GORDON MOORE
ORAL HISTORY

COMPUTERWORLD HONORS PROGRAM
INTERNATIONAL ARCHIVES

Transcript of a Video History Interview with
Gordon Moore
Chairman Emeritus, CEO & President, Red Hat

Recipient of the 2000 PricewaterhouseCoopers
Leadership Award for Lifetime Achievement

Interviewer: Daniel S. Morrow (DSM)
Executive Director, Computerworld Honors Program

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DSM: Well, I'm Dan Morrow, the Executive Director of the Computer World Smithsonian Awards Program--a partnership of the Smithsonian's Natural Museum of American History and Computerworld.

We're interviewing today, March 16th, 2000, Dr. Gordon E. Moore, Chairman Emeritus of the Board of Intel Corporation, who will—on June 5th, 2000—be formally recognized by the Smithsonian Institution, the American people, and his colleagues in the industry, and future generations for his contributions to the history of Information Technology and a lifetime of achievement.

This interview is taking place at Intel, 2200 Mission College Boulevard in Santa Clara, California. And it's made possible by a generous grant from PriceWaterhouseCoopers. This interview is being recorded for presentation to the permanent research collection at the Smithsonian's Institution's National Museum of American History and for the Computer World Smithsonian Program.

Without objection, the video-audio transcripts of this interview may become part of the permanent research collection at the Smithsonian and made available to the general public, subject to the standards of the Smithsonian Institution governing access and use of its collection and those of the Computer World Smithsonian Program.

This discussion, however, is private. And should any participant wish to withhold from the public record all or any part of the recordings of this session that request will be honored for a period not to exceed twenty-five years or the life of the interviewee. Present here besides Dr. Moore and myself are George Lang, Maggie Baxter, Thomas Lippert and Glenda Cudaback. These terms are agreeable to all present? No exceptions and objections having been expressed, it's my great pleasure to finally begin this interview.

DSM: I'd like to begin the interview, Dr. Moore, by having you please identify yourself formally for the record by stating your full name and your place and date of birth.

GM: I'm Gordon Earle Moore, born in San Francisco on January 3rd, 1929—San Francisco only because it was the nearest hospital. My hometown is actually Pescadero, a small farm community forty or fifty miles south of San Francisco.

DSM: Now, tell me about your parents—your dad and your mom.

GM: My father was the local law on the coast side of San Mateo County. He was the entire law enforcement agency from Santa Cruz County to San Francisco County, a distance of some eighty miles, and had from the ocean to the top of the ridge, which is probably an average of ten miles in that direction.

DSM:	And your mom?

GM:	My mom was a homemaker. They were both born in Pescadero, so they were really local folks. And they were right in the middle of the town of about 500 that constituted Pescadero.

DSM:	How did your family get to Pescadero?

GM:	My family got there very early. In fact, one of my father's ancestors arrived before the Gold Rush in California and moved to Pescadero shortly after that. Initially he was a farmer and rancher.

DSM:	That must have been a wonderful place to grow up. 1929 to 1934 just before you started—still, that's pretty hard times in the United—what was it like growing up in Pescadero as a small boy?

GM:	Well, for someone as small as I was, you didn't really notice that anything was unusual. My father did have a full-time job, which was a real advantage. The family had a cow that we kept behind the store across the street that got milked every morning and evening. I tried to help with that occasionally. But it was a typical small town. I had a small circle of close friends since there weren't many contemporaries that lived nearby, and we enjoyed ourselves.

DSM:	Do you remember the names of some of those early friends and kids you used to play with in Pescadero?

GM:	Yeah. Well, one of them is Ron Duarte, who currently has a restaurant in Pescadero o that's very well known. And a lot of my friends from Silicon Valley and San Francisco go down there occasionally to have dinner. Another one was Frank Huglin. He was really my fishing and hunting buddy for the early years of my life. I think he lives in Oregon now. I see him occasionally.

DSM:	Were there any signs when you were just a small boy—were there any family stories of things you used to do as a kid that gave any hint of what you were going to do when you grew up?

GM:	Well, certainly not at that time. My father never got to finish grammar school. He had to quit school in the seventh grade when his father died to help support his family. My mother finished high school, but that was the extent of their education. I only remember knowing one person who went to college, one of my cousins, when I was in Pescadero. So there was no real history of involvement in a technological or intellectual activity.

DSM: Well, you and I are not that far apart in age. And electricity didn't come to my mother's house in South Carolina until well into the '30s. How advanced technologically was Pescadero?

GM: We had electricity. We had a telephone system. It was a party line where you had to turn the crank to ring and if you wanted to avoid the operator you rang twice and got my aunt instead of the operator. If you only rang once, I think the operator came in and asked, "Number, please?" And we still had that kind of telephone at the time I left in 1939, as near as I can remember.

DSM: Did you go to grammar school there?

GM: Yes, I did. I went to grammar school in Pescadero until the middle of the fifth grade.

DSM: And how about some of your early teachers? Do you remember learning to read?

GM: I do, actually. There was a new young teacher that came in to help with reading in the first and second grade, very early in that time. And she ended up marrying my cousin, so she still lives over there. And I remember thinking very highly of her.

DSM: So this is—you entered grammar school about 1935?

GM: That's correct.

DSM: And would have stayed in—well, would have gone into high school right in the middle of the war—'43, '44.

GM: That's right.

DSM: What was high school like?

GM: Well, by the time I went to high school I lived in Redwood City, which was a significantly larger community. My father essentially accepted a promotion and moved into the county seat, where he got a higher position in the Sheriff's office.

DSM: So this was 1939?

GM: 1939—yes. And I finished grammar school and started high school in 1942. You know, high school was a very interesting time for me. I was mediocre in a wide number of sports, so I was out for something all year long--you know, never the top at anything, but always able to participate, it seemed like. And I probably worked harder on that than I did on my schoolwork, I'll have to admit—although I took a relatively difficult course.

You know, math came easy for me. I was doing enough with chemistry at home that I was way ahead of the chemistry class and so math and physics and chemistry really came pretty simply for me.

DSM: Tell me about chemistry at home.

GM: Well, my interest in chemistry began when my next-door neighbor got a chemistry set for Christmas. And I found out that there were some remarkable things you could do with the chemicals that were then available in those sets, and got very interested in making explosives in particular.

DSM: Oh, I see.

GM: And from that I got more generally interested in chemistry. And by the time I was eleven or twelve, I decided I wanted to be a chemist—although I didn't exactly know what that was going to entail.

DSM: So you were working on propulsive systems and, I guess, explosives of some kind later on in your career?

GM: Well, I did some work on that.

DSM: So when you were eleven or twelve—I mean, this is about the time Pearl Harbor's bombed.

GM: That's right. Yes.

DSM: Do you remember where you were?

GM: Oh, I do, actually. I was visiting my aunt in Pescadero when we heard on that Sunday afternoon that the Japanese were bombing Pearl Harbor. It's one of those events--I think almost all of us who were my age or older at that time remember where we were when we first heard of it.

DSM: This was just an extraordinary period of time in the history of not only the United States but the world. When you were growing up, before the war broke out, I mean that was sort of the Golden Age, with radio, and kind of the Golden Age with Saturday afternoon westerns at the movie theaters, and great books for kids. Who were your heroes when you were a child? What I'm getting at is who were your heroes when you were growing up, and did they change after the war broke out?

GM: That's an interesting question. I don't really remember having any special heroes during that time period. Yeah, I went off to the movies and--after we got to Redwood City where there was actually a theater. I listened to the radio programs. But nothing stands out as having had hero status to me at that time.

DSM: How did the war touch you in Redwood City? Did members of your family go into the Army?

GM: My older brother went into the Army right out of high school. He was about three years older than me. But he went in, I guess, that would have been '43 probably, that he went in. So it was later on in the war. We had the usual impacts—gas rationing, which is always a limitation, and food rationing. I remember blackouts and my father made very tightly fitting pieces of plywood we could stick around the windows in one room so we could actually have the lights on in the house and still adhere to the blackout requirements outside.

DSM: You dad was in law enforcement, so he actually enforced blackouts?

GM: Well, any time there was a blackout he had to run out. In fact, he was always on call. I don't remember my father going anyplace without carrying a pistol, for example. It was always part of his immediate readiness to go to work when he was called. But, you know, the war was a time of some shortages. We had our victory garden in the backyard and grew a lot of our own vegetables. We had chickens and rabbits during that time. I tried to do things to help out but I was still pretty young during the first part of the war

DSM: Now, you make the decision to go to college and you [unintelligible]. Tell me about that decision. Was it—before the war it was really rare for any American to go to college, I mean less than five percent of the population. Then the class in which you became an undergraduate became one of the most extraordinary classes in the history of American education. What was it like at Berkeley when you got to college?

GM: Well, I didn't start at Berkeley. I went to San Jose State--at that time San Jose State College, today San Jose State University—for the first two years. And frankly, it was convenient. I could commute by train from my parents' home in Redwood City to San Jose every day. A lot of my friends from high school were going there, so we would have our pinochle game on the way down and the way home.

And it actually was good for me, because I really hadn't studied in high school. I got by with a minimum amount of work. It was fairly easy for me. But getting into college, I found out I had to work quite a bit harder. And San Jose State was a relatively soft entry from that point of view, in that the competition probably wasn't as great as if I'd gone to Berkeley right away.

On the other hand, I was in the class that had all of the returning veterans. And some of them were quite mature and really well suited for college. Others just didn't know what else to do. But it completely overwhelmed the facility. All the classrooms were jammed. I remember long lines down the hall for the men's room, you know, putting up temporary facilities wherever they could on campus to try to accommodate all the people coming back. It was an interesting time, but I don't think it interfered with the quality of the education I got there.

DSM: Were there teachers that stand out in your mind today from San Jose or Berkeley?

GM: Well, the one I happen to remember, I suppose, is my chemistry teacher—well, my physics teacher also, for kind of a different reason. The chemistry teacher, whose name I forget, was a lady who was really quite supportive and we got along fine. The physics teacher, on the other hand, I remember quite from the other point of view because physics was the course they used to kind of weed out those who ought to go into a technical career from those who shouldn't. So freshman physics was really tough, and a lot of my friends fell by the wayside in that course. Fortunately, I was able to struggle through and get reasonably good grades. But those were the two that I tend to remember.

DSM: Well, you had all that prior experience in chemistry.

GM: I did, and again chemistry was quite easy for me--but the physics course wasn't. I didn't realize how little physics I'd actually learned in high school.

DSM: Now, tell me about the transition from San Jose State to Berkeley.

GM: Again, in my desire to be a chemist I thought I ought to go to one of the schools that was really recognized for their chemistry department. I had always favored Berkeley. You know, to grow up in this area you either are a Stanford kid or a Cal kid, and I was in the Cal contingent since my cousin had gone to Cal. She was about the only college graduate I knew when I was growing up.

So I wanted to go to Berkeley, and I transferred over there after I'd taken essentially all the required courses at San Jose State. So in my two years at Berkeley, I took nothing but chemistry, math and physics.

DSM: And so you got your degree from—your undergraduate degree--from Berkeley in--what?

GM: 1950, two years after—two years at San Jose State, two years at Berkeley.

DSM: And then to Cal Tech--

GM: That's right.

DSM: Who directed your work at Cal Tech?

GM: Directed by Professor Badger, Richard Badger. I interviewed several of the professors down there and decided what he was doing appealed to me most. And it turned out he was a very good guy to work for. He'd leave me alone when I wanted to do things by myself, but he was generally available if I had a question or wanted to discuss anything so I was very happy with the arrangement.

I was using infrared spectroscopy to study the structure of small molecules. For me, a complex molecule had four atoms in it. I preferred that there had been only three, where I could find ones and the structure hadn't been determined. I worked on such things as HN02, N02, NH2CL, NHCL2—a variety of relatively simple things where you could resolve the spectra and really determine something about the bond lengths and the bond angles and such.

DSM: You were going to be an academic chemist?

GM: That's what I thought. I think most people who go through to get a Ph.D. in science have some idea that they're going to get an academic job when they get done. But actually, my thesis advisor suggested that I ought to look at some industrial opportunities that he thought I would find very interesting. I don't know why he had such insight, but I certainly looked at those as well as looking for academic jobs when I got finished.

DSM: Well, as someone who's been in that job search, this is a question I've always wanted to ask. Can you remember some of the guys who turned you down when you were looking for that first job?

GM: One place I think I would have gone had they made me the proper offer was the Dupont Research Lab. I interviewed Dupont and they interviewed me, both at their central laboratory and at one of the works that's across the river from Wilmington—I forget the name of it. And I got only an offer to go to work in the factory. And at that time, that didn't appeal to me that much. Had they offered me a job in the research center, I think I would have accepted it.

DSM: Robert—in preparing for this thing, we have this piece that Robert Lindsay did on you in Forbes. And he tells a story about a Dow Chemical psychologist who told you you were never going to be a manager. Is that—is this when that took place--?

GM: By golly, that's right too. Yes. I was interviewed by Dow and they were setting up a laboratory in Pittsburgh, California. And their initial idea was I could come to work for them in Midland, Michigan for a couple of years when I learned about Dow and some other things—and then come back to California in some kind of a managerial role. And that was an interesting possibility. But part of the deal was they sent me for some psychological tests. And I went down there and had to look at pictures and say what I thought of them—the usual battery of tests, including more or less IQ tests. And the result came back sort of, you know, "This guy's very bright—probably a good research scientist, but he'll never be a manager."

DSM: Never make it—

GM: And because of that, Dow offered me the job in Midland but they removed the possibility of coming back to California. And I thought that starting with kind of a stigma was not the right way to go.

DSM: So you got hired and went to Johns Hopkins?

GM: Yeah, to the Applied Physics Laboratory, which is really a government laboratory run by Johns Hopkins. It was the laboratory that developed some of the missiles for the Navy. They had a central research facility that was doing some things that were somewhat similar to what I did for my thesis, so being able to continue working in the same field was attractive.

And I'd never lived out of California before that, so spending a few years on the East Coast also turned out to be interesting.

DSM: Now, this is about 1954, right?

GM: '53, actually.

DSM: So the Korean War was just coming to an end and Eisenhower's on the—

GM: That's right, yeah.

DSM: And you're working systems for the Navy ?

GM: Well, I was working on basic research. As much as anything, I was still doing infrared spectroscopy. I'd extended it into visible and ultraviolet spectroscopy as well—but still looking at molecular structure, molecular interactions, some study of flames which have peculiar molecules in them—but not so much because it related to propulsion, just that it was a way to get some transitory chemical compounds you can't find any other way.

DSM: So you were there about two years?

GM: Yeah—about two and a half, actually.

DSM: And didn't William Shockley?

GM: That's right.

DSM: Tell me about that meeting and decisions—

GM: Well, the group I was with at the Applied Physics Laboratory was falling apart. My boss was leaving. The Assistant Director of the little group was leaving. There was a lot of internal turmoil. And I found myself calculating the cost per word in the published articles that were coming out on my work and wondering if anybody was reading them, and if the taxpayer was really getting his money's worth at $5 a word.

So I decided maybe I ought to get closer to something practical, so I started looking to see what other opportunities existed, with a strong orientation that I wanted to get back to California if I could find something. And one of the places I interviewed was the Lawrence Livermore Laboratory. By that time there really were some technical opportunities in California. There essentially hadn't been when I got out of school in 1953. Anyhow, what they wanted me to do at the Lawrence Livermore Laboratory, something like take spectra of its nuclear explosions, didn't sound like something I was very excited about so I turned down their offer.

And Shockley got permission to go through their records of the people to whom they made offers that had turned them down to see if there was anybody there he ought to pursue. He thought he needed a chemist. They'd done useful things in his group at Bell Laboratories, so he gave me a call one evening. I picked up the phone. He says, "Hello. This is Schockley." And surprisingly, I knew who it was, because I heard him give a lecture not too long before that in Washington.

DSM:	He literally called you up on the phone?

GM:	Yeah. And we arranged an interview. I came out and talked with him. And at that time he was interested in making a diffused silicon transistor, something that had been demonstrated at Bell laboratories but no one was doing commercially. And he's a very persuasive recruiter. It happened to be five miles from where I grew up, and it was in an area much more practically oriented than what I was doing. So it kind of fit all my criteria, so I really jumped at the opportunity to join him. I was his eighteenth employee. This was really a startup that was just getting going in an old storefront that was not much more than a Quonset hut in back.

DSM:	Where was that?

GM:	It was on San Antonio Road in Mountainview, right next door to a shopping center that has Sears as its anchor tenant these days.

DSM:	Tell me when you're ready. Actually, Shockley called you while you were in Baltimore.

GM:	Well, I was actually in Silver Spring, Maryland. Yeah.

DSM:	And you came west for the interview with him?

GM:	Oh, yeah.

DSM:	Which was no small thing in 1950. I mean, how long—did you drive or fly?

GM:	I flew out for that, for the interview, yeah.

DSM:	But even flying—

GM:	An old DC9 or something—very noisy.

DSM:	We were talking about your interview with Mr. Shockley. And you moved back to California from the East Coast. But you got married about that time?

GM:	Okay. I got married before that, actually. When my then girlfriend and I were considering the fact I was going to be moving to Pasadena to go to grad school, it didn't appeal to either of us to separate so we decided to get married. We ended up getting married on Saturday in Northern California and I had to start school on Monday at Cal Tech by taking a bunch of tests, so our 8:00 Saturday ceremony—8:00 in the evening—turned into a drive to Pasadena for our honeymoon and starting school the next day. And then she proceeded to go to work and put me through school—that plus my teaching assistantship.

And as a result, she got a Ph.T. signed by Mrs. DeBridge, the wife of the President at Cal Tech, for "Put Hubby Through."

DSM: Oh. How did you meet your wife?

GM: I met her when I was at San Jose State my last year. We both went off to a pre-September starting date meeting to discuss student government or something. And this was out at Asilamar, a local conference site. And I met her there and we just started dating. And when she finished San Jose State—she was a year ahead of me—she actually moved to Berkeley and lived with her aunt and uncle and worked in San Francisco. And of course, I got to continue to see her there. When I was running off to Pasadena, she just didn't want me to do that by myself—nor did I want to.

DSM: And you've been married for--?

GM: It'll be fifty years this year.

DSM: What's the date?

GM: September 9. Interestingly enough, we got married on California's 100th birthday so when California's been a state for 150 years we will have been married 50.

DSM: That's great. Okay. Now, let's talk about Shockley changing his mind.

GM: Well, if you don't mind my digressing a bit—

DSM: Not at all.

GM: --Shockley's interviewing techniques also included a psychological test and I had to go to New York to go through the equivalent battery that I did for Dow Chemical.

DSM: So you had flown West to the interview—

GM: No, no. This was after he decided he wanted to hire me—after I interviewed. Before he made a final offer, I had to go to New York to go through this batch of tests. And he sent all of his senior staff through that sort of thing. And he hired me anyway. But subsequently I got to read the report. I not only got to read mine—I got to read the one on Bob Noyce. And the general conclusion on both of us was we were great scientists but neither of us would be a manager. So strike two! At least the psychologists were consistent!

DSM: Indeed—right on the money! Psychology [is a science.] Well, you were at Shockley and met some very interesting folks there. Tell me about meeting Bob Noyce.

GM: Well, Bob Noyce came to work for Shockley on a Friday and I came the following Monday. And I always wondered what would have happened if I'd driven across the country faster and gotten there on Thursday! Anyhow, Bob was a very personable guy. He was one of these people that everyone liked the moment they met him. He was comfortable in almost any situation. And he had the additional advantage that he was about the only one in the group that had any previous semi-conductor experience. He actually knew what a transistor was and how to make them by certain techniques. He had been working at Philco Semi-Conductor and had actually done his Ph.D. work in physical electronics. So his background was directly oriented to the task we had at hand.

DSM: Did you become friends immediately?

GM: Fairly rapidly. I think the whole group was kind of drawn together. We were all a bunch of, you know, young scientists who were sharing the same kinds of problems so we got along very well together.

DSM: Eugene Kleiner?

GM: Yeah. Eugene Kleiner came a little later. Shockley was thinking he was going to go into manufacturing some day. Gene came from an industrial engineering background and came there to start recruiting a group of people that could really put together a manufacturing operation and the like.

DSM: Later with James Larsen?

GM: Later on, yeah.

DSM: Julius?

GM: Julie came about the same time Gene did. He was a mechanical engineer and again had the experience at Western Electric and was presumably going to help build a lot of the apparatus. In fact, that's really the role he fulfilled there. He oversaw the machine shop that was building the machines we were using in the laboratory. And I think he ran the purchasing and one thing or another also.

DSM: Jean Hoerni.

GM: Oh, Jean—Jean Hoerni. Yes, Jean was a post-doc at Cal Tech in the chemistry department. Shockley and I went down to interview. Jean was trained as a physicist but, you know, there's a borderline area where physics and chemistry overlap.

I more or less operated in it and so did he. And Jean was a theoretical physicist—which, of course, is what Shockley's main strength was technically. And Jean came to work to kind of do deskwork while at Shockley. In fact, he was initially set off in a different facility. We were kind of out of office space there and Shockley dealt with him directly. So actually, we didn't have too much interaction in the beginning but as things wore on he got more involved in some of the things going on in the laboratory.

DSM: Now, Jay Last—

GM: Jay Last was trained as a physicist. He and Jean Hoerni spent their free time off climbing mountains in various places, and they became very close friends. Jay had a marvelous sense of humor and I always enjoyed him. I worked fairly closely with him in setting up some of the diffusion and other processes that we thought we were going to need.

DSM: Two more of the eight—there's Sheldon Roberts—

GM: Right. Sheldon was a metallurgist, previously experienced at Dow Chemical. A lot of the kinds of the things we did involved metallurgical processing—you know, the alloying of various metals with silicon, the concern with the structure in the silicon. At that time silicon was hard to get in sufficiently pure and sufficiently defect-free crystals. And Sheldon had experience that was very applicable to those problems. He was able to set up a metallurgical laboratory for us, for example, where we could see the things we were doing a lot better than we would have been able to do without him.

DSM: And then there's Victor Grinich

GM: Yeah. Vic Grinich was the only electrical engineer in the group. Vic could actually test these things and tell us what the electrical parameters were, set up electrical apparatus so the rest of us could do measurements—and generally operated as our electronic consultant in what was essentially an electronic business if we ever got it going.

DSM: So this extraordinary group of folks, I guess, met while at Shockley. In about 1957 you—tell me about the Sherman Fairchild and the movement towards that.

GM: Well, things at Shockley weren't all sweetness and light. He turned out to be a rather unusual personality—very bright, phenomenal physical intuition, but with relatively little idea how to work with people. He was extremely competitive, to the point where he had to compete with the people who worked for him—particularly those who had any similar background. I was a little exempt from that because I was a chemist and he was a physicist, so I got to do the stuff I knew without feeling that competition. But people like Jean Hoerni felt it really strongly—they were both theoretical physicists.

And the net result was that some of the group found him extremely difficult to deal with. And he had some rather Draconian measures. You know, he said to a group of these people one day, "I'm not sure you're suited for working in this industry. We'll see. We're going to set up a production line and you're going to be the people that run it. I want you to be out there every day and start making these things one after another." This is our Ph.D. production line, as we referred to it.

But I think the crowning glory was when he wanted to put us all through lie detector tests to see who was responsible for a rather minor problem. One of the clerks had cut her hand on something that was left in the door. And he started to go through the whole staff with lie detectors, you know, thinking he knew who the culprit was.

DSM: Like the Caine Mutiny—

GM: Yeah. Well, that—it was exactly that. This was the strawberry incident on the Caine Mutiny. And he got started, but the rest of us kind of revolted. And Sheldon Roberts, our metallurgist, looked at this thing that Shockley felt was put there maliciously and found out it was the pin out of a glass-headed tack where the head had broken off. Somebody had evidently pinned something there with a bad tack, and when opening the door she cut her hand. And, you know, it was really kind of bizarre and getting more so.

Anyhow, the eight of us liked working together. We thought the original goal of making a transistor—which Shockley subsequently changed to a four-layer diode—was a worthy goal. So we actually went around Shockley to Arnold Beckman, the source of his financing. Dr. Beckman came up and talked to us and, you know, kind of—the exchange with Shockley really left an opportunity for us to correct an impression Shockley was leaving. So we called Beckman and said, "You know, what Shockley said really wasn't true. He couldn't take all of us with him if he went someplace else." And Beckman took this as an opportunity to say, "Things aren't going too smoothly up there, are they?" We said, "No, not really." So he came up and met with us. And we had a series of meetings with Beckman, the idea being that Shockley would become something like a consultant. He could become a professor at Stanford. He had just won a Nobel Prize.

DSM: Yeah.

GM: And Stanford would have been wildly enthused about getting him. But we wanted to take advantage of Shockley's technical ability, but get someone in there who knew how to manage a company. Anyhow, after a few meetings with Beckman, someone got to him and convinced him this would absolutely ruin Shockley's career. So he changed his mind and said essentially, "You know, Shockley's the boss. You guys better learn to live with it."

So we thought we'd burned our bridges so badly by then that there was no way we could stay. So the group—you know, we were all going to go look for other jobs. And Gene Kleiner wrote to a friend of his father's who happened to work at one of the investment banking firms in New York, and said, "the group of us like working together. Do you think there's a company that would like to hire us all?"

DSM: Wow.

GM: And they sent a senior partner and a young Harvard MBA out to see the group. The young Harvard MBA was a fellow by the name of Arthur Rock, who has become very well known since then as a venture capitalist. Anyhow, they spent an evening with us and at the end said, "Well, you don't really want to look for a company to work for. What you really ought to do is set up your own company, and we will find you financing." So we said, "Gee, okay. That way we won't have to move." You know, we'd all had houses and everything. We'd set it up here.

And so we sat down with a copy of the Wall Street Journal and went down through the companies on the New York Stock Exchange, listing everyone we could think of that might want to support a semi-conductor operation. And I think we identified thirty-five companies. They talked to all thirty-five, and all thirty-five turned it down without even talking to the group of us.

DSM: Is that right?

GM: And then more or less by chance they ran into Sherman Fairchild, who really was a technology buff. You know, he wanted to do aerial photography so he set up an airplane company and a camera company.

DSM: Fairchild Camera and Instrument.

GM: Yeah—Fairchild Camera and Instrument and Fairchild Aircraft both. Anyhow, he thought this sounded interesting so he introduced them to the Chief Executive of Fairchild Camera and Instrument. And Fairchild Camera and Instrument sent actually the Executive Vice President out to visit with the group, a fellow by the name of Dick Hodgson—who recently died, by the way, just a week or two ago.

And after visiting with us for an evening he decided that yeah, they'd be willing to take a chance. We needed a commitment—we figured 1.3 million dollars to do everything to get the company going. So we ended up setting up a company, Fairchild Semi-Conductor Corporation, where Fairchild Camera and Instrument had an option to acquire the company after two years.

DSM: So you were a subsidiary of—

GM: We weren't initially. Initially we were a separate company. Then we got acquired by Fairchild in two years.

DSM: Two years. So this is about 1959?

GM: That was '57. In '59, we got acquired.

DSM: You got acquired?

GM: Yeah.

DSM: Now, at Fairchild your first goal wasn't integrated circuits.

GM: No, no. The first goal was to make silicon transistors, the thing that Shockley had abandoned. It still sounded like a good idea to us. And there was a tremendous advantage to being able to start over, you know. At Shockley we learned a lot of things, including a lot of ways not to do it. And we had built some pieces of equipment that didn't work very well and—

DSM: That is at Bell Labs?

GM: But we were doing things differently. Bell had built a laboratory model and there's a long way between a laboratory model and a production device. None of the equipment was available then. We had to design and build it all ourselves.

So anyhow, we started out to complete the job that Shockley had originally done. And now we had a pretty good idea where we wanted to go. You know, we divided up the work among the several of us to each develop the particular part of the processing that was needed and develop the equipment. And we set about to make a transistor.

DSM: Now, your first two chips were—you describe them as being mesa-shaped. Were the works on top?

GM: That's right. We were making, near the beginning, mesa transistors. This was a step forward from what Bell Labs had done in the laboratory, but the nature of the device was that you made a lot of them on a wafer of silicon and then you etched away the silicon, leaving a little mesa-shaped—mesa, like one of the Southwest mountains—transistor that had to have two contacts on top and then in the back of the transistor was one. So you made all of these at once. Then you cut them apart and put them in separate packages.

And there were several critical things we had to learn to do this. One of the significant ones was to find a metal that would make a good contact to both the N-type silicon and the P-type silicon, as both the emitter and the base of the transistor—so we could use photolithography on the metal to make the patterns on top. And much to my surprise, we discovered aluminum worked very well for that. I had been trying a whole bunch of very complex alloys, using all my chemistry and all of Sheldon Roberts's metallurgy to see how we could come up with an alloy with the right properties. And Noyce suggested one day why didn't I try aluminum? Now, I thought—everybody knew aluminum did not make a good contact N-type of material. That was the way you made a rectifier.

DSM: Sure.

GM: But I tried it, not having any other better ideas. It worked perfectly.

DSM: So what made him suggest aluminum?

GM: I haven't any idea. If there was anyone in the group who knew aluminum wouldn't work, it would have been Bob. But he was absolutely right. And it was several years before we understood the physics and why aluminum made a good contact to the emitters.

DSM: Now, this is where Jean Hoerni comes up with a way to solve some problems you were having with this.

GM: Yeah, absolutely. The sensitive part of a transistor is where the so-called P-N junction comes to the surface. You have two different kinds of silicon, depending on the impurities. And right where that terminates is a very strong electric field. And it attracted every piece of dust and one thing or another that you can imagine, and ruined the electrical characteristics of the junction.

Anyhow, Jean—the resident theoretician—wasn't very active in the setup of Fairchild initially, you know. Most of the rest of us were experimentalists so we were out building apparatus and one thing and another. And Jean was sitting in his office scribbling in his notebook. And he realized that when you diffuse an impurity into a hole in the silicon oxide—through a hole in the silicon oxide into the silicon—the junction actually formed in underneath the oxide a ways, because the impurity diffused sideways as well as down. And indeed the silicon oxide would cover the junction at the sensitive part of it. So he came up with the idea of a transistor whereby using photolithography and several steps you could leave the oxide over these junction regions where it was formed. And he wrote it in his notebook.

Now, it was an interesting idea, but we couldn't try it. We'd developed this mesa transistor, and the mesa transistor only required three indexed masks. And we had designed all our equipment around three indexed masking operations and the planer transistor took four. So we had to get the mesa transistor out of the way and be able to put our attention on something else before we could even try his idea. And the convention wisdom out of Bell Laboratories was that oxide was so dirty by then you wanted to get rid of it anyhow, so nobody had any real good idea to suggest this would work.

But anyhow we finally got around to trying it, and it worked beyond [Hoerni's dreams, I think. It really solved major problems that related to the termination of the junctions previously. So we had a transistor that we could make much more reliable than previous ones, with much more dependable electrical characteristics. But probably more important than that, we really had the basis of an integrated circuit. Bob Noyce saw this when we were patenting the planer transistor. The patent attorney said essentially, "Gee, this looks important. Have you considered all the ramifications and extensions?" And Bob went away and thought about it. And my view of that is he had a meeting with the other people in the laboratory. (I had a parallel position to Bob's, and I wasn't part of the research laboratory.)

And during this meeting he came up with the two inventions necessary to extend the transistor, the planer transistor, to a complete circuit—the idea of including extra junctions to get electrical isolation between the transistor, and the way one could run the metal up over the edge of this oxide to interconnect things. So the isolation and the interconnection, the two things that had to be added, were both Bob's inventions.

DSM: Wow.

GM: Now, subsequently Bob did not get a patent on the isolation because there had been a similar use of it for a diode array someplace. But he did get the patents relating to the interconnection.

Now, Bob Noyce and Jack Kilby are often called co-inventors of the integrated circuit. Actually, they did completely different things. Jack Kilby at Texas Instruments made a laboratory integrated circuit by etching peculiar shapes and wirebonding on the thing to show that indeed you could make a little integrated small circuit--but completely by laboratory techniques. Bob saw how you could take the planer technology and make a practical integrated circuit that could be mass produced. So they both made important contributions, but they were really different.

DSM: Very, very, very different. One of the questions I was going to ask you is how you distinguish between those two contributions. From 1959, Bob is—this is year zero, that first planer transistor….

GM: That's right. The planer transistor came out in '59 and Noyce's patent application for the integrated circuit was filed in '59. And that was the year we were acquired by Fairchild Camera and Instrument.

DSM: Hmm—good timing! Now, when moving towards integrated circuits—tell me about the customer base for integrated circuits. I should think this would threaten some folks' livelihoods in one sense of the word.

GM: Well, that's actually the case. You know, this was initially a technology looking for a market, I guess. The principle customers for the kind of silicon transistors we made in those days were actually the military systems people. The silicon transistors were expensive and they gave the military the high operating temperature and reliability they needed. But when we walked into our customer, our usual contact was a circuit designer. And going in to him and saying, "Hey. We can build a complete circuit. How do you like this?" we didn't get a completely enthusiastic reception.

I remember going to one aerospace company where we showed them an integrated flip-flop, which was actually the first integrated circuit we tried to make. And their immediate reaction was, "You know, we have 16 different flip-flops of very special applications and we have an engineer who's responsible for each of them. And there's no way we can use anything like this—and besides, we can't measure the properties of the transistors to know if they're going to be reliable. The resistors are terrible because they have huge temperature coefficients. And we can't measure them anyhow and they're not very precise. There's no way we can use this." And that was a fairly typical reaction in the beginning to the integrated circuit. Of course on the other hand, we couldn't make many of them!

But this was, again, an area where Noyce made a major contribution. He said, "Okay. We'll sell you the circuit for less than you can buy the individual parts." And now, this was a shock—because we couldn't make them for less than they could buy the individual parts, but Bob extrapolated that we'd be able to make them cheaper if we could get a volume base going on them. And that kind of tipped the scales. All of a sudden, they could begin to use circuits that they could only measure from the terminals. And then a major breakthrough was that the Minuteman 2 program decided to go extensively with integrated circuits. And that was a large volume, cost-insensitive customer that required a wide variety of circuits, so a lot of technology had to be developed to include additional features. And we could make a bunch of them, so that really got the volume going. And then combining it with Bob's push to make them low cost, which really came after the military thing got going, really got integrated circuits well established.

DSM: There were two incidents in pretty close proximity in the early '60s that I'd like to have you talk about—one in 1963 about you interviewing a young man named Grove. Tell me about that interview.

GM: Actually, I still remember something about that interview. It turns out the easiest people in the world to interview are fresh Ph.Ds because they've recently done something and they're all interested in talking about it. I remember talking to Andy Grove, who was just finishing his Ph.D. at Berkeley. And he'd done some interesting work in fluid dynamics.

From my point of view, the interview went very well, even though his experience wasn't directly applicable to semi-conductors. You know, I came the same kind of route. I didn't know what a semi-conductor was when I joined Shockley, almost. So, as part of the interview, I got his references—in particular, his thesis professor's name. And I remember writing his thesis professor for a recommendation and getting my letter back with a comment on the bottom—"This is a truly unusual individual. Whoever hires him will be very lucky." That was the total recommendation.

DSM: Oh, no! This is great.

GM: And I succeeded in hiring him, and he worked out very well.

DSM: Not too shabby a hire for a man who's never going to be a manager? Okay. The next thing I'm going to ask you about— Moore's Law. Electronics Magazine asked for an article for their 35th anniversary issue to be published in 1965.

GM: Yeah, they asked me to write an article predicting the, I guess, the future of semi-conductor components or electronic components—I forget which—over the next ten years. And I wrote an article, and the main thrust of my article was to try to get across the idea that integrated circuits were going to be inexpensive. Up to that time, most of the applications had been military and integrated circuits were getting a reputation of being high priced. And in the laboratory we could see the direction that things were going. We were decreasing defect density, so we could make larger and larger circuits. And to try to show how this might go, I looked at the circuits that had been introduced and the next generation working in the laboratory. And I started back with the planer transistor in '59 and then the first integrated circuit that had about eight components on it in 1961. And I plotted these and noticed that it was about doubling every year. The one we were going to introduce in '65 had something like sixty components on it.

So I just took that line and extrapolated it for ten years and went from sixty to sixty thousand as what I thought the complexity of an integrated circuit might be—with the idea that if that happened it was going to be very much cheaper per transistor or per component. But that extrapolation of the doubling in complexity every year turned out to be amazingly precise—much more so than I ever imagined it would be. And one of my friends—I believe it was Carver Mead at Cal Tech—dubbed it "Moore's Law." And I had a chance to update it at the end of those ten years at a conference of the IEE in Washington, where I suggested it was going to slow down and only double every couple of years after that. And it did.

But it's been far more than what I ever imagined it would be. First of all, anything that changes exponentially that remotely relates to the industry is called Moore's Law these days and I'm happy to take credit for all of it. Secondly, more than just chronicling the history of the industry, it's kind of become a driving function because the companies in the business recognize that unless they progress at least that fast, they're going to fall behind. So we really are using it to decide how fast we have to develop new technology and how rapidly we have to introduce new products.

DSM: Where do you think it's--what's the future of—I remember you and Seymour Cray were having a talk about that at Montebello just before—

GM: No exponential can go on forever in the physical world. You always come to some kind of a catastrophe. And that will be the case here too. Short-term, I think it will go on for another decade or so. We can see the changes that'll let us keep doing the things we've done in the past to get this rate of improvement, generally making things smaller and making the chip slightly larger so we can put a lot more stuff on the chip.

But we're approaching the point where the fact that materials are made of atoms becomes a serious problem. By shrinking things still further, the materials don't behave properly anymore in such small chunks, and the electrical properties of the devices start to change. And that's going to limit how much smaller we can go, at least on this technology path.

But you don't want to stop progress. Maybe instead of doubling the complexity every two years, we'll double it every five years for a while after that, just by making things bigger and being more clever. And that'll still allow a phenomenal range for people to be creative. By that time, we'll be putting a billion transistors on a logic chip. The circuit designers can have an awful lot of fun with that kind of complexity, coming up with a wide variety of functions. And these will be quite high performance, so there's a lot of room left.

DSM: A billion transistors on a logic chip? Now, for somebody from three hundred years from now looking back on this time, what was the cost of a transistor in year zero?

GM: Fairchild's first transistors sold for $150 apiece. And when we got to fairly high volume production we were still selling them for a few dollars per transistor.

Now for a few dollars you can buy a 64-megabit DRAM with something like 67 or 68 million transistors on it for the same price we used to sell a single transistor. I can't identify another technology where the cost of the product has dropped that dramatically. And that's really been, to me, the big driving force in the electronics industry—having the cost come down as dramatically as it has because of the leverage of putting more and more stuff in an integrated circuit.

DSM: And in 1965 you were already sort of seeing crazy things like chips appearing in phones and automobiles.

GM: I was trying to look for places that could use these things. In rereading that article I find I even predicted the home computer!

DSM: You tell an interesting story about home computers and Intel getting into the PC—

GM: Well, that's right. One of our engineers came to me in the early days of the microprocessor era, describing how he could build a home computer with one. But the only application he could think of was a housewife putting her recipes on it. And I couldn't imagine my wife sitting at the stove with a computer, so I didn't think it was something Intel ought to pursue. Probably we would have screwed it up if we'd had. It took a company like Apple to really popularize the thing initially. And I don't really regret having missed it, but I would rather have missed it for a different reason than just thinking it was impractical.

DSM: You have a reputation as being wonderfully modest and unassuming, but one who learns from his mistakes. I've heard stories and I can't pass this up without asking about a piece of jewelry that you wear. Is it true that you're the only man in Silicon Valley that has a 15 million-dollar wristwatch?

GM: I'm actually not the only one. Dick Boucher the former head of Microma, has one also! I suppose we ought to divide them by two and say they're each—

DSM: Do you still wear it?

GM: I usually do. I don't have it on today, actually.

DSM: Would you tell that story?

GM: Yeah, sure. Intel was actually the first company in the commercial liquids crystal display watch business. We acquired a group of a half dozen people who were working with the technology. At the time, we thought it was going to be another product that could use a very complex piece of silicon.

We were thinking in terms of a portable electronic system that could do a variety of things. I guess it would be an Internet appliance today, but that was before the days that the Internet was well known. And we frankly miscalled what people wanted. They wanted a watch that may have day and date, but not much more. So I think we got in the business in '72. We got out in '75. And the watch I have was one of the models we were about to introduce when we decided to exit the business. It's an engineer's delight. It has an alarm that's low enough frequency and loud enough it'll wake me up. I can't hear the alarm on most wristwatches, but I sure can on mine.

But of course, the 15 million dollars represents what it cost Intel in losses for the whole business. And that's the memento I have to remind me of that activity.

DSM: And I have digressed egregiously here. We were at Fairchild—this is in the late '60s, about '67, even '68—and some interesting things were going on there. A couple of CEOs [unintelligible] and within six months there's a three-man triumvirate looking for somebody to run the company. And it had a pretty profound impact on you and Bob Noyces and then on Arthur Rock. Could you tell that story?

GM: Yeah. Well, you've laid the situation out pretty well. Fairchild had gone through two CEOs. The second one was Dick Hodgson, actually the person we had dealt with initially when we first joined Fairchild—the one who was willing to take a chance on us. And Dick had left. I've never been sure if that was his instigation or the board's instigation, frankly.

Anyhow, they were looking on the outside. Noyce was the logical internal candidate and for some reason they were passing him by, so Bob was not too enthused about that. I was a little frustrated, as it was getting increasingly difficult to move things from the laboratory into production anyhow. And when Bob said he was going to leave, I said, "Okay. I will too. I'd rather leave before the changes take place than afterwards."

So we left and decided to set up another company to take a shot at a slightly different portion of the market. And this was at a time when it was relatively easy to raise venture capital. We called Arthur Rock, who at that time was a successful venture capitalist in San Francisco, and asked him if he'd be willing to raise the startup capital we needed. We actually had enough from our success at Fairchild to get this company going, so Bob and I financed it initially. And then Arthur called really several of his friends and in an afternoon got commitments for the other 2.5 million dollars we wanted as our initial round of funding.

DSM: Now, the legend is that there was a one-page business plan.

GM: Well, Art said he needed a document that he could have in front of him when he was talking to these people—so Bob wrote something down. There's a copy of it in the Intel Museum and I have a copy at home. It's a one-page document that says essentially nothing—that says we're going to work with semi-conductors and we're going to do diffusion and things like that; we're going to make interesting products. We actually had a clearer picture than that. I don't know why we were quite so coy with it, but that was all we needed to raise the money we wanted.

What we saw was semi-conductor memory as an opportunity to kind of change the ground rules in what was important in the semi-conductor industry. And we set off to develop technologies that were specifically oriented toward semi-conductor memory and to introduce a series of products that would supply this—it's the one function that's universal to all digital systems. They all have to have memory in them. And we thought we saw some real opportunities there for semi-conductors to displace some existing technology and to open up some capabilities that didn't exist previously.

DSM: So in 1969 the first Intel product is--?

GM: Yeah. It took us just about a year to get our first products and processes developed.

DSM: The bi-polar memory chip—and sales that first [unintelligible]--?

GM: Oh, the year the sales were trivial. Most of our income was interest on the cash we had from the financing we did.

DSM: Do you remember whom your first customer for an Intel product was?

GM: No, I don't.

DSM: We've got it. We'll look that up. That's something [unintelligible]. What was keeping you awake at night, or did you know that you'd really hit on--?

GM: Well, I sleep well. Things don't keep me awake at night easily. My view is the startup of Intel was amazingly smooth—in that we got our products done on the schedule we thought we were going to do them on; people actually bought the things. Our initial goal said we had to get the 25 million dollars in sales in the first five years in order to be big enough that the established companies couldn't put us out of business when they saw where we were going and changed their direction. In fact, we got to something over 60 million and it took our competitors a couple of years longer to get turned around.

So to me, it was amazingly smooth. Now Andy Grove, who went through the same thing, considers it the most trying time of his life. He was always afraid we were going to go broke and all kinds of things. I can't imagine—we both lived through the same event and have such a different recollection of it. I guess it's kind of a "What, me worry?" attitude.

DSM: Well, his book is "Only the Paranoid Survive."

GM: Yeah. Well, he probably qualifies—but not as well as Shockley did on that basis!

DSM: Oh, this is great! Okay. So, about $3,000 in sales that first year—you become profitable by 1971.

GM: Yeah. We became profitable in '71. We also went public in 1971. We went public on the same day as Playboy Enterprises, at the same price per share.

DSM: Is that right?

GM: Yeah. And one of the analysts a few years later, in looking at the reports, announced, "The market has spoken. It's memories over mammaries ten to one!"

DSM: Oh, that's great! That's great. So that's when DRAM—I mean, you are building this company on memory chips. Things are really going well. You are really reaching the point where you can't produce enough to meet—I mean, demand by what, '83, '84, is really—

GM: Yeah. '83-'84 was a real boom period in the industry, it looked like.

DSM: And then—boom. The bottom falls out [unintelligible]. What happened?

GM: Well, what happened is that the boom we were building for in '83 and '84 was because of exaggerated expectations by our customers. Our customers had predicted their demand at three times what they actually turned out to be. So the whole industry had been essentially building factories and equipping them as fast as we could. And for Intel, we had a new generation of products that came out in that time period. When we saw the demand that was predicted for them, we set up multiple sources. In those days you tended to set up a second source in order to get a customer to accept your product. And for one of our key products, the main microprocessor that went into that generation of PCs, we not only put AMD in business but we put Fujitsu and Siemans—

DSM: To build 286s?

GM: To build 286s. And when the demand didn't materialize--the standard semi-conductor problem of a large fixed investment business—the prices just fell through the bottom. So it wasn't a decrease in number of units that caused the big recession in the last half of '84 and '85. It was really the price collapse.

It also happened to coincide with the Japanese finally discovering that EPROMs were a major product, something we had kept very well concealed until then. And the prices on EPROMs also collapsed. So it was a very tough period.

DSM: Oh, yeah. This is the period of thirty-dollar EPROMs down to—

GM: Down to three. Yeah, they went down over ninety percent in a six-month period in price.

DSM: So in '86 Intel actually lost money?

GM: Yeah. And we postponed it from '85 to '86 because there were some contractual commitments that our customers had to live up to in '85. But by '86 we had to wash them out, so that was a difficult time. During that time we lost a third of our workforce and we shut down several plants. I forget exactly how many. Not the kind of an operation that's very pleasant to go through, but one that was necessary under the circumstances.

DSM: Especially after a fourteen-year history with—

GM: Yeah. Well, we had had an equivalent thing happen when the oil crisis hit about ten years earlier, '73 and '74—mid-'74. The bottom fell out of the market. But it was at a time when we were extremely profitable and while our profit margins went in half and our workforce again shrunk by a third, we remained nicely profitable through the period.

DSM: And it turned out to accelerate this just a little, simply because of the time—but would you tell the Ted Hoff—

GM: Yeah. Let me wipe my nose a second here first.

DSM: Break. I want to talk about this move from the memory [unintelligible] microprocessors—

GM: Yeah. Okay. That's my handiwork. [Unintelligible.] I sweat a little bit after a while.

DSM: Is the Ted Hoff story the story the right story to ask you about?

GM: Yeah. The microprocessor—how all of that came about? Okay.

DSM: Go. Tell me the story. We're about to make a transition from a heavy focus on memory to microprocessor. Tell me about Ted Hoff and his calculator.

GM: Okay. Intel's business model was to make complex integrated circuits—and memories were the first examples we saw where you could make a complex circuit and sell it in large volume. That's what the semi-conductor technology does well, is reproduce something in large volume.

So we were looking for things beyond memories. And one of the ideas at that time was the electronic calculator, which was just really coming into vogue. So we started looking for a calculator company that we could work with. Now, most of the established calculator companies had already found established semi-conductor companies. This was in '69, I guess we were doing this. But we found a Japanese startup, by the name of Busicom, that wanted to do a family of scientific and business calculators. And they had done the logic design for some thirteen very complex chips that they thought they could make these calculators with, and wanted us to make them.

Well, we looked at them and reducing their logic diagrams to chips was a huge job—you know, far beyond what Intel's small engineering group could do at that time. While we wanted to play in that field, we couldn't respond directly to what they were asking. But Ted Hoff, who was the guy we had hired because he had significant systems experience, was looking at these and said, "Gee. You know, I can do all of these calculators with a general-purpose computer architecture. And the processor shouldn't be any more complex than the memory chips we're making today" which was a couple of thousand transistors.

So we undertook the role of convincing the Japanese to throw out all the work they had done and switch over to our approach, which was one complex logic chip instead of thirteen, and a couple of memories, which--we were doing memories otherwise so they were relatively straightforward for us. And where we expected a major selling problem, it turned out they said, "Okay" when we proposed the idea.

Now, Ted saw not only could he do all those calculators but told us he could do elevator controls and traffic lights and a variety of other things as well—that this was a general-purpose logic function when it got done. So I was excited about the possibility of having a general-purpose logical function—again, something we could build in large volume. And we undertook then to make this thing that later got called a microprocessor.

Now, again, we were short of engineers. So the first thing we had to do was go out and hire out a crew that could take on this additional work, since we didn't want to drop our memories. And we hired an engineer who we'd known at Fairchild by the name of Frederico Fagin to come in and run the development gang on that. Interesting thing on that—he arrived a week before the Japanese came over to examine our progress and he hardly knew where the restroom was by that time. So one of the engineers from the Japanese company also joined us, and the two of them kind of together developed the first microprocessor along the lines that Ted had suggested.

And that got introduced also in 1971. 1971 was a great year for us. We shipped the first ones in February. I remember looking up the date several years back. And an interesting part of the story was that the Japanese customer had paid for the designs, and they wanted a lower price than we could give them. We told them, "We can give you a lower price if we have more volume. And one way to get more volume is to let us sell these things for other applications, not for calculators." So they said, "Okay." So we got the rights back to sell this design for non-calculator applications.

DSM: Wow.

GM: But even then, the Japanese company was having financial problems. So they came back several months later and said, "What else?" So we bought the rights back for everything by returning what they paid for the development—I think it was something like $65,000. And we were able to introduce the microprocessor as Intel's product then, in an ad in late '71.

DSM: And it was an extraordinary year, wasn't it? Now, describe if you would—again, we're about twenty after the hour—describe if you would sort of the timetable of this shift from memory to being a microprocessor company.

GM: We liked the microprocessor and it came in a lot of different flavors—but what we discovered was they were not easy to use. They needed some support tools. So we developed development systems for debugging software and hardware. In fact, we even sold what we called single-board computers, where we had done the development, so people had a whole deal to work with.

DSM: The blue boxes?

GM: The blue boxes—absolutely. But for several years we sold more in development systems than we did in microprocessors actually. But we viewed each one of the development systems we sold as essentially a salesman that was working for us in the account. So we could see that the volume was developing there. And the business grew, but it grew relatively slowly.

And clear into the '80s, memories were a significantly larger business for us than microprocessors. But the microprocessor was growing, particularly as the PC took off after IBM's introduction in 1981.

DSM: I was going to ask you that. How important was landing that IBM contract?

GM: Well, in retrospect it was very important. At the time we were doing it, though, we were competing with Motorola to get our 16-bit microprocessor established broadly. And we'd given our sales force a goal of getting 2,000 design wins—that is, new applications—for this particular microprocessor in the '79 time period. I forget just how long we'd given them. And we actually got about 3,000—one of which was the IBM PC.

DSM: Who was the—do you remember who the account rep at IBM was?

GM: Yeah. It was Whiteside, who was dealing with this outfit in Boca Raton, Florida. He couldn't see what they were doing. They had a conference room with a blanket hung down in the middle of the conference room and they'd ask questions from one side and he had to answer them, but he couldn't see what they were working on.

DSM: I've heard that story, that it was literally a blanket.

GM: That's what I understand, yeah.

DSM: Oh, that's great.

GM: Anyhow, we got all of these design wins. And as the PC started to take off, it became an increasingly large part of our business. And after the big fall-off in '85 and—really in mid-'84 it started—we were looking at drawing the next card in the dynamic memory business. And we had just completed the design and the process development for the first 1-megabit device, and I think we had regained our technical lead.

But at that time, people were selling DRAMs for significantly less than their cost, the true cost of making them. And we couldn't see that turning around, and we were looking at a 400 million-dollar investment in plants in order to put our new process and product into production. So while it was the first product we really developed a big business on, it was very uncomfortable to draw that next card. And sitting down with Andy, you know, we have slightly different views of how we decided it—but we decided that we couldn't do that, that we were going to drop out of the DRAMs business, but that we had the microprocessor to focus on. That was just at the time our first 32-bit microprocessor was coming out, the 80386.

And focusing on that and on technology that was appropriate for microprocessors turned out to be a very fortunate decision. Before then, our technology development had to be split in a few different directions. When we dropped DRAMs, we had a development team we had to reassign and the first thing was what were we going to do with them—and then we did the right thing. We focused them also on technology for microprocessors, and ended up getting a lot more focus on that than we would have if we'd stayed in the memory business. So it worked out very well for us in that the PC continued to grow.

DSM: We talked about the 286, then the 386 and the 80386. Can you remark a little bit about the RISC craze in the late '80s and early 1990? I mean, RISC was—

GM: There certainly was a lot of attention on a new approach to computer architecture called RISC or Reduced Instruction Set Computing. The original origin of RISC was that with semi-conductor memory, logical speeds and memory speeds were becoming comparable. And the net result was you could do a lot of simple operations going to memory very rapidly, where previously memory was a lot slower than computing, so you went to memory as seldom as you had to—the so-called complex instruction, where you did a lot once you got the stuff out of memory.

That was a very interesting idea during that time period. But people succeeded in extending the idea of RISC to include everything that was new in computer architecture. And in fact, we did everything else with our architecture. We could do all of the out-of-order execution and all the modern things while maintaining the old instruction set. And our approach called CISC took more transistors typically—but transistors were cheap, as long as we had the production volume—which was an idea that I don't think other people realized how important was. We were making an awful lot of these things, which gave us a tremendous advantage on that end.

We kept our performance essentially neck-and-neck with the various RISC processors and had the added advantage of all the software running on our products—things that were written for Microsoft's operating system. A lot of things favor having a very large base, where you can use everything. So the RISCs that are still around are ones that companies are using for their proprietary systems, you know? Sun has one. IBM has one. HP still has one, although I think that'll eventually disappear with the work we're doing jointly with them.

And the RISC turns out not to have had that significant an advantage. The real advantage was you didn't need as many transistors, when you came right down to it. But now we've gotten into an era where we again have the situation where it's hard to keep memory speeds current with processor speeds. So maybe the CISC processors will even be better positioned than they have been.

DSM: You've been part of this revolution—this extraordinary Information Technology revolution—since really the very beginning. What excites you most about what's going on right now? What really turns you on?

GM: The rate of change. This business changes so fast that it's hard to keep up with. It's so exciting. You know, I can't get away from it. I'm nominally retired—my wife says with a little "r." I come into Intel a day a week when I'm around here, as much as anything to keep track of what's going on. It's very stimulating. You know, I hear discussions now that sound like we're relegated to the old industries now. It's all Cisco and the network and one thing and another. You know, it was only a few years ago when we were right at the center of the revolution. I don't know what the next big thing will be, but the evolution we're undergoing is just phenomenal.

DSM: A question that I've asked all the folks I've interviewed is—I call it the "where does innovation come from" question. Some folks say that breakthroughs in innovation come from frustration in a sense. Folks just bang their heads against a problem for so long that somebody says, "Ah. Here's the way to do it." Others say it's one guy sometimes, who has just a brilliant insight. But you've been in one of the most innovative companies in one of the most innovative parts of the world for thirty or forty years now. Where does innovation come from?

GM: It comes from a variety of places. You know, you have to be in an environment where innovation gets accepted and utilized in the first place. That's not true everywhere. A lot of industries change extremely slowly—not this one. And the net result is we're continually looking for the new idea and where things are going. I've been fortunate that I've been with the companies that have kind of found the mainstream—the mainstream of technology and the things that go along with it. And there's a lot of room for innovation just to stay on the trends we've been on and keep driving this phenomenal machine.

But the real innovations or the things that change the way things are done spring up occasionally. You know, I look at my history in the semi-conductor industry. It seems to me that there were three major innovations. The first one was the transistor, which gave us the basic switch. The second one was the integrated circuit. The integrated circuit is what really drove the cost—and to me, the decrease in cost is the principal driving force for what's happened subsequently. And then the third one was the microprocessor, which gave us the stored program machines that can be stuck every place. You know, the microprocessor isn't just what you find in your home computer. Your automobile probably has twenty to fifty of them in it. Every major appliance—the blue-collar microprocessors, as someone called them, are hidden in all of the control applications in the world. And this has just changed the way things are done. It's increased the efficiency of your automobile dramatically, while cutting emissions. It's made a lot of things much less expensive than they would have been with the old mechanical controls. It's really been a revolutionary product.

DSM: It's a glorious time to be alive. I'm going to ask you one last question that's two parts—and again, it's something that I've asked everybody. One is—given your career and extraordinary achievements, looking back on this period of time who are the folks that you really most admire? That's part one—who do you admire? And the second part of that is—how do you like Gordon Moore's role in this revolution [unintelligible]?

GM: Well, I've admired a lot of folks along the way. I never really had a true mentor that I followed for any period of time. I certainly have admired many of the leading scientists. Many of my colleagues—you know, people like Bob Noyce and Andy Grove are truly unusual individuals that you can't help but admire. I've admired my wife—even my kids most of the time.

Now, the second half of the question--?

DSM: The harder part of the question maybe—especially, I know this is—I'm going to ask it anyway. How would you like to be remembered a hundred years from now?

GM: Oh.

DSM: Some graduate student looking back on his—

GM: First, being remembered a hundred years from now would be a goal in itself! I think as having been a contributor to the development of this fantastic industry. I'm afraid if I'm remembered at all, it's going to be for Moore's Law—which I used to kind of laugh at when people said, and I guess I've come to take it more seriously in later years. But I'd hate to think that that was my biggest contribution. I've been with companies--you know, Fairchild Semi-Conductor during the late '50s and '60s I think was the location of most of the significant developments in the industry. I think Intel has fulfilled that role subsequently. I've had a fairly intimate association with both of them and I'd like to think I contributed along the way.

DSM: I'll close on a personal note, if I may. One of the things I read in preparation for this is that looking back on the demonstrations and the revolutionaries of our youth in the '60s, you remarked that there was probably more revolution created and made in the laboratories and the people working in this industry than came out of the revolutions that were going on in the streets.

GM: Yeah. I made a comment along those lines that we were the real revolutionaries during that time period when there were free speech movements at Berkeley and one thing and another. The things we were doing, by that time, you could see were really changing the way a lot of the world was going to operate--you know, a detail I couldn't have predicted where we are today but it was going to have an increasingly major impact and it was getting fairly clear. So I commented at that time that I thought we were the real revolutionaries.

DSM: On a personal note, having been one of those guys in the streets, I think you were absolutely right. This revolution's changed the world, and I am honored to have spent this time with you this afternoon, Dr. Moore.

GM: Okay. Well, thank you. I enjoyed it.

DSM: Thank you so much.