, and I also brought the mask girls in, because I knew them from Philco. So we brought a whole bunch of people in that had been at Philco, which worked out great because there weren't that many MOS companies around at that time. And Philco had just gone belly up on the West Coast.

**Hendrie:** Right. And these people had experience doing --

**Karp:** They were available.

**Hendrie:** -- layout for MOS? They knew something about it.

**Karp:** Right.

**Hendrie:** They'd worked on MOS circuits. I mean, they could be trained from bipolar to MOS.

**Karp:** But we had an instant group that could do the layout and do the masks all at once. So I brought them in. And we started designing the chip. Now, designing an MOS circuit in those days is not like -- we didn't have any computer programs. And we certainly didn't have any kind of transient analysis type of -- they had no- there were transient analysis capabilities available in those days. There was a program called Scepter that the military people used. But as far as, you know, it had no MOS capabilities. So there really was nothing for transient analysis. Even for the static type analysis there was nothing. We had to develop it ourselves. So the first computer program that we had was one that I put together that Andy Grove helped me with. And I was sitting in Andy's office and we took his equations out of his book. He had written this semiconductor physics book in, uh.. 1968.

  

**Hendrie:** That's right. He was a physicist, wasn't he?

**Karp:** Right. So had written the classic tome on MOS physics. And so we took his equations and he showed me how to program in Fortran. He just showed me what -- you know, he said, when you -- he said, "This is what multiplication looks like and this is what addition looks like and this is what subtraction looks like." And so we just took those equations and just made them into a bunch of punch cards. And I'd go up to this service bureau up in Palo Alto. Nobody had IBM computers in their shop. You, you know, you had to --

**Hendrie:** You went to a service bureau.

**Karp:** You had to go to a service bureau.

**Hendrie:** Oh, yeah. You couldn't afford one.

**Karp:** So I had put together this whole bunch of punch cards and went to the service bureau and I'd stay there while they'd do these runs for me. And basically what we'd do is I'd just get stacks of numbers out of this computer. And then I would take these numbers and I'd have these big pieces of graph paper, like 11 by 18, 11 by 17 pieces of graph paper and I would take all this data and just plot it on these graphs. And basically these would be transistor characteristics. So, Grove would say, "Well, this would be the maximum oxide thickness and the minimum", you know, so we'd set up various tables of parameters and then we'd just basically develop the transistor characteristics based on those parameters. So we'd have a transistor that would be representative of the slow process and a transistor that would be representative of the fast process. And then I would just draw load lines on these (laughing) drafts to design these circuits.

**Hendrie:** How?

**Karp:** It was all done by hand like that. So the 1101 was completely done by hand.

**Hendrie:** It's all actually graphical.

**Karp:** Yeah.

**Hendrie:** I mean, the actual design is graphical.

**Karp:** Exactly.

**Hendrie:** You think the, you know, well, it isn't any different. I mean, what did you do when you were designing transistor circuits 10 years ago? Did you --

  

**Karp:** Well, I don't know if I designed any transistor circuits 10 years ago, but I know what they do now on computers is that it's, uh..

**Hendrie:** Oh, yeah. But, I mean, yeah. People used load lines on transistor characteristics.

**Karp:** Yeah. Now, but see, this was all static circuitry, so it worked really fine for that. And, there were no clocks on this thing. So --

**Hendrie:** There were no clocks?

**Karp:** No. This was just a static RAM, so -- the 1101, so it was all basically power dissipating ratio type of inverter stages. So, you had to design all the inverters and they had to figure out the time constants. And it was all done by hand. It was all hand calculation. But there was one big screw up. And that was because -- again, because you really had no no computer means of analyzing these things. There was a race condition that would occur when you'd select a cell, it would be a race between the cell you were deselecting versus the cell you were selecting. And so what would happen is that the bit lines would get dragged down by the unselected cell while you were selecting the new cell, and so you'd actually flip the information. And so, we discovered that problem the very first time we got working 1101s, we already knew -- Vadasz and I already knew we had that problem.

**Hendrie:** You knew there was a conflict here of timing (inaudible).

**Karp:** Right. We already knew about that, but we knew that at least in terms of being able to test the integrity of the circuit to know that everything was hooked up, we could write the test program in such a way that it wouldn't be sensitive to that issue.

**Hendrie:** Yes. Of course.

**Karp:** Just by using a different pattern of information.

**Hendrie:** Yeah. You'd use a pattern where it wouldn't be -- the aligns wouldn't be adjacent when one is going up and the other is going down.

**Karp:** Right. So we had this test pack, we knew it wouldn't pass certain test patterns, but when the green light started coming up on the tester, the place went crazy. And I remember the operator, the receptionist was also the company operator. Every time we got a new green one, she'd be coming, "And now there's seven good die, and now there's eight good die", you know, and so the whole place went nuts. And Grove said, "We're all going across to the Wagon Wheel to celebrate." I remember sitting at the bar at the Wagon Wheel with Grove on one side and Vadasz on the other side and everybody is celebrating and happy and I'm sitting there with this -- Grove is saying, "Why do you look so glum?" I said, "Andy", I'll use good language for this, "Andy, the thing doesn't work." And he said, "Tomorrow you can worry about that.  Today these people need a reason to celebrate today."  (Laughing).  So, we did worry about that.  And so that led to now we're at the summer of '69.  And, it's a Sunday.

**Hendrie:**  So it's taken you a while to design this thing.

**Karp:**  This has been a year -- a year has gone by now.

**Hendrie:**  A year has gone by?

**Karp:**  A year has gone by.  We're in- it's the summer of '69 and Intel's shipped a few bipolar -- we still never shipped an MOS memory and so it was really pushing hard to get to that point.  Vadasz and I are in the conference room in the front of this building on 365 Middlefield.  We got a portable radio in there and we're listening to the man land on the moon.

**Hendrie:**  Oh, my goodness.  Oh wow.

**Karp:**  And so what -- we're in there with Xacto knives putting load devices onto all the bit lines with Xacto knives on the Ruby right there in the conference room.  And, that afternoon we fixed up the masks.  They shot them out -- went out to the mask shop the next day.  And within a matter of days, we had fully working 1101s.  And it was all at that same time as the man landing on the moon.

**Hendrie:**  Isn't that something?  So the solution to the problem was just -- yeah, putting some --

**Karp:**  Right.  You needed to be able to recover those bit lines.

**Hendrie:**  Exactly.  Bring some load on them.

**Karp:**  Right.

**Hendrie:**  That's fascinating.  So, Intel was really -- I mean everybody pitched in to do everything.  I mean, this was not --

Joel Karp:  Bob Noyce used to come in when we were getting ready to- before you would actually cut the Rubies, you'd draw the composite.  And you drew everything on the composite.  You drew every line.  Not just one cell and then replicate it, you actually drew every cell.  And Noyce used to come in.  And then you'd color everything to make sure everything is there.  You'd color code everything.  And Noyce used to come in and work with the crayons along with us.  You know?

**Hendrie:**  And color the composite?

  

**Karp:** Color the composites.

**Hendrie:** All right. That's great. Okay. That's pretty interesting. So, you got it so it was working? What happens next?

**Karp:** Well, then the next thing that happens is -- oh, I actually skipped over something here.

**Hendrie:** Okay.

**Karp:** Because during that whole year, I wasn't working full time on this 1101. It was in the spring of '69 that the guys from Control, uh.. from Honeywell came out to see us to talk about this- this weird idea they had for dynamic memory.

**Hendrie:** Okay.

**Karp:** And, uhm.. they -- we already knew we were in trouble because -- at Intel because we had a 256 bit memory. We didn't know how to get to a 1K memory. We didn't know how to do it.

**Hendrie:** Too big a chip?

**Karp:** Right. It would not have been economical.

**Hendrie:** Yeah. You worked IBM with the --

**Karp:** To make the 1K. And --

**Hendrie:** You'd have to charge too much and (inaudible).

**Karp:** You couldn't -- technologies weren't shrinkable in those days like they are now. We were working with eight and ten micron wide lines, which is quite a bit bigger than what we have now. Now, we're sub .1 microns. And so we really didn't exactly know what we were going to do next. And actually, even some of the economic incentive for doing the memory had gone away in a sense that the core memory industry, which was the competitor at that point, you were competing with a totally different technology, not with other companies. And, they'd been able -- the original target point for the 1101 was five cents a bit, which would have been basically $12.50 for a chip. And Intel could have made tons of money on these $12.00 chips.

**Hendrie:** Okay. They could yield them nicely as well -- significantly lower cost.

  

**Karp:** Right. And, of course, you can see with these small wafers, you don't get that many. So you couldn't -- $12.00 was a really good price point for that chip. Well, it turned out at that point that they were going for the nickel a bit, that's where the cores were. Well, as soon as the core memory industry sensed that the semiconductors were kind of knocking at their door, they lowered their prices. So the new target became a penny a bit very quickly, and you couldn't do that with the 1101. That was a $2.50 chip. They couldn't make money at that. So, you knew you had to get --

**Hendrie:** You had to do something.

**Karp:** And if you laid out a 1,000 bit static RAM at that time on those kind of design rules, it wouldn't be economical. It just wouldn't have been economical.

**Hendrie:** So, now what was the -- in the 1101, what was the minimum features? What was the gate width? Do you remember?

**Karp:** It was either eight or ten microns, probably ten.

**Hendrie:** All right.

**Karp:** Now, so we knew we had a problem as far as what do you do next to get to the next level. So the Honeywell guys come in and they talk about this three transistor cell. And, they left.

**Hendrie:** Do you remember who came in? Was it Jordan and Regitz?

**Karp:** Regitz came. I don’t remember -- I don't think Jordan was there. I think it was Regitz and maybe one or two other guys, but I don't think Jordan was there at that point. And we didn't say much while he was making the presentation. And we told him we would get back to him. And he was going around the whole industry. He went everywhere.

**Hendrie:** Oh, absolutely. That was the strategy.

**Karp:** He went everywhere.

**Hendrie:** Because we knew we had to get somebody else to make it and if it became a standard, we'd win because we would know how to build the memories from it long before anybody else ever figured it out.

**Karp:** Exactly.

**Hendrie:** You know, we could easily be a year, a year and a half, ahead.

**Karp:** Well what happened was, after he left, Vadasz and myself and Ted Hoff, got in an office to talk about it. And, you know, it was like, is -- is this thing real, you know, will this thing really work?

**Hendrie:** Now, nobody had proposed doing a dynamic memory at Intel up to this point?

**Karp:** Up to this point.

**Hendrie:** Okay. So the idea came in through the front door?

**Karp:** Right. And, I think we were too busy trying to get a technology to work and --

**Hendrie:** Oh, of course. You had tons of stuff on your plate and you didn't quite yet know that you -- that the 1101 just was not going to make it in terms of being a core replacement.

**Karp:** Right. And I'm still the only engineer. We still don't have any other engineers at that point. So, we sat there and we studied it and Ted Hoff figured out very quickly a way to get around the major problem that that cell had and that's really what led to the 1103. But the cell that Regitz had proposed was a three transistor cell and it had one word line and two bit lines in the cell, so it had a total of three transistors, whereas for example, the static device had six transistors. So, you could build that in a much smaller area. So, that was key. But, there was a known problem right from the start because of the fact that you had to access it through a single word line, you had to develop a very special analog kind of a signal for that word line to be able to sense the cell. And I think we ended up calling it IVG, an intermediate voltage generator, which is in that paper that I've given you a copy of, which also ended up being a problem on a graduate EE final at Stanford. They put that circuit on there and they asked the students how it works. (Laughing). And I don't know if any of them even figured it out, either. But, anyway, we felt that there were very tight margins that would be needed to make that cell work. But we thought it was workable. And so we called Regitz back and said, "We think we can make it work." And, he said he'd gone everywhere in the industry. He said we were the only ones that understood what he was talking about. And he told us that at that point, and they gave us the contract. And so, basically, Intel was all alone doing that. And so we started the 1102 design at that point. Now, I'm still talking spring of '69 while I've designed the 1001, we'd gotten it ready, gotten the masks, but basically, they were fighting technology issues all through the winter, and in spring of '69.

**Hendrie:** You mean (inaudible).

**Karp:** Yeah. This was the time when Gordon Moore came up with the key invention that made silicon gate work. It was all in that time frame. This was the idea of, well, what happens with polysilicon is that it's very brittle. And so, when it ran up and down steps, it would tend to crack. I'm sorry. The polysilicon wouldn't crack, but because the polysilicon had such sharp edges on it, when you laid metal down over that, the metal would crack when it went up over the steps.

**Hendrie:** When it went over a polysilicon.

**Karp:** Right. So you'd get a micro crack in the metal. And so, they really couldn't get any circuit integrity. They did a great job with when you made tip parts, you know, big transistors to check your transistor characteristics, those worked fine becausethey were wide metal busses and everything. But when you actually went into the integrated circuit --

**Hendrie:** And you're trying to make everything small --

**Karp:** It wouldn't work. So, the breakthrough was a technique which was an annealing technique that Gordon Moore came up with. And basically his thought was you've got this polysilicon that has all these sharp edges. If you can heat it up, not to the point where it melts, because if you melt it, it will lose its integrity. But right before it melts, it would soften and the edges would just round a little bit. And if you could find that critical temperature, it would be like heating solder, but only to the point where it just starts to melt, I mean right before melting. And, that was the solution to making silicon -- the whole thing just came alive at that point when they put that annealing step in there.

**Hendrie:** So, before you lay down the metal, but after you've put down the polysilicon, you go anneal it to just the right temperature.

**Karp:** Just the right temperature. Right?

**Hendrie:** Isn't that cool? Okay.

**Karp:** And that was THE major secret at Intel for years, because people all over the industry were trying to make silicon gate and no one was able to do it. And in order to keep that thing, they even disguised it on the run card. So even if someone got an Intel run card, they wouldn't be able to understand that step.

**Hendrie:** Is that right? Oh, wow.

**Karp:** And, I think it wasn't 'till, you know, a long time after that when people actually left the company and brought the technology outside that people were able to make silicon gate successfully. Because it was clearly a breakthrough at that point. So that was all going on in that same timeframe when, you know, when we were starting to look at this DRAM.

**Hendrie:** So, you're not so much involved in the 1101

**Karp:** At that point, I wasn't- I wasn't that involved with it.

  

**Hendrie:** Because they're trying to yield it now and that's not a circuit problem, it's a -- they're in the throws of the process?

**Karp:** Right. So I'm already moving ahead and starting to look at these dynamic memory cells. And so, the first thing I'd had to do there was build a test chip. And I built two circuits on the test chip, but Honeywell only knew about one of them. And, one of them used the cell that was ultimately became the 1102 and the other one was the cell that became the 1103, which was a much simpler circuit. The 1103 is a much simpler structure than the 1102. Although it's got an extra line going through the cell, the process had actually evolved to the point where it actually made that cell even smaller than the 1102 cell, even with the extra line. That's why the 1103 ultimately became the production device. But, it didn't --

**Hendrie:** It didn't make the cell smaller. It wasn't a matter of more contacts (inaudible)?

**Karp:** It was the introduction of the buried contact to the process that allowed them to do the 1103 cell.

**Hendrie:** Oh, okay. I was going to say.

**Karp:** At the time of the 1102, it was basically a four mask process and you didn't have a buried contact. So, the only way you could connect a gate to a diffusion would be to have a metal contact in the diffusion and then run the metal into a contact in the gate. So, that's how all contacts are made. The buried contact allowed them to actually, using another mask, allowed them to connect poly to the diffusion directly. And, so that was another innovation that was coming in at that time. So we built this test chip that had both types of cells on it. But the only one that at that time that Honeywell was interested in was, of course, you know, their 1102 cell.

**Hendrie:** Right.

**Karp:** Well --

**Hendrie:** Now, did you deliver these to Honeywell?

**Karp:** These were eight bit test chips, 16 bit test chips. I'm sorry, they were 16 bit chips and it was the 0008. And so we built the -- at that time, they were just getting the silicon gate thing to work and they were getting ready to run the 1101. And then we had that little thing where we did the devices. So I was kind of being pulled into the 1101 project for those sorts of issues for the design related issue. But I was spending most of my time working on the DRAM stuff at that point. We had to build a special tester and so we made those chips. We couldn't get them to work. We couldn't get those --

**Hendrie:** These are 16 bit?

**Karp:** We couldn't get those 16 bitters to work.

  

**Hendrie:** Wow. Is it just one row of cells?

**Karp:** It was a four by four. We just couldn't get them to work. And so, we were sending some back for Regitz and his group to look at because they had different types of test gear than we had. You know, it just wasn't working. And we didn't have the diagnostic tools. You know, we didn't have computers to figure things out.

**Hendrie:** I understand. But they weren't working and you didn't know why.

**Karp:** Well, it was always some reason why we thought it wasn't working. So, the process guys would say, "Oh, the punch through was really bad on that run and, you know, it had this process parameter that was wrong or this process param." So we always thought we had some, process parameter that was --

**Hendrie:** I think we better --

**Karp:** Go to another tape?

**Hendrie:** Yes. One thing I had forgotten to ask you when you were going on in the discussion was you had indicated that when Bill Regitz showed up with this dynamic RAM, three transistor dynamic RAM proposal for -- to see whether Intel was interested in working on it and building it, that you then went, you know, went back and started talking about this idea. And I know you eventually got another idea which was a competitor to the 1102 which turned out to be the 1103 cell. Could you just tell us a little bit about the sequence of events as you remember them that sort of wandered through and ended up there?

**Karp:** Okay. So, after Regitz made his presentation to us, then as I- as I mentioned, Vadasz and I and Ted Hoff sat there and, you know, and started discussing it, it didn't take us very long to kind of zone in on the real central issue with the 1102 cell which was the idea of having to make this kind of analog signal. And, of course, you know, in today's MOS technology, those kinds of circuits, really wouldn't be very difficult to do. But in those days, you just didn't have the control on the process that you'd like to have to do analog type things. So we recognized that having to have this intermediate voltage generator for the word line on the cell was going to be a real tough design task. But we convinced ourselves that looking at the process and we looked at how the process varies and so forth and we convinced ourselves we could make it work, that it was designable. At the same time, Hoff said of course if you had a separate read and write line going into the cell it would be a lot easier. You wouldn't have to have that and that was clearly a good solution. The only problem was, and again we're looking at us taking a snapshot at a point in time, if you didn't change the technology, if you used the same exact technology, then the 1103 cell would by definition be bigger than the 1102 cell because it had an extra line running through it, right? So it would have to be bigger than the 1102 cell. So, that was the thing against it at that point. The real thing that swung things later on in favor of the 1103 was the introduction of the buried contact, which allowed you to then make the 1103 cell in actually a smaller space than you could make the 1102 cell. With the 1102 cell, you had two transistor gates. You had three transistors. One was the word line, which connected directly to one gate. Then you had to connect the, for the storage node, you had to connect the diffusion area of an access transistor directly to a gate. So the only way we could do it in the 1102 cell was with a full-blown, contact, what we called a butted contact at that time. And that took a lot of space. When the concept of the buried contact came into being, which was actually shortly thereafter, and then you took another look at the 1103 cell, you could make the 1103 cell smaller than the 1102 cell. Of course, what also I haven't said here was if you then said, "Well, what if we apply this technology to the 1102 cell?" Guess what? The 1102 cell would still be smaller. But things don't work that way in this industry. You're always dealing with, you know, you're taking a new snapshot in time. The 1102 already existed. No one was even considering totally redoing the 1102 with the buried contact and going back through that route. Once the idea of the 1103 cell came, it was so simple. It was so easy to make. It just made sense to go that way. But going in that direction was -- I kind of jumped ahead of the story because at the point we're at, where we're dealing with these test chips, we weren't thinking along those lines. In fact, the test chip had an 1103 cell that was built -- you know, the process was exactly the same as the process for the 1102 cell. So the 1103 cell was actually larger than the 1102 cell in that test chip.

**Hendrie:** Okay. Is the 1103 cell sort of the obvious alternative if you add another line?

**Karp:** Yes.

**Hendrie:** I mean, you know.

**Karp:** Yes.

**Hendrie:** That's just --

**Karp:** Right. You have to be able to isolate the reading and the writing to get away from having to put that intermediate level type signal on there. I mean, what I had to design was a signal generator that when you're reading the cell, put out a voltage that was just above 2VT. Just enough to be able to let the cell pull the bit line down enough to be able to read it. In the 1103 case, you had full level signals available for both reading and writing. So not only did you avoid that really tricky design issue, but you also had a much faster cell because you were able to make the cell read much faster because instead of having a signal that was just a few tenths of a volt above 2VT, you had a full level signal going into the cell to be able to read it. So, everything was -- the 1103 had far superior characteristics. But at that point in time, the 1102 was a smaller cell. And the entire philosophy at Intel at that point was speed doesn't count. We're already so much faster than the core memories, that doesn't matter. And, you know, they thought having 300 nanosecond access times and 500 nanosecond cycles and so forth, that that was acceptable at that point.

**Hendrie:** Yeah.

**Karp:** So, this small cell was the answer. And we went down that path. Well, again, we still don't have the things working, right? So, now we're in the summer of '69, struggling trying to make these things work and, at the same time, now we're back on the 1101 because now we've got the process fixed. And now we're --

  

**Hendrie:** And you want a product to sell.

**Karp:** And now we're just discovering that the 1101 doesn't work because of this problem I talked about earlier. So this was the, again, the summer of '69. And lots of stuff happened that summer. We went to the moon, we fixed the 1101 and within about two weeks, they built about 600 of these things after fixing the masks. And so I was asked to take a suitcase full of these things back to the East Coast and go directly to the distributors and I gave a speech in front of all these distributor salesmen and showed them the part, and talked about the wonderful new world of semiconductor memories and so forth. And left the 1101s with them and then drove down to Framingham to see my buddies at Computer Control. So I get down there and they're all grinning like Cheshire Cats. “What's going on?” “Come in the lab.” “We've got something we want to show you.” I go in the lab and they got the thing working. How did they get it working? Well, again, there was some very subtle things going on in those days. We had built this homegrown tester at Intel. I think it was actually the guy whose picture I showed you earlier, he built the tester for me and we called it a T1 tester. And, uh.. you know, I’m not sure now. We had -- everything was Ts. We had T1s and T2s. Anyway, he was building the tester for it.

**Hendrie:** He built the tester.

**Karp:** But it was basically a tester that had a bunch of knobs on it. And, you know, there were no digital controls or readouts or anything. It was like scopes and knobs. And, so, I would sit there all day long turning knobs trying to find some place where the thing would work. And, you know, I could start to see some kind of activity at a very certain voltage and a very critical timing. But, you know, you couldn't say it was working because you can't say something works at 10.82 volts and doesn't work at 10.83 volts, that it's a --

**Hendrie:** That doesn't count.

**Karp:** So, I'm sweating over our little tester and I can't get it to work. I go back to Boston, show up there and he takes me in the lab. Alright, it's working. Well, what happened? Well, it turns out the tester they had was -- they had a tester that they'd adapted from their core memory testers. And so they had degrees of flexibility on their timings that we just would -- we would have never even dreamed at Intel of having to have those kinds of levels of flexibility. We were learning. We were learning. And, it turned out that there were two main clock signals that you ran into this thing. And I would always have the reference edge and I would always start delaying the other clock. But I could never move the second clock in front of the first clock because the first clock was the reference. Well, on their tester, they could move everything every which way.

**Hendrie:** They could move anything anywhere.

**Karp:** Right. And it turned out that what you needed was a couple of nanoseconds overlap between those two signals and it came to life.

**Hendrie:** And it all came to life.

**Karp:** So that was a good day, delivering the 1101s and finding out the 1102 1103 is working. And then the next day was even better. The next day I flew back to California and it turned out that the other thing that had gone on the same weekend was Woodstock. (Laughing). So we had the landing on the moon, we had Woodstock and all these big rock bands from Woodstock were all on the same plane with me and I got to hang out with all my heroes on the way back to California. So that was kind of, you know, I'll never forget that. This was in the summer of '69. Then the work started. Then the work started because now we've got to design this thousand bit chip. And I still don't have any kind of computer programs that, you know. Well, actually, Ted Hoff had come up with a very bare bones kind of -- in fact, we were running it on a PDP-8 or something like that, some little mini computer. And it was a very bare bones kind of analysis program with -- didn't have any kind of capacity of overlaps, didn't have any kind of -- didn't have any subtle effects, didn’t have any second order effects. But it was all we had. So that's what I used to design this thing. So we design it -- we get the first chip out and we decided that we wanted to present it at Solid State Circuits Conference, which now would be February of '70, Right? So, we're in the summer of '69, we're really only now starting the design of the chip. And we get the chip out. We got it out in time for Solid State Circuits Conference, at least time to take pictures -- at least at a point where we could take pictures of it. I don't believe it was actually working as of the time of, uh..

**Hendrie:** Yeah. Solid States Circuits Conference is a show. The pictures Intel. It isn't a hardware conference.

**Karp:** Right. Well, there were several major problems with the chip. One was, again, Andy Grove was -- he's the keeper of all the parameters for the MOS device. He's Mr. Physics there. So he tells you what the design parameters are. He says this is what the threshold variation's going to be. This is what the junction depth variation is going to be. This is what the poly resistance. Poly resistance was a very key parameter.

**Hendrie:** Oh, yes. I remember.

**Karp:** Because the word line, the entire word line for this memory is just poly, right? And so in order to, there was all sorts of circuits on there to, you had to worry about time constants because you couldn't turn on the, we called it a column amp. Now they call it a sense amp. You couldn't turn on the column amps until the signal had fully propigated down the length of the word line because if you turned it on too early, then some cells wouldn't have a good signal. So, Andy had given me parameters for the polysilicon. And the maximum resistance was 50 ohms that he had given me. Well, so the design would have been okay for 50 ohms and it would have met the parameters. But the actual silicon that came out was more like 200 ohms.

**Hendrie:** Oh. They couldn't make 50 ohm poly.

**Karp:** Exactly. So that, of course, meant that you could get in there and kind of make it work, but the time constant on the word line was just horrendous. It was just too slow.

**Hendrie:** Yeah, because it's a distributed R, a distributed C.

  

**Karp:** Right.

**Hendrie:** It's like a delay line.

Joel Karp: So we figured out the solution to that, which was to re-lay out the chip and put the decoder in the middle so you get a factor of four difference on those time constants immediately. And we never patented that, by the way, and that as -- you know, those are the kind of things we were coming up with, essentially breakthrough ideas all the time, none of which we were patenting at that time.

**Hendrie:** So you drive it -- yeah. Exactly. You put the decoder in the middle and you drive --

**Karp:** Right.

**Hendrie:** -- either way, rather than from the edge.

**Karp:** So that gives you a quarter of the time.

**Hendrie:** Yeah, exactly.

**Karp:** Then, there was another problem with the chip. And, again, we couldn't see it at Intel, but they could see it back at Computer Control, because they, again, had very sophisticated test patterns that they'd used for core memories. And they were just throwing all these sophisticated core memory patterns at the device.

**Hendrie:** Oh, yeah. They used to shmoo core memories to find out the center of the operating region for the whole thing.

**Karp:** Right.

**Hendrie:** I mean, it was very sophisticated stuff.

**Karp:** Right. And so what they were doing is they were going in there and they were just banging away on certain cells and then jumping to other parts of the memory, you know, doing these kinds of tests which, of course, we had no way of doing those kinds of tests at Intel. But they found a sensitivity which looked like all the cells around the edge of the array were failing. And, when you ran these kind of patterns. So when you ran these kind of very complex patterns, the chip failed. And it took us a while to figure out what that was. Well, that was was injection going on, was actual injection of carriers by forward biasing portions of the device, just overshoots. Again, I was back to overshoots, the same thing I'd had at Philco two years before that. Well, the solution to that was to put a substrate bias on the chip. So the substrate, instead of -- this was P channel at the time. So, the substrate would -- you'd put it I guess had a negative potential, whereas now with end channel, you put the substrate on a positive potential.  So, that took care of the problem by biasing the substrate.  Well, how do you go ahead and -- you know, do you just add a power supply to bias the substrate.  Well, sure you do.  The only problem was, we were in a 16 pin package and we'd used all the pins.  So, that was going to be a little difficult to put a substrate bias on it.  Right?  Well, I had discovered by accident, and the accident was I'd by accident grounded the- the DIP packages were ceramic packages with a metal lid.  And, I had grounded the lid of a -- at one point with a scope probe of- of, uh.. by accident, and I'd burned up the device.  So, I realized that the lid was actually connected to one of the pins on the package. I'm sorry. The lid actually got connected into the substrate, onto the pad where the chip is layed down.

**Hendrie:** (Inaudible).

**Karp:** Where the dye attach is, right?

**Hendrie:** Yes, where the dye attach.

Joel Karp: And so because of the way the package was wired, that the electrical potential of that substrate was actually right on the lid.  So, whatever voltage was on the substrate, actually you got on the lid of the package.  And we found they'd actually changed the package at some point, because that wasn't something you wanted to have.  But, I found in the back, in the back of Intel in a storage area, I found a whole bunch of packages of the old packages that had the lid tied to the substrate.  So, that first system, I believe, that got built at Computer Control, had a bus wire that was wired then soldered right to the lids of the packages and that provided the substrate bias.  So if you saw that system there, you may not remember that, but the first system was built with those funny packages.  And then, of course, the real solution was to get an 18 pin package which, you know, we got and --

**Hendrie:** They did have 18 pin packages in that era?

**Karp:** We didn't have -- well, we had a --

**Hendrie:** You didn't, but somebody was making them.

**Karp:** Yeah.  We had to get -- these weren't things you could buy off the shelf.  You know, people all owned their own package tool.  So we had to tool our own 18-pin package at that point.  But that was the solution to the substrate bias problem.  But in the meantime, while all this work, really the learning, is going on on this 1102.  But in the meantime, the marketing folks were really anxious to get a high-speed part out.  They thought, boy, it would be really sexy to have a high-speed part out.  Well, so, they wanted me to work on the 1103, but I just didn't have the time.  At this point, we'd brought another young designer into the company, by this point.

**Hendrie:** Who was that?

**Karp:** His name was Bob Abbot. He's up in Portland now. And so --

**Hendrie:** Now there are two of you.

**Karp:** Yeah. But he wasn't working on this memory stuff at that point. But there was a designer there. So, Vadasz tells me, "Look", he says, "You know, marketing is really pushing hard to get this 1103 started. So, you know, why don't you come over to my house tonight and we'll talk about it?" So I went over to Vadasz's house and we sat there and we basically architected the 1103. And designed the chip. We figured out where the pads should go and just kind of did a kind of mock-up of the thing.

**Hendrie:** Oh, my goodness. Yeah.

**Karp:** And figured the timing out and what kind of clock signals and so forth. And so, I remember we -- I did a little bit of, uh.. again, I was still pretty well tied up with the 1102, but we did a little bit of layout, laid out the cell. By this time we had the buried contact, so we knew it was going to be a smaller cell than the 1102.

**Hendrie:** Now, who did the buried contact, another guy? Was it done at Intel first or the industry figured that out?

**Karp:** There is some controversy on that. Federico Fagin always said that he invented it at Fairchild, but Vadasz got a patent on it at Intel I believe. So, there was always a little bit of controversy about where that came from.

**Hendrie:** And then Fagin ended up at Intel, so --

**Karp:** Right.

**Hendrie:** Exactly. All right. Okay.

Joel Karp: So I had my layout technician basically lay out the cell, lay out some decoders, lay out the core of the chip. But then we brought Bob Abbott into it to actually do the design. So he started doing the design work on the 1103 while I was basically still trying to build 1102s. And we had to go through a whole new design cycle where -- you know, put the decoder in the middle and dealing with substrate bias and all those issues.

**Hendrie:** Now, the intermediate voltage generator, I mean, that seemed to work?

**Karp:** That worked pretty good, yeah.

  

**Hendrie:** You solved that problem?

Joel Karp: It was -- it worked pretty good. I mean, it was a little touchy and, you had much wider variations in access time than you'd like to have, you know, 'cause it was very sensitive. A tenth of a volt difference on that IVG, would give you tens of nanoseconds of access time difference. And, you know, so it was touchy, but we were zeroing in on it. In the meantime, Bob was working on the 1103 and, then at some point, and I can't remember exactly when this would have been, they brought another engineer in.

**Hendrie:** Now this is probably the fall of '69?

**Karp:** No. We're now after Solid State Circuits Conference. We're after that and we --

**Hendrie:** You've announced the 1103

**Karp:** The chips that were shown at Solid States Circuit Conference, if you have that paper there that I showed you, if there's a chip photo in there, that should be the one that has the decoder on the edge. That's the original design.

**Hendrie:** All right. This is the -- okay. That's the paper.

**Karp:** Right. I believe there might be a photomicrograph on the last page there or something.

**Hendrie:** Let's look and see. Yes, here we go.

**Karp:** And I think you can see it's got the decoder on the edge.

**Hendrie:** Well, there's a bunch of stuff in the middle.

**Karp:** Those -- the, uhm.. that's the column stuff. The, uh.. if you look over -- if you --

**Hendrie:** Oh, I see.

**Karp:** That's the row decoder there, right.

**Hendrie:** I see it. Okay. So you can see the decoder over here on the edge.

**Karp:** Right.

  

**Hendrie:** Very good.

**Karp:** So that was too slow. During the spring of '70 when I was going through the redesign on that. And they were basically trying to do the design of the 1103. They brought another engineer in some time in that time frame by the name of John Reed. And then, at that point, Vadasz shifted the 1103 project over to him. He was a much more senior designer than Bob Abbott was. I think Vadasz -- Actually, Abbott got the first silicon out on the 1103. But it had myriads of problems. And that was just about the time that Reed came in that they switched the project over to him. So he worked on it for a while and solved some of the problems. But it still was left with one -- I'm now talking about 1103s. I don't know if you're really there yet or if you want to go back more into the 1102 stuff.

**Hendrie:** Yeah. Well, the 1102, we ought to wind up the 1102.

**Karp:** Right. So, basically to wind it up, the 1103 was going on in parallel and we're building 1102s, shipping them to Honeywell to build, you know, test systems and so forth and they're soldering packages on the lids. And then, at some point, they probably got an 18-pin package. But, when the 1103 came out there was --

**Hendrie:** But Intel has decided that they really want to bet on the 1103?

**Karp:** That bet -- it was the summer of '70, I believe, when Intel made that decision. And it was --

**Hendrie:** Yeah. They had been working on both.

**Karp:** They were working on both.

**Hendrie:** And then decided?

**Karp:** They really decided to put -- and Honeywell- Honeywell wasn't happy with that decision at all. I remember that.

**Hendrie:** I actually remember when Noyce came to Honeywell. I sat in on the meeting, where he told everybody, "Well, we have this other chip and this is the one we really want to use."

**Karp:** Right. I might have been at that meeting, too.

**Hendrie:** Anyway, continue.

  

**Karp:** Once they got functional 1103s, it was clear that the performance was so much better than the 1102 and it also by that point was a smaller die. Even though it had an extra mask, it actually was a higher yielding part. And so Intel had to then make that decision. And, for me, it was tough because I was being told what you just spent the last two years on we're not going to pursue that one anymore. We're going to switch over to this other chip. But they softened the blow by telling me that I could start designing a 4K at that point. So that was going on at that point. Reed started working on the chip. He built a whole bunch of new different clock generators for it and got things working pretty good, except it still had a sensitivity that was referred to as TOV. The industry knew it as Intel's TOV problem. And that TOV was a timing parameter and OV means overlap. And it turns out that the way the 1103 worked, you had a signal called precharge and you had a signal called chip enable. And you had to have a certain amount of overlap between those two signals for it to work. That's how it worked. It generated an internal signal on that overlap condition. But there was no margin on it. So it would work with a 10 nanosecond overlap, but you give it 11 and it dies. And the spec had to be something like it had to meet a spec of 25 nanoseconds because of being able to put it in the system they needed that kind of margin. Right? And they were able to get it to work under certain conditions, and people were actually able to build systems to test it under those conditions. But when you actually tried to test the overlap for the full spec, the yield would go almost to zero. And, in fact, they had barrels full of devices that were being thrown into the barrels. And there were chips that were functional, but couldn't meet the TOV spec. So, at some point, I was asked to come back into the -- Oh, I know what had happened. Now I remember what happened. After I got off the 1102, I didn't start the 4K right at that point. They asked me to do the product engineering on the 1101, which they were having a lot of troubles with their manufacturing. And they asked me to take it over as a kind of product engineer. And it was a real high point, that thing, because I have to say I did a fabulous job on that, and figured out some relationships that to this day MOS designers will still use those relationships. And it's a very fundamental relationship. It's the relationship between poly width and speed. And, those sensitivities weren't well understood because we didn't have computers to analyze it all.

**Hendrie:** You could have a perfect (inaudible).

**Karp:** That's right. So, I did a lot of work on measuring speed as a function of poly width and had graphs and I did all sorts of work on doing temperature correlations so you didn't want to have to necessarily test everything at high temperature. You like to test things at room temperature. But you like to know what the changes of it. So you had to correlate all those things. So, I remember doing a really thick report and spending a lot of all nighters at Intel to get the 1101. They were so happy with that at that point that they said, "We'd like you to do that now on the 1103." So, they pulled Reed off the 1103 and they made me the 1103 engineer again. So that's why we always say the 1103 has a bunch of godfathers, but no real father. Although I think that Intel has officially made Regitz and I the fathers of the 1103 because the --

**Hendrie:** You're the ones that really got it moving.

**Karp:** Right. The ones that the Smithsonian exhibit has Regitz and I as the designers of that. So I'm happy with that. Because actually, once I got back on the 1103, I really made that work.

  

**Hendrie:** Well, isn't that a pattern of Intel's? That sometimes the people who do the designs move on and actually continue with it and try to make it work? Is that -- I sort of heard that story a few times and it seems to me maybe a reaction to what happened at Fairchild where --

**Karp:** I think you're totally right on that.

**Hendrie:** They do the things in research and then --

**Karp:** And then they threw it over the transom, right, and --

**Hendrie:** And it never worked.

**Karp:** Right. You stayed with it 'till it was in production. And, although I initially started the design and then got off and did other things, but then I think they were so happy with the work that I did on the 1101 that they just said, "Just do the same thing on the 1103." And, there was a huge breakthrough that occurred shortly after that. And, I don't remember exactly how it came about, but another one of the misconceptions we had about the silicon gate technology was that not only did you have the resistances of the poly lines were clearly way overestimated in the first go around. But we never considered overlap capacitance. We thought because of the silicon gate, we could neglect overlap capacitance and we could neglect various coupling capacitances because we had such thick field oxides. Well, it turned out that wasn't the case. Because of the way the 1103 cell was laid out, you had this big fat metal line that had full level clock signals running right over the storage node. And that's what was causing the TOV problem. But there was really no way -- we couldn't figure out any way around it. And- and so --

**Hendrie:** You couldn't figure out where to move the line?

**Karp:** There was no place to move it. And so I'd hit on the process guys and say, "You know, if you could give me a narrower line, I could probably fix this." And they'd say, "No, we can't make" -- you know, at that time we had eight micro lines and I was asking for them to do six. And they were saying, "No, we can't do six. We can't do six."

**Hendrie:** (Inaudible).

**Karp:** Right. So this kind of percolated for a while. And I remember this part. Vadasz was out of town somewhere and I got a call from the guys -- they were doing the processing all in Mountain View. By this time, we'd already moved into the building in Santa Clara, so this had to already be early '71 now. But they still had a lot of process work going on in Mountain View. They had the fab there and then they'd started up a fab. I don't even think the fab was fully running yet in Santa Clara. And they said, "Can you come to a meeting over here in Mountain View? We want to discuss this TOV problem." So I show them what we thought was the problem with the metal. And I said, "If you could give me a six micron line, then I have enough space to jog it like" -- and I show them on the board how I could jog the line to basically take it off the node and get practically a full solution to that problem. So, they conferred with each other and they said, "Let's give it a try. Let's see if we can do this." So I went back to my office in Santa Clara and got out the Xacto knife on the Ruby and a ruler and just kind of drew this thing out. And, I can't even remember what we were using as a mask process at that time, but it was a kind of step and repeat, similar techniques to what I'd used at Philco several years before. So you had to draw, like one cell or maybe four cells and then they could repeat that.

**Hendrie:** Yeah. You drew all the ones that were in different ______.

**Karp:** Right. So- so I basically drew up the new metal and, in fact, I think we had to change one or two masks. We didn't have to change all the masks. And they went out and made the mask and it was like a matter of a week before we had the silicon, and that TOV was gone. That was a big celebration at Intel because that busted the thing loose. I mean, that was the company. And that chip was the company for years to come until they really got into the microprocessing business.

**Hendrie:** You couldn't yield it until --

**Karp:** That's right. So -- that's kind of my --

**Hendrie:** It's the fundamental problem. Yeah. You got a combination of understanding how electricity works and the circuits and --

**Karp:** Right. But we did have a lot of -- I mean, we thought that the silicon gate process was a lot more bullet proof than it really turned out to be. We thought we could really neglect certain things and it turned out not to be the case. And again, it didn't help the fact that we didn't have any kind of computer analysis tools that allowed you to put these kinds of inter-node coupling kinds of effects in. We just had no ability to do that. And so you couldn't predict -- you know, when I finally realized that it was getting voltage into a zero cell, it was the voltage you were coupling in there, that could -- I sat down and did the hand calculations on it. And even the hand calculations showed that it was a major problem. You actually get several volts of signal into that cell by coupling.

**Hendrie:** You can see it once you've sat down --

**Karp:** Right.

**Hendrie:** -- and did it by hand.

**Karp:** Right.

**Hendrie:** You could see that this was not something that should be on the list of things to ignore.

  

**Karp:** Right. So that was --

**Hendrie:** Wow, that's exciting. Very good. So now you've solved that -- the -- how long did you stick with the 1103, working on that?

**Karp:** Well, by that point, I was already starting to work on the 4K. So that was really my main project. The 1103 was my --

**Hendrie:** This was sort of coming back (inaudible).

**Karp:** My activity -- right. My activity --

**Hendrie:** (Inaudible).

**Karp:** After the TOV, I was pretty much finished with the 1103.

**Hendrie:** Okay.

**Karp:** I mean, they had other issues that were going on. They had single bit failures that were packaging related.

**Hendrie:** So, the story is shifting now to the 4K.

**Karp:** Right.

**Hendrie:** Okay.

**Karp:** So, after all that disappointment with the 1102, what do we do with the 4K? We go down the same path.

**Hendrie:** Intermediate?

**Karp:** Yeah. Only much more complex than in the case of the 1102.

**Hendrie:** Oh, my goodness.

**Karp:** Because, of course, the real --

**Hendrie:** So it is the buried contact.

**Karp:** Now we got a buried contact. You know, now we're getting the design rules, you know, we're getting now a thinner, so now we're in the six micron range. But now we're back to- we need to make the smaller cell because the whole name of the game is to make the smallest possible die. Right? Now, there had been some rumbling about 1T cells in that timeframe, but we basically -- when I say "we", I mean me and Vadasz, Regitz, the team.

**Hendrie:** Now when did Regitz arrive?

**Karp:** Well, he arrived there sometime either the end of '70 or early '71, sometime in that timeframe maybe.

**Hendrie:** Okay.

**Karp:** And basically Intel had hired the whole team from– [Computer Control Corporation].

**Hendrie:** Yeah. I know they hired --

**Karp:** They hired, you know, Jordan.

**Hendrie:** (Inaudible).

**Karp:** Right. So, I --

**Hendrie:** What was Regitz doing during this period?

**Karp:** They brought him in as my boss.

**Hendrie:** Oh, all right. So he was your boss?

**Karp:** At- at one point, Vadasz had said to me that he wanted to move up in the company. And he said, "I would like you to take my place." And, I was, like, "I'm not interested in management. You know, I just want to -- I really want the technical stuff. Management doesn't interest me. I don't want to be a manager." And so, he took that to heart and hired a manager for me. (Laughing). So he brought Regitz out. He brought Regitz out as the manager. So, basically what we did with the 4K was we didn't really think that we were ready to try to do a 1T type design. We just didn't think that the processing was advanced enough or that our tools were advanced enough design wise to be able to design things that had the kind of sensitivities you needed to make 1T devices work. And so, we decided to go with the 3T cell again. We had a very --

**Hendrie:** Yeah. Something you thought you could execute and then yield.

**Karp:** Right. And so --

**Hendrie:** Now, was anybody else doing 1Ts? Or people just sort of talking about it?

**Karp:** They were talking about them. When I gave the paper at Solid States Circuits Conference on the 4K in 1972. We had the first dynamic 1K and that was really the first 4K paper. There were papers at that time on techniques for 1T cells, but no one had actually done a 1T device. But there was a paper in '72 that taught the industry how to sense the thing and it was using a flip-flop. Basically where you start it off in balance and then let the cell kind of tip it one way or the other because you were only dealing with millivolts of signal coming out of that cell. And, so there was a paper on this. On the sense amp technique, but the only actual device was the Intel device at that point.

**Hendrie:** Who invented -- where did the sense amp technique come from?

**Karp:** From Siemens.

**Hendrie:** From Siemens?

**Karp:** A guy by the name of Carl Stein at Siemens. And the 1T cell I think had -- I'm not exactly sure where the invention of the 1T cell came from because a a number of people have taken credit for it. There's- there's a Shell development has some issues -- Shell, the oil company, had some kind of program going somewhere where they were talking about 1T cells. And then the guy at IBM, Dennard (sp), Robert Dennard, he has a patent on 1T cells. So, the idea of a 1T cell was around, but, I think the first 1T devices really came out somewhere in the '73 timeframe.

**Hendrie:** So, anyway. So --

**Karp:** So, we started down the --

**Hendrie:** Committed yourselves again --

**Karp:** Committed ourselves again. And so now whereas the 1102 cell had been what we called 1X2Y, so one row line, X would be the row line and they combined the reading and writing on one line. But we had two separate Y column lines, one at the front end of the cell and one at the back end of the cell. Well, what we did for the 4K cell, for the 2107 was go to a 1X1Y cell. So, another level of multiplexing.

And, you had to turn signals around and the signal got automatically complimented when you read it. And so the chip had a lot of really incredible features on it, plus it was the first chip that actually incorporated timing on the chip, which Intel patented and we got gazillions of dollars for licensing that patent for years and years to come.

**Hendrie:** So the timing generator was actually --

**Karp:** Put on the chip. Right. Whereas, in the 1103 days, all the timing was controlled externally.

**Hendrie:** Yeah, okay.

Joel Karp: So, it was -- was it five volts or 12 volts? I forget. I think it still had a 12 volt supply on it. But, the intermediate voltage generator for the 4K, for this device, was much trickier, much, much trickier, much harder and was a real bear. It was just starting to work at the -- I left Intel in early '73. And we were just really starting to get it to work. It was just starting to come to life. But when I left, they gave the chip to Bob Abbott, the guy I mentioned earlier who'd been this young engineer that had just come in. So they transferred the chip over to him. And then it went away for a long time. Now, something really funny happened with the 2107. Here's what happened. I think they were very close to being able to ship the part when I left. And about six months later, Abbott had it in pretty good shape. Well, Texas Instruments decided to come out and second source the chip. So they come out with their version of the chip. The only problem was --

**Hendrie:** Now this was a legal second source? This was a second source agreement?

**Karp:** No, there were no legal second sources in those days.

**Hendrie:** It was their knockoff of it..

**Karp:** It was their knockoff of it. And, well, what they did was they made two errors with the -- well, there were two problems with the part. They put the part in the package backwards to the way Intel had put it in the package. But that would be easy to solve. Right? The problem was by switching the chip around like that, it switched the X and the Y addresses. So, now, where on Intel's part the refresh addresses were on one set of pins. You couldn't just flip the chip around and. You couldn't just flip Intel's chip around and have the TI chip because of what they'd done with the addressing. So, in order for those two chips to be the same, somebody had to re-lay out their chip. Intel decided to re-layout theirs to meet the TI pinout.

**Hendrie:** Oh, my goodness. They were that afraid of --

**Karp:** They were that afraid.

**Hendrie:** -- of TI?

  

**Karp:** They were that afraid. TI had never been able to make the 1103. But, I was not at Intel, so I don't know all the details of the decisions that went on at that point. But it was very surprising to me when I saw that happen, when I saw them do that. But I guess they felt having TI out there was going to help in having them out there when other people were talking about other kinds of devices and there was noise now being made about 1T devices. By the middle of '73, the 1T devices were starting to appear. So I don't really think that that 4K part, that 2107, which became the 2107A when they re-laid it out to --

**Hendrie:** Oh, okay. That's the difference. Yeah.

**Karp:** I know they shipped that part. I know they were shipping that part to Western Electric, and that's where the alpha particle problem was discovered, on that chip.

**Hendrie:** So, Western Electric ran all these. Being a telephone company, they really ran all these really stringent reliability tests.

**Karp:** Right. And they kept getting these single bit failures. That was the tip of the iceberg for the alpha particles. One of the reasons was that the solution to alpha particles was to realize that there's a critical charge that you need to have in the cell, which implies you have to have a certain voltage level of storage and a certain size capacitance. Not to mention various things you would do to the process to try to reduce the generation of the hole/electron peers and things you do to the packaging materials and then putting the polyimides a lot of stuff done to address the problem. But the reason it showed up first on this 2107 was 'cause it actually had much less capacitance in the cell 'cause it wasn't a capacitance. It was a three transistor device. You didn't depend on storage capacitance. So, the actual amount of capacitance in the storage node was way below the critical charge around. And that's why it was actually more sensitive to alphas than the other devices. But it gave Intel a very early lead on solving that problem. Intel was the first company to solve that problem. And they had the solution in hand for well over a year before anybody else figured it out.

**Hendrie:** Oh, wow. Okay. Well, that's cool.

**Karp:** So, by that time, I'd left. I left Intel in '73.

**Hendrie:** One more question about the 1103. It was the 1103 and then the 1103A. What was the difference?

**Karp:** The 1103A was a kind of a redesign, which was moving it to a newer process because by that time, they'd already shrunk design rules and everything. So it was shrinking the chip down. And, I think they were trying to change some specs and maybe they were trying to run at five volts or something. I don't remember the details. But they did go to the 1103A. I don't even really know as I sit here whether the A actually every got into production. I know Regitz worked on the A. I remember they had power problems with it when it first came out. But I just don't remember. I didn't work on that one directly. So --

  

**Hendrie:** All right. So, why did you -- you left Intel. I mean, you were doing really great stuff at Intel.

**Karp:** You know, when you're in the middle of history, you don't know it. You don't know you're making history. You don't know this company someday -- You know, Noyce once said to me, we were sitting in the cafeteria having a coffee. And Noyce said his vision for Intel was to be bigger than IBM someday. And then the next thought it was like, "I don't know anybody here anymore." He said, up to about the point where Intel was 200 people, he knew everybody in the company. But then once it grew beyond that, he just couldn't keep track of every -- and so, he personally felt bad that he could walk around and see people he didn't know.

**Hendrie:** (Inaudible).

**Karp:** And -- but he -- but- but there was this --

**Hendrie:** (Inaudible).

**Karp:** There was -- right. There was this vision, though, of someday being -- so, you know, I'm sure he'd be very proud of what happened to his company if he was around now.

**Hendrie:** But personally, you're --

**Karp:** So, personally, if I look at the '72 timeframe, I was going through a divorce. I was going through some level of personal stuff. But basically, I left Intel over disagreements with Regitz. And we had been very close friends up to that point. In fact, my daughter ended up marrying his son, years and years later.

**Hendrie:** Years and years later.

**Karp:** She's also divorced from him now, but --

**Hendrie:** But the point – yeah, that the families knew each other.

**Karp:** And maybe that was part of the problem, that he was torn because he knew my wife and he knew me and, you know, I don't know. Things were pretty rough there for a while there for me at Intel, and I just decided at one point I just didn't want to stay there anymore.

**Hendrie:** He wanted to go one direction or did he want to --

**Karp:** There was some technical aspect, but I think it was mostly personal.

**Hendrie:** Okay.

**Karp:** And, actually, a lot of changes got made at Intel after-- At the point I was there. I think they tended to think of engineers as commodities. And, for example, I got a raise right before the paper. In 1972 they gave me a raise. Another company was after me, and so Intel found out and they decided to give me a raise. So, at that point, they had me up to $20,000.00 a year. I was the first engineer at Intel to break the $20,000.00 barrier. The word was if you wanted to make more than $20,000.00 in this company, you got to be a manager. Well, John Reed, the other senior engineer at the company, had left a year before, and he really had been very unhappy. He left and then I left. And then somebody figured out, "Why are these guys leaving? What's going on here?"

**Hendrie:** You were really good engineers. You're doing great stuff.

**Karp:** Yeah, what's going on here? And, a year later, things were totally different. Regitz was moved off in another job. They brought new people in and Vadasz became the microprocessor guy and basically moved out of the memory area. And a lot of changes went on at Intel after I left. And I think some of the things were a realization that maybe we should be a little nicer to these guys.

**Hendrie:** Exactly. Maybe this is one of the most valuable assets we actually have are these engineers.

**Karp:** Intel had a --Tthe way they did reviews, they'd give you a review every six months, but only give you a salary raise once a year. So, I'd get-- One review would be without a salary raise, right? Well, I'd get a review that you didn't expect a raise, and it would be like, "You're the best thing since sliced bread. You're so wonderful. We're going to, you know, make statues to you." And then six months later, you'd have a review with a raise. And by that point, you were the worst thing in the world, so you didn't get much of a raise. So, there was a pattern. It was like, hmmm, when it's time for the raise, you're a bad guy. When there's no raise, you're a good guy. What's going on here? Anyway, I don't want to badmouth those guys too much. I mean, I mean, it's -- but when you're in it, you know, it's- it's like, uhm..

**Hendrie:** You were ready to get out.

**Karp:** Yeah. And, you know, I'd already exercised the first full stock option. And, even at that point, you really didn't know how valuable the company was going to be. You know, you couldn't imagine it.

**Hendrie:** Wow. Okay. So you decided you were ready.

**Karp:** So I left. I left and, uhm..

**Hendrie:** How did you get recruited?

**Karp:** That wasn't hard because my name was, you know, was already out there.

  

**Hendrie:** Yeah, they knew who you were.

**Karp:** Yeah. I mean, once you get your picture on the front page of Electronic News, you know you're out there. And, I remember interviewing a company called Advanced -- not AMD, but AMC -- not AMC. It was memory, Advanced Memory Systems, AMS. Advanced Memory Systems.

**Hendrie:** AMS.

**Karp:** There was a whole industry that started up following Intel, and at one point there were like 13 or 16 companies trying to make an 1103, and the only company that ever successfully made an 1103 was actually AMI. All the other big companies, Motorola, Fairchild, TI, AMD, they were-they were never able to make an 1103. It's amazing, isn't it? Well, so I interviewed AMS, and they wanted me to come in and be like a supervisor of a design group, and I interviewed Intersil at the time. The reason I was interested in Intersil was because they claimed to have an 1103, and they claimed they were drivin' the price. There would be a full-page ad in Electronic News on their price for an 1103, and Intel would have to lower their price because of the competition, right? So I thought, well, you know, this company is doin' the same similar kinda thing, so I interviewed them. I ended up going to work at Intersil 'cause I decided that they needed me more than the other company needed me. The other company already had a lotta capability. These guys, it seemed to me, really needed help. So I go into this company. The first day I say, "Well, where are all these 1103s? Oh, where are the 1103s?" The guy, who I'm workin' for, reaches down and he pulls open a drawer from his desk, and he says, "Here they are." I said, "That's the 1103?" I said, "Aren't you makin' these things?" He said, "We made a few. We can't really make it." Why, I said, "Why are you out there advertisin', ya know, cheap 1103s?" "Oh, that's marketing. I don't have no control over them." This was like on day 1 it's like I'm at a vastly different company. The other thing that was interesting was in 1972, Intel's sales were, I think, 23 million dollars. In 1973, Intersil's sales were 23 million dollars. So you'd think they're close on their heels, right? So, as I'm goin' around the company and I'm sayin', "Well, where are the computers?" and "Where's this?" and "Where's that?" and "Where are the testers?" If, you know, Intel had 23 million dollars and they had stuff, and they had profits. These guys had the level of sales, but they didn't have any stuff, I didn't know where the money was going, and they weren't makin' money, so there was somethin' wrong with that picture. And I started a 4K design there, which was a similar three-transistor design, and I worked on a 1K static RAM there, but I just never really got really that interested. Within I guess it was a little over a year, I left that company. I don't even think it was a year, and then it was like, "what am I gonna do next?" So what I did was I called a newspaper editor that I knew, and I told him that I had left Intersil, so Electronic News had put a small thing in that Joel Karp has left Intersil, blah blah blah, just a little thing, just a short, little thing. And at that time I was already divorced, and I had these friends down in Bel Air, and they had this beautiful home down there. They said, "Look," you know, "if you want to come down and uh.. hang out," you know, "you could have the run of the house." Actually, they were gonna be away, and, "You can stay here and just have a good time." So I'm down here in Bel Air in this absolutely gorgeous house, layin' by the swimming pool, and that phone rang off the hook all week long, and people wanting to talk to me. So I got the idea at that point, well, if so many people are really that anxious for my body, maybe there's a way I can like share my body with all these people <laughs> and become a consultant. So that's really where I went, and that's the direction I went in at that point, and I went back, got back in contact with John Reid, who had been the Intel engineer that I'd mentioned earlier, and we'd been roommates, office mates, at Intel, and I convinced him that to do it, and he- At that time he was working, he was at AMI, and he left and we started a two-man consultery in '74, and that was very, very successful. That was very, very successful.

We did some great stuff and-and got some very significant patents, which unfortunately we gave up the rights to too early.

**Hendrie:** That's interesting. Tell me about some of the things you did during your consulting.

**Karp:** Well right at the beginning of the consulting, the two companies that had initially called me was Burroughs down in San Diego and National Semiconductor here in Santa Clara, and they were both interested in bringin' us in to work on 4K devices, and so we took on both projects, but we couldn't share the technology between the companies 'cause you have this, so we hadda kinda put a wall in our brains so that when we were at National we were doin' National stuff, and when we were at Burroughs we did-- So we developed 1T cell devices at both places, and the one at Burroughs was actually a much more advanced device 'cause it had all these advanced -- They got the patents, and we had one patent that was called a folded bit line, which was kind of a breakthrough architectural twist on the 1T cells that really made the 1T cells work, and that became a very important patent, which garnered hundreds of millions of dollars a licensing over its life. It also tied in with a later time in my career because the company I ended up going to in the 90s actually bought that patent, and that's how they became aware of me. They bought that patent from Burroughs at some point. So we did 4Ks, we started getting calls from overseas, and we consulted with Siemens over in Germany, we went to Italy to SGS, we went to Japan to Mitsubishi. I was consulting with DEC back in Boston because as these memories were coming into the marketplace, the user side needed help in understanding the different designs and, how the vendors do things differently and which one had which kinda problems and so forth. So I know we did a lot of work at DEC, and we were at Control Data in Minneapolis. We stayed pretty busy and for, you know, we were actually under contract at National for about eight years, and so this two-man consultery thing took us through the rest of the 70s and took us into the 80s. So then, as we got into the '80s -- Do you want to just move along in or do you have any more questions during --

**Hendrie:** Well, yeah, I'm interested in particular things you did during your memory consulting. You got some stories to tell?

**Karp:** Well, I mentioned the patents. Those-those certainly were big things. I probably have stories to tell. One interesting story was where we went to Japan. They had a 4K design which was very marginal, and they were starting to work on a 16K, and so we helped them with design issues. It was Mitsubishi, and we were very successful there actually. We put them in the memory business, <laughs> and at that point Japan still wasn't – The memory was still an American thing.

**Hendrie:** Yes. They had not taken over the memory business.

**Karp:** Japan had not taken it over at that point, but while we're there, they're taking us all over the place and asking us all sorts of questions, so, I also like to dabble in the process side because of, you know, working so closely with process engineers at Intel, so, they wanted me to go through the fab and then tell them what I thought. Well, they take me into the fab, and I had never seen anything like it. It was so clean. I mean it was SO clean. Now lemme tell ya what the idea of cleanliness was at National. The big breakthrough in there at National was when they told the girls to leave their smocks in the fab when they went to lunch. They didn't want 'em takin' peanut butter sandwiches back into the fab 'cause they thought that would not be good. That was a big breakthrough at National. So after I saw what was going on in

Japan, I went back, I told National management, I said, you know, "You guys got a long ways to go. I mean the stuff they're doin' over there is, you know, they're gonna eat you at lunch if you guys aren't careful." And basically they didn't listen, and, you know, five years later, Japan, Inc., ate their lunch. But they paid attention to microcontamination. The U.S. guys just weren't that concerned about it. Fabs were just things you could practically walk in them in your street clothes here in the U.S., but all of a sudden now they had space suits and air locks and, you know, that stuff they just hadn't started doin' that kind of stuff. So the quality level, and that was a big thing in the early '80s, was people like H.P. writing, ya know, talkin' about the quality levels between Japan and the U.S. Things had really turned by then, and, you know, when we were kids, Japanese stuff was always looked down on as being like really inferior products, but by the '80s it all turned around, and it was the U.S. that was coming up with inferior products, and,you know, DRAMs are really sensitive to-- DRAMs have always been great things to bring fabs up on because they're so sensitive. If you have any kind of contamination in your fab, the DRAMs gonna show it faster than any other circuit because of the fact that you're dealing with the refresh, and the leakage on these cells has to be so low. Any kind of microcontamination the first thing to go with is the leakage. So if you're building microprocessors or static RAMs, you don't even see it, but if you're building DRAMs you'll see it, and the way it manifested itself in the early '80s was you'd get a part from Hitachi and measure the refresh on it. It'd be seconds. You measure a part coming out of a typical U.S. fab, well at that time I measuring parts coming from National, and it would be milliseconds. So that tells you right there's somethin' goin' on, and it wasn't until they really cleaned up their act here in the U.S. that they started getting those kinds of, you know, second type refreshes, so that was one interesting thing. Dealing with the foreign companies, I enjoyed that. I enjoyed the travel. I can remember one time going into Rockwell. Rockwell had an integrated circuits thing going there, and they had a problem there where they had this mask-making system that was second to none. They could just do magic with their masks, but it created a problem for them because they'd make the masks so fast that an engineer would look at a chip and he'd see a problem, and he'd go make a mask right away, and they'd make this mask and it would come out, and he'd fixed the problem he'd been lookin' at, but he didn't see the other three problems that were there, so he'd make another mask. So at any given time, you never knew where your baseline was 'cause there were so many changes in the-- So I went in and we tried to straighten some of that stuff out at Rockwell, and I can recall calling a vice president at Rockwell on a Sunday night at home, and telling him what he needed to do. I said, "Look. You're probably gonna fire me when ya hear all this stuff, but I don't want to hide this stuff from you. I'm gotta tell you the truth," and I laid out all this stuff of what, you know, what they needed to change, and instead of firing us they kept us on for another couple years. So that was that was pretty much runnin' around the world for, you know, for eight years from the '82 time frame.

**Hendrie:** When did you stop doing that or what was next?

**Karp:** Well, it was clear. By the early '80s, the memory activity in the U.S. was already tailing down because the Japanese had really come on so strong that American companies were getting out of the memory business, and it was about '85, I guess, when Intel got out, but National was doing well. They did very well with the 4K. We built 'em a super 4K, we built 'em a super 16K, but then they went really aggressive on the 64K, and tried to go to a triple poly process, and they had a lot of trouble with that. They were ahead of their time. I mean we were building poly plate capacitors, and everybody else was using planar capacitors in the cells, and, there was a lot of innovations that were going on there. There were a lot of patents were coming out of it, but they just didn't have the processing to be able to do it. So they kind of stumbled when they got to the 64K level, so by the early '80s they'd already moved the memory group to Salt Lake City, and things were gettin' really slow there, and so National at one point said would we, you know, they'd had a big layoff and they fired all the consultants, so that would have been in ’82. We had to find something else to do clearly, and it took a while to figure out what we wanted to do, but at the end of ’83, we went out and got a bunch of venture capital and started a semiconductor company.

**Hendrie:** You’re kidding. In ’83?

**Karp:** In ’83. You know, I saw all these people out there getting’ money. I thought, gee, you know, if they can get it maybe I can get some too. So we started out this plan to build a high-speed DRAM, and build a DRAM that ran as fast as a static RAM, and -- The project was kinda doomed from the start because first off we started at a time when the industry was in a boom, and just after we started the company things turned south on the industry. ’85 was like the worst recession in the history of the semiconductor industry. Grove says ’85 was worse even than now, and things are pretty bad now, but, according-, you know, Grove has said that ’85 was even worse, and uhm..—

**Hendrie:** I know Intel got into some real trouble at one point. It was in serious financial trouble.

**Karp:** It was. Uhm.. Well, the venture capitalists basically chickened out, and didn’t want to come up with any more money, so they sold the company.

**Hendrie:** What was the name of the company?

**Karp:** It was called Visic, V-i-s-i-c, which was my acronym for Visionary Integrated Circuits, and we -- I mean we actually did some pretty neat stuff. We built some very fast memories, and --

**Hendrie:** Who were your venture capitalists?

**Karp:** Hambrecht and Quist. We had all top-notch, ya know, Hambrecht and Quist, Graylock, uhm.. Kleiner Perkins almost came in, but at the last minute got talked out of it by Cypress ‘cause they thought we were gonna compete with them, and uh.. it was three or four guys that-- So they sold the company. The company got scaled back, ya know, first off, was what happens. And so we got rid of all manufacturing people and all support people and basically just kept the corps of engineers. And so the company got sold to VLSI Technology right at the end of ’86. So they only really funded it for two years, which is a pretty short time to, ya know, to fund a semiconductor company. In fact, after they funded us, they were putting out the story that this is going to be the Intel of the ‘90s, but ya gotta keep a company goin’ for longer than two years if you want to be an Intel. But anyway, that was not a really wonderful chapter in the sense that, it was pretty stressful during that time, but then when they sold the company to VLSI, I stayed with it as the head of it, and we brought about 25 people over to VLSI Technology to basically be the design and development arm of their memory business. We mostly did static RAMs while we were there, very high-speed static RAMs, and I started up a joint development program with Hitachi, which was a real feather in our cap because at that point Hitachi had never done anything like that, and they were a real leader at that point. So we started developing parts jointly with them. I started basically making monthly trips to Japan. So this was ’87, ’88, ’89, and toward the beginning of ’90, I was beginning to sense that things weren’t really wonderful over there. That the memory business just wasn’t going well for them. They were bringing up a new fab in San Antonio, and they were tryin' to run this stuff, they couldn't run it, and, you know, we were able to get good parts from the outside vendors, but they just couldn't make 'em internally.

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**Karp:** So, we're now in the middle a '90, and oh, I guess I've skipped over something here which is part of the story if we're gonna go the end here. In '86, I got a call from a friend of mine that I'd worked with at National, and he'd actually worked with me at Rampower for a short time, a Korean guy, and he'd been one of the principals in starting up Samsung Semiconductor here in the Valley in the '82 time frame. He calls me in '86, and he says, "We're being sued by Texas Instruments. Can you help us and be an expert witness for us?" I was still involved in the Visic project, but this was now at a point in time when it was right before they were getting' ready to sell the company to VLSI. So I thought, you know, I couldn't think of it. There was no-certainly no conflict there, and I'm the boss. I don't even have to ask anybody. <laughs> So I said, "Yeah, I'll do it." So that was kinda my beginning as an intellectual property expert, and this was a major litigation that was in 1986, where Texas Instruments sued the world. I don't know if you remember this.

**Hendrie:** I remember. They got on a jag and—

**Karp:** They sued the world.

**Hendrie:** --they sued the world, and they were going to make their patents a huge profit center.

**Karp:** Right. And they did. They were at one point probably getting a billion dollars a year from these patents. So I got involved in that litigation as Samsung's-- They sued seven Japanese companies, seven or eight Japanese companies, and one Korean company, Samsung. So I got involved as Samsung's expert, and so I met all these legal people that work for them. Basically they were using these law firms in Washington, so I became friendly with all these lawyers. So now we're -- Let's skip forward to early '90. I get a call from this lawyer I'd worked with. "Hi. I'm in town," you know, "wanta go to dinner." So we go out to dinner at this nice restaurant up on Skyline Boulevard up here, and just a friendly, you know, just dinner. Now he had actually at this point, he had left the Washington law firm and had moved his family to Korea for a three-year contract, so he was actually now in-house at Samsung. So I'm talkin' to him about what's Korea like and all this kinda stuff, and he said, "Well, how ya doin'?", and I said, "Well, so-so," cause I already at this point felt VLSI wasn't gonna be in the memory business for very long, and he said, "Would you consider coming to work with us over in Korea?" And I said, "Boy. I've never given that any kinda thought but, you know, lemme think about it." I came home that night, and I remember sayin' to Ann, "What would you think of movin' to Korea?" She says, "My bags are packed." <laughs> She's much more adventurous than I am. She's also lived all around the world, ya know. She's lived in many countries, so for her it was, ya know --

**Hendrie:** There's no fear. It's just a country she'd like to live in.

**Karp:** So I called him back and said, ‘Well, what do you want me to do there?” He says, “We have no idea, but, you know, let me talk to the management-level people, the chairman, and see if they’re interested.” So anyway, that basically became the next phase of my life. We ended up goin’ to Korea in September of ’90, and that was truly interesting because, you know—

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**Hendrie:** So you moved to Korea.

**Karp:** So we moved to Korea, and basically at that point in time, they were just starting their 64 megabit, so, you know, I’ve been talkin’ about 4Ks and 16Ks, and now all of a sudden here’s 64 megabit, and so they were able to bring me in on a kinda special R&D kinda deal where for five years they don’t have to pay taxes on-and so forth, so there was kind of a special R&D incentive thing that the Korean government had. So they brought me in under the agis of the 64 meg program, which I worked on to some degree, but they also really wanted my help on the IP stuff because basically they were being sued by everybody in the world, and they really liked my-- they liked me working with them with analyzing patents and helping to find prior art, ya know, all the typical kinda stuff ya do. So I would say that I spent -- I would work Monday through Friday for a full day, which was roughly 8 in the morning to 6 or 7 at night, but I had a one- or two-hour ride each way commute, and I hadda show up for any so I could sit in the back of the car and sleep or read the newspaper or something while I’m goin’ to work, but it was a very long day, and then on Saturdays ya hadda half a day. So I’d work in the factory, down in their main factory, which is about 20 miles south of Seoul, I’d work down there Monday, Tuesday, Thursday, and Friday. On Wednesdays and Saturdays, I would go to the main office in Seoul and work with the intellectual property center. So that was really a change in career at that point, and I mean it was quite interesting ‘cause this company had come from nowhere, where they had really only started, gotten into the memory business in maybe the ’82 time frame, ’83 time frame, and now we’re eight years later and they’re, you know, they’re already knockin’ on the door of bein’, the real major supplier, and now they’re number one. They’re number one uh.., ya know. So I was there through all that growth, and I worked continuously with the people in the IP area, this one lawsuit after another, one negotiation after another, and then on the semiconductor side I was the vice president of strategic product planning. So I was involved in the standards organizations here in the U.S. andjust, you know, did all sorts a neat stuff, yeah. And so we came back to the States right at the end of ’96, and we originally went to stay there for three years, but we stayed in Korea for a little over six years, and then so I came back here, I was still an employee, and I got attached to the group here in San Jose. But once I came back here I was strictly workin’ as a consultant to the intellectual property center, and they had about three or four litigations going at that time that I was helping them with. So that gets me back to the really the beginning a ’97. Things changed again. In October of ’97, I went to work at Rambus, and I became their vice president of intellectual property. I don’t know how much you’ve followed the Rambus story up to this point, but you’re lookin’ at the guy who was in the middle of all that.

<laughter>

**Karp:** So I’ve been in the middle of a lotta stuff, I guess, ya know. So I retired from full time in 2000. I was on a board of a small company here in the Valley for about a year. I’m still a consultant to them, but I am not on the board anymore, and I've been consulting with Rambus, you know, in their ongoing litigation stuff, so I still have a relationship with them.

**Hendrie:** Very good. Rambus was the way to go, and then it's funny. I haven't followed it closely enough to understand the ups and downs.

**Karp:** Well, if you want to talk about Rambus, you've gotta start all over again, put the tapes in, and go for another three or four hours cause it's a story. That's a story, and I'm sure there'll be books on that one and-at some point in the future. That is a story.

**Hendrie:** We should do that probably another time. I think I've used a lot of your time. It's almost 5:30, and I really appreciate you spending all the time to go over this.

**Karp:** No. This is a pleasure. This is-this is uh.. I've enjoyed this as I'm sure as much as you have.

**Hendrie:** This is great. Okay. Good. Well, thank you very much, Joel.

**Karp:** Uh.. <clears throat> Yeah. This is an 1103 wafer.

**Hendrie:** Okay. Yeah. There we go. Just turn it a little bit to the side. There. Just so the light doesn't shine in. Yeah. Great. Oh, there we go. There we can get it. I'll zoom in on it. Okay. That's an 1102?

**Karp:** 1103.

**Hendrie:** That's an 1103 wafer.

**Karp:** And this is uh.., ya know, circa early '70s 'cause this-this is a two-inch wafer, so, you know, now, of course, the wafers are the size of dinner plates—

**Hendrie:** So you could easily count the number of die.

**Karp:** You could easily-You could actually count the number of die, and I forget what the number is, but it's not that many.

**Hendrie:** What kind of yield was Intel able to get in those days? I know they wouldn't tell you figures today, but— Do you have any idea of what just rough order of magnitude?

**Karp:** Uh.. First of all, you didn't have anything like the kinda yields you have today. I mean if you had a 25 or 30% yield on a memory wafer, you were probably doin' real well, and now, in the '90s, it's a whole different world, but anyway, that's a two-inch wafer, so that's a relic. And this was Intel's first brochure, Intel and the Impractical World of Semiconducting Memories, so right on the front page is-this is the 1101, and this is the famous Intel picture that everybody in the world has seen, and I told you the story as to why I'm not in the picture.

**Hendrie:** Yes. 'Cause you're working on the 1101.

**Karp:** I'm sitting in the room with Regitz testing 1102s. He was still at Honeywell, and I said, "Hey, lemme go out and get in this picture," and he said, "Ah, you don't needa be in that stupid picture. This is more important," so I-- He's a customer. What can I do? What can you do? <laughter> "But, Bill, it's gonna be historical." That's a historical document, that picture. And you can see here's a young Bob Noyce, and here's a young Gordon Moore, and and here's Andy Grove, and then here's the company controller, John Cobb, and then here's the middle-level managers, and you see Ted Hoff here, and this is Les Vadasz in the front here, and this is Gene Phlaph right behind Les. He was the manufacturing head at Intel for many years, and-- No. I'm sorry. This is Gene Phlaph here. Sorry. This is Gene Phlaph, and this was Dick Bowen here. He was Intel's original bipolar design guy. Let's see what else is in here. Oh, this is Bob Graham, Intel's first marketing VP, and here's the fab. This is the fab there at Intel in the original building. This was the masking room. And then this is Nancy and Judy, and they're actually cutting the 1102 here in this picture.

<crew talk>

**Hendrie:** They're cutting the 1102?

**Karp:** Right, and as I mentioned earlier, this the one, the girl here on the.. the blonde girl. I don't know what'd be on your right or left. It's too hard to figure it out. I brought her over from Philco, as I mentioned earlier, so she-- And then this is me with my-one a my technicians, Betty Hiple, and here we're checking out the 1102, and I don't know why they put that picture in there. That doesn't look like a very good picture. That's the back of John Cobb's head, it looks like. The picture I just showed you, this is the original for that picture I showed ya a few seconds ago, and then this is kinda funny. Here's a much younger Joel Karp here. This was, I guess, around '71, and I was posing here with my technician. We'd just written a– built a specialized piece of gear, and we'd written an article for one of the electronics magazines, and—

**Hendrie:** That's great. That's wonderful. Cool.

**Karp:** That's pretty much it.

**Hendrie:** Okay. Very good. Well, thank you very much.

**Karp:** Okay.

END OF INTERVIEW

  