THE HENRY FORD

COLLECTING INNOVATION TODAY

INTERVIEW WITH

GORDON MOORE

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INTEL CORPORATION

SANTA CLARA , CALIFORNIA

Interviewer: Barry Hurd

Producer: Judith E. Endelman

QUESTION:

06:00:56;14 Let's just start, just give me a little bit of the background. Maybe starting when you graduated from college and went off for that first job at Johns Hopkins?

GORDON MOORE:

06:01:05;19 Yeah, I went back to the applied physics lab. Which was a Navy lab that Johns Hopkins ran. And then one evening when I was looking for a new job, I got a call by Bill Shockley, he invented the transistor. He was setting up a new company out here in the west; thought he could use a chemist. They'd been useful at Bell Laboratories. I wanted to get back out here, I'm a native of this area, and getting back to the Bay area was a valuable deal. So anyhow, I came out here and went to work for Shockley.

QUESTION:

06:01:45;23 And then you stayed with Shockley for a

while and then...

GORDON MOORE:

06:01:48;11 I was with Shockley for about 18 months. He turned out to be an excellent physicist but a very poor manager. And we had kind of an internal revolt where we went around him to try to get him pushed aside. But we discovered that a bunch of young engineers and scientists had a tough time pushing a new Nobel Laureate aside. So we ended up burning our bridges sufficiently that we thought we had to go elsewhere.

06:02:21;11 And we happened to catch up with an investment banking firm called Hayden Stone. Turns out that one of the group's father had used Hayden Stone for their brokerage. And Hayden Stone came out here and convinced us that rather than going off and looking for jobs separately, what we really ought to do is set up our own company. And

they volunteered to find financing for us. So, they went through all the companies we could find in the Wall Street Journal that might want a semiconductor operation. And got blanks from all of them.

06:03:03;09 None of the companies even talked to the group of us. They all turned down the possibility. And then, quite by chance, they ran into Sherman Fairchild, who had a fortune in IBM stock, whose father was involved in the founding of it. And who was a technology buff. And set up a company to build aerial cameras and another one to build airplanes so he could do aerial photography. And he introduced the Hayden Stone representatives to the people at Fairchild Cameron Instrument.

06:03:40;02 And they were willing to take a shot on a semiconductor company. They were looking to expand into new areas. So,

they agreed to finance us starting out. And we set up Fairchild Semiconductor initially as an independent company. But they had the right to acquire it within two to five years. And at the end of two years, did exercise their option, acquired us. So, we became Fairchild, the Semiconductor division of Fairchild Cameron Instrument.

QUESTION:

06:04:14;02 And what were you doing there? Were you managing the place or engineering or chemist...

GORDON MOORE:

06:04:18;11 A group of eight of us founded the company. But we had had such an experience with Shockley that we recognized that none of us had any managerial experience. So, the first thing we ought to do is run out and hire our own boss. So, we went out and hired a general manager to come in and run the company that we were starting. We picked a person who had been an

engineering manager at a semiconductor operation at Hughes Aircraft.

06:04:46;11 And he taught us a lot of things that we really didn't know. None of us had ever really operated in a company previously. And we went off in the direction of making a diffuse silicon transistor. A big improvement over any of the silicon transistors that were available at the time. And were successful in creating such a device. And in making a major improvement on the idea of the device called the planar transistor, that has kind of been the technology that the industry has grown from ever since.

QUESTION:

06:05:27;10 And you stayed there for a while?

GORDON MOORE:

06:05:31;08 At Fairchild, not only did we make this improved transistor, but it turned out to be the basis of the integrated circuit, which Bob Noyce, generally

considered the co-inventor with Jack Kilby of Texas Instruments. Unfortunately, Bob died before the Nobel Prize was awarded for the invention, or he would have shared in it. I got the consolation prize of going to the Nobel ceremony that year. But evidently, the very year he died was the one where they had planned on awarding the Nobel Prize for the invention of the integrated circuit.

06:06:09;15 And it really screwed up the Nobel committee. They had to come up with an alternative fairly rapidly. And it was several years later, they got around to giving the award to Jack Kilby.

QUESTION:

06:06:23;16 Okay, but now you're at Fairchild for a while. I'm just trying to sort of get the timeline.

GORDON MOORE:

06:06:25;29 Okay, we were at Fairchild; Fairchild was founded in 1957. And we were there

until 1968. During those eleven years, a lot of the trends in the semiconductor industry were established. And Fairchild was a major participant during that period. Then in 1968, again for some rather negative reasons, we decided it was time to try again. So, Bob Noyce and I set up the Intel corporation. Again, we went back to the person who had been involved in the financing of Fairchild to get Arthur Rock, to get him to get the financing established with Intel.

06:07:15;20 And he was able to do this in a very short period of time, like an afternoon. And Intel began business in 1968. Initially pursuing a version of the technology to make semiconductor memories. A product that we could see could be made in large volume and sold into all digital systems. And you know, it turned out that we started out with three approaches for making

semiconductor memory; three different technologies.

06:07:49;09 And one of these proved to be too easy. The existing semiconductor industry copied it relatively quickly. One was too difficult, in that we were trying to put a lot of different chips in a single package. And that proved to require techniques that weren't available to us then. And the third one, using a different kind of transistor, called an MOS transistor; turned out to be just right.

06:08:19;10 I call this our Goldilocks strategy, in retrospect. The silicon gate technology was something that we were able to do, able to make work when we were focusing on it. But the established companies didn't put the same amount of attention on it and it was several years, actually, before we had any direct competition in that

technology. So, it was an extremely important lucky break that we chose the right technology early in the game.

QUESTION:

06:08:53;20 Well, let me ask you, you were always shocked when you said things got kind of negative. But Shockley was a very innovative company when you were there. Then Fairchild, but after a time, things got rotten a little bit again, you moved on. Was the innovation that you were involved in being stifled, or why did you, why did you feel a need to keep moving and opening new things.

GORDON MOORE:

06:09:14;29 Well, at Shockley, it was strictly his management techniques, the way he dealt with people. Very unattractive. And when we didn't succeed in solving the problem internally, we really thought we had burned our bridges so badly we had to go someplace else. At Fairchild, I thought I had the best job in the industry, as head of R&D. Quite

a productive laboratory, in my opinion.

06:09:46;03 Several of the major advances came out of there and a lot of the science underlying the important parts of the technology. But the Fairchild Cameron Instrument ended up getting rid of two chief executives within six months. And we started to even look on the outside for a new one. My colleague, Bob Noyce, was a logical internal candidate, and he was clearly being passed over the way they were approaching it. So, this kind of bent him out of shape.

06:10:15;07 I thought if they were bringing in a new management team from outside, that my laboratory would probably change pretty dramatically. So, I decided it would be better to leave before than afterwards. So, Bob and I decided to go out and try again.

QUESTION:

06:10:30;28 Because Fairchild, at the time, was a pretty innovative company, wasn't it?

GORDON MOORE:

06:10:34;03 Yeah, Fairchild was, Fairchild.

QUESTION:

06:10:39;03 Tell me about some of the innovations they brought or the bunch of news that ...

GORDON MOORE:

06:10:42;15 I mentioned two of the most important ones. The planar transistor and the first integrated circuit. And then a lot of other integrated circuits. Also the science that allowed the MOS transistor to become a practical device was done there. This was a long series of papers by a productive group in the laboratory. A variety of other things were done there, too. But the most important thing related to the mainstream of the semiconductor industry.

06:11:15;05 Essentially, the technology that has

continued to be developed over the last 40 years that has really driven the industry for the most part originated at Fairchild.

QUESTION:

06:11:25;19 Okay, now when you were at Fairchild, did you start as an engineer then transition to management?

GORDON MOORE:

06:11:32;02 At Fairchild, the original eight of us kind of broke up the job, initially by pieces of the technology we were developing. And then we started to set up a bit of an infrastructure. Noyce was in charge of research and development. I was in charge of the engineering activities and quality control. While we had Ed Baldwin, the person we had hired from Hughes as general manager. When he… Baldwin left and set up a competing company fairly soon after we got established.

06:12:13;10 At that time, we decided that we

weren't gonna look outside again, and Bob Noyce became general manager of the semiconductor operation, I took over the research and development in addition to some of the engineering. And ever since then, I guess I've been more or less a manager.

QUESTION:

06:12:32;10 Now, do you rue the day you had to switch for more research and development, engineering demands, when you're out of that...

GORDON MOORE:

06:12:38;10 Not at all. It's been an exciting industry at both ends. I never got too far away from the technology. I couldn't do much of it myself but I could stay pretty close to what the people working for me were doing. So, I got my rewards that way. In addition, I had an opportunity to participate in the business aspects of the company.

QUESTION:

06:13:08;13 Now, when you sort of transitioned into management, what did you do to keep these people motivated and happy and coming up with the innovations? Did you just fly by the seat of your pants or how did that work?

GORDON MOORE:

06:13:19;25 You give good people the opportunity and they go out and do the innovations. It's hard to control it very much. In fact, I think the more you control it, the more you're likely to stifle innovation. It requires the people be given a fair amount of latitude if they're gonna proceed and come up with new and different things.

06:13:42;09 Now, we were fortunate that we were very early in a very rich technology. In fact, Fairchild was a source of a huge number of spin-offs. Because we're developing opportunities a lot faster than Fairchild semiconductor could grow to exploit them. So, dozens

of companies, literally, spun out of Fairchild to exploit some of the new ideas coming along. It was a very innovative time period and did much to seed the entire industry.

QUESTION:

06:14:28;04 Semi-conductor industry. I want you to just take us back and sort of paint the picture of what it was like at the time. Was it like sort of the gold rush? Everybody was out here in California inventing the future? Give us a little picture of how that was happening? All these companies spinning off all these ideas, feeding on one another.

QUESTION:

06:14:48;19 Tell us a little bit about what it was like back when the sort of information and high technology business was being born. It sounded like you were right at the center of it.

GORDON MOORE:

06:14:56;27 Yeah, I was lucky enough to begin

really at the beginning of the industry.

QUESTION:

06:15:12;26 So tell us, you were at the very center, you were at the big bang of the high-tech business.

GORDON MOORE:

06:15:16;17 Pretty much so. Maybe the big bang was the invention of the transistor at Bell Laboratories. But in particular, silicon technology was lagging behind. The original transistors were made of germanium, which was an easier material to work with. On the other hand, it didn't make as good transistors. Shockley set out to make the silicon transistor, actually Texas Instruments had introduced one in 1955 and Shockley was starting in early 1956.

06:15:50;04 But he had an approach to make a much better silicon transistor. Unfortunately, he abandoned it and decided to make a more obscure device

that, kind of a, much more limited utility than the transistor. But he at least introduced us to silicon. There was a lot to be done in the technology to make anything in those days. And we were not successful in developing any products while we were at Fairchild, excuse me, while we were at Shockley.

06:16:21;22 But, we were pointed in the right direction. So, when we set up Fairchild, we decided to pursue the same objective that Shockley had originally said he was gonna pursue, that is the diffuse silicon transistor. And that was a very important technology. It was something that made transistors in a batch manner. So all the costs weren't on one particular piece of silicon, you could spread them across several pieces of silicon.

06:16:52;04 And it looked like a much more economical way to make a much better

transistor. Just required a lot of technology to be developed. And that's essentially what we did in the early days of Fairchild. Then, as we started exploiting this technology, we developed a whole bunch of other opportunities that resulted in, really the formation of what generally is called Silicon Valley today.

06:17:19;17 It was the development of the engineer-entrepreneur. The engineer would see the opportunity, run off and get financing, set up a company to exploit it. It was really the blossoming of the venture capital industry along with the technology out here that created the phenomenon known as Silicon Valley. Now, there were electronic companies in the area before. Hewlett Packard and Vary & Associates being the most well-recognized ones. But they were more like typical East Coast companies.

06:17:58;03 They were fairly stable, moving in the various areas where they thought their business could grow. They didn't have this explosive effect of spinning off a myriad of other companies, pursuing new ideas. That really blew out of Fairchild, which itself came out of Shockley's original commitment to silicon.

QUESTION:

06:18:28;01 Was this, you said the engineer-entrepreneur, the reason there were so many spin-offs, was it to seek better places to innovate or cause it to make your own fortune?

GORDON MOORE:

06:18:38;10 It's always, it's difficult to try to guess what people's motivation was. I suspect some of it was make your own fortune commitment. But more than that, just to exploit a technological idea, in an environment you controlled yourself, pretty much. A company like Fairchild just couldn't pursue all

these opportunities. The things we were pursuing were growing as fast as we could grow the company.

QUESTION:

06:19:18;06 Was it being by yourself to exploit your own ideas, that's kind of an important thread that seemed like it motivated a lot of people. Tell me a little bit about that.

GORDON MOORE:

06:19:29;08 Well, if you were in a bigger company, and Fairchild was bigger.

GORDON MOORE:

06:19:51;06 You know, in a bigger company that was going in the directions that were consuming all of its capability, if an engineer came up with a new idea, it was rather frustrating to see that his idea wither on the vine while the business of the company was being pursued as diligently as they could. It was much more attractive to spin off, have an opportunity to exploit the idea that came along in an environment

that was pretty much controlled by the engineer himself.

06:20:25;12 So, it was attractive from that point of view, too. And it's hard to say just what any individual's motivation was. Financially, none of them felt they could suffer. That was another thing that happened. It became relatively low-risk to set up your own company. In this area, failure wasn't a stigma. You could go out and set up a company and fail and get a job the next day at another company. Probably at a higher salary because of your experience.

06:20:59;17 And that's been the case all along. Failure has not been something that has been negative here. I think that's one of the big advantages Silicon Valley has had. Certainly over some, like the European environment where nobody wants to go out and be part of a failure.

Here, people just didn't seem to give a darn.

QUESTION:

06:21:23;05 Now, later, when you were at Intel and had all these people trying to be innovative, what did you do when these innovative people wanted to leave? I mean how did you retain them and keep them happy and in a big company? I mean what did you do?

GORDON MOORE:

06:21:35;29 Well, I'm sure we didn't retain all of them. Intel has had its share of spin-offs also. And generally, for the same reason, people get excited about an area that Intel was not in a position to exploit. We've tried to keep an innovative environment at Intel. We've tried to channel the innovations, however, in directions where Intel could take advantage of them.

QUESTION:

06:22:07;21 I want you to tell me how you channel this innovation. You were starting to

say at Intel they sort of control it to some degree.

QUESTION:

06:22:17;01 Tell us how did you channel this innovation to help retain people to control the ideas here at Intel?

GORDON MOORE:

06:22:22;28 Well, I wanna go back a little bit. At Fairchild, when most of the technical capability was in the laboratory, we had a relatively easy time transferring new technology into manufacturing. The more technically competent the people became in manufacturing, the more difficult the transfers became. To the point where the laboratory was developing things that were being exploited by spin-offs and even spin-offs of spin-offs before we could get them into the manufacturing area at Fairchild.

06:22:55;22 It was increasingly frustrating. So when we set up Intel, we decided not to

set up a separate laboratory. We would do our research and development in the manufacturing facility. So the technology was already transferred. We didn't have to go through this discontinuity of moving it from one organization to another. Now that destroyed some of the efficiency of manufacturing but it made this technology transfer very much more effective and certainly in the beginning, that was a very valuable way to do it.

06:23:37;23 We got technology into manufacturing much more rapidly. And we've continued that to a considerable extent. Now new technology is developed in a dedicated facility. And by the development group, has taken up significant volume. So, from there on, it's a question of just duplication to increase the manufacturing capacity. It's a[n] expensive way to do it but it has

worked very well for Intel.

QUESTION:

06:24:06;07 What are some of the other things you did at Intel, from a management standpoint, to make it easier for people to invent things, to be open, not to be afraid of failure, et cetera. I mean you, there were some new policies and principles you thought through and worked through. Tell me a little bit about that.

GORDON MOORE:

06:24:23;17 You know, it's hard to say.

QUESTION:

06:24:38;29 We tried to just preserve an environment where people could do new things. If they were consistent with what our business model was. For example, when one of our engineers invented the microprocessor. For years, the industry had talked about some day putting a whole computer on a chip. Well, that was way out in the future. But one of our engineers is

looking at a family of calculators that we were asked to produce. Saw, heck, I could make a general purpose computer architecture, do all his calculators, and be useful for a variety of other things, too, and it wouldn't be much more complex than the memory chips we're making.

06:25:26;02 That was really an intellectual breakthrough. He saw the opportunity to make what has become the microprocessor. And we pursued that and it, over a period of time, has become Intel's principle business by far. But you know, we've tried to encourage our engineers to think like that. To come up with completely new ideas. And they've been successful often enough that the company has grown quite significantly.

QUESTION:

06:26:00;02 But was that the 4004 you're talking about?

GORDON MOORE:

06:26:01;22 That's right, the was the 4004.

QUESTION:

06:26:02;11 But who was it? A guy named Ted Hoff?

GORDON MOORE:

06:26:05;04 Ted Hoff.

QUESTION:

06:26:05;11 I mean did he come into your office one day and say, "Boss, I got this great idea!" I mean what's the story of how that happened? And you said, "Well, go work on it, pursue it?"

GORDON MOORE:

06:26:12;18 No, the story on that was Intel's business model was to find chips that we could make in large volume that had a lot of complexity. Because we wanted the processing of the silicon to be the important advantage, rather than having a large, low-cost assembly plant in southeast Asia, which is kind of where the industry has developed.

06:26:38;07 After we started on doing some memory

chips, we were looking at other opportunities to make a complex chip in large volume. And one of the opportunities to find a product that's made in large volume, and put the electronics for that on a single chip. And the business was just developing for electronic calculators. So, we wanted to explore the calculator business. But the established semiconductor companies had already teamed with the established calculator companies. We were kind of late to the party.

06:27:13;04 But we were introduced to a Japanese startup, an oxymoron in itself, that wanted to make a family of scientific and business calculators. And they'd done the design of some 13 different chips that they were looking for a semiconductor company to make for them. But we looked at this opportunity and 13 chips was more than we could even

conceive of. We were having trouble making a couple of memory chips, let alone 13 complex logic chips.

06:27:46;03 So while the opportunity was there, we didn't see how we could take advantage of it. And that's when Ted Hoff looked at those and said, "You know, we could make all of these out of a general purpose computer architecture. And it shouldn't be much more complex than the memory chips we're making already." That was really an insight. He also said, "And not only will it do the calculators, but it can do controllers, like elevator controls, traffic lights," I remember were two examples he came up with. So here's a general purpose chip that can do a lot of different functions and we should be able to make.

06:28:24;09 So we succeeded in selling that idea to the Japanese. A much easier sale than

I thought. They abandoned their 13 chips and decided to do it our way. And we went ahead and developed the 4004 for them. For their calculator. Well, they had an exclusive, since they had paid a development fee for these things. But then they came around wanting lower prices. And we said, "The only way we can give you lower prices is if we have higher volume."

06:28:55;03 So, we negotiated that we could sell these chips for non-calculator applications. They would remain exclusive only on the calculator applications. So, we started selling them much more broadly. And then, six months or so later, Visicom, our Japanese partner, got into financial difficulties and we were able to buy back complete rights to the 4004 family.

06:29:23;13 That really got us going in the

microprocessor area. Now, those first chips went into all sorts of weird applications. Generally, by a little company, they're written by individuals. I remember one of our directors one time saying, "When are you gonna get a customer I've heard of." These things were going to really obscure places.

06:29:43;24 But that was the nice thing about they microprocessor. It could fit into all of these applications and we were very happy to encourage that. Now, that was the first of a large number of microprocessors to come subsequently. That first one contained about 2200 transistors. Today, our processors contained as much as a billion and a half transistors. The complexity has really grown over the last few decades.

QUESTION:

07:00:11;10 Tell me something about Moore's Law that you've never told anybody.

GORDON MOORE:

07:00:15;14 Oh gosh.

QUESTION:

07:00:16;26 I mean what 65-year-old now, did you really think this was gonna turn into this big thing you were known by?

GORDON MOORE:

07:00:21;17 No, of course not. This was an article in one of the industry throwaway magazines. Their 35th anniversary edition, and I was in a unique position to see what was happening with the development of integrated circuits. Up until then they'd just been expensive. You know, the military used them or they were really interested in the size and weight. But they didn't compete commercially. But I could see things were changing. That this was gonna be the cheap way to make electronics.

07:00:52;15 And that was the art really, the purpose of the article was to get across the idea that the trends in the

technology are gonna make electronics cheap because of increased levels of integration. And I just took the first few points. They'd been about doubling every year since the first planar transistor. And we were making the things in the laboratory then had about 60 components on it.

07:01:18;13 So, I extrapolated for ten years and continuing to double every year. Went from 60 to 60,000, which is pretty wild. And had no idea it was gonna be at all accurate, I was just trying to get the trend in there. And instead of ten doublings, we only had nine during that time. But it followed amazingly closely. And one of my colleagues named it Moore's Law. Now, I couldn't say the term for 20 years, I don't think. It was kind of embarrassing.

07:01:55;09 And I finally have gotten relaxed and I, it shows up every place now. In

fact, I Googled it recently, and I Googled Murphy's Law, and there were twice as many references to Moore's Law as there were to Murphy's Law. So, I'm better known than Murphy at this stage of the game.

QUESTION:

07:02:14;17 Well, that's something to be, that's pretty famous. Being better known than Murph[y] but I mean this, was this like a ten minute thing? As you're typing this article, you really think through it...

GORDON MOORE:

07:02:24;09 No, I, it took more than that. I had to dig out the data and make some plots.

QUESTION:

07:02:28;22 Okay, go back when the 4004 microprocessor was invented, you said it was all kinds of crazy applications that people put the thing into. What were two or three of those things?

GORDON MOORE:

07:02:41;21 Well, one guy automated his henhouse. Now, I don't quite know how yet, how you automate a henhouse. But that was one of the early applications. There was a marijuana sniffer that was used for drug detection. Just all kinds of controllers that previously would have been built by individual components. People found that they could program this little computer to do the function they wanted. Just a whole bunch of them.

QUESTION:

07:03:13;18 Let me ask you about all these spin-offs that were going this industry's like flowered and growing, and it was okay to fail, you'd get a job the following week. Was there sort of a critical mass at which people knew it was time to jump for that venture capital and move on?

GORDON MOORE:

07:03:26;10 Well, it's something you kind of developed over the several years, once

the technology got developed enough, people could pretty well duplicate it or get close to it. And the nature of intellectual property and the patents in particular in this industry, was complicated. In that it's a long serial operation to build these things. And everybody who has participated has some patents along the way.

07:04:01;08 So, people's general concern was to get a strong enough position that they could trade with the people who were already there. So there was very little enforcement of patents that would result in people not being able to pursue their business. It was kind of get enough so you can trade and go ahead and do it, you know. Some of the real early players, like Western Electric, the patent agency for Bell Labs, collected royalties when they signed these cross licenses. But they left people alone until they were big

enough to pay some significant fund.

07:04:35;02 I think they had to do the cross-licensing, so, they just waited and collected money. They couldn't have put people out of business because of the consent decree that they'd gone through I think in 1955.

QUESTION:

07:04:51;21 It must have been a heady time with all these innovations popping up all over the valley.

GORDON MOORE:

07:04:55;10 Yeah, it was. You never quite knew which ones were gonna stick. And the important thing was to have enough of them. I'm surprised that actually, that so few of the companies actually have survived. There must be 100 semiconductor companies the started up and died someplace along here. I've never really seen a map of that. They all can trace their origin back to Fairchild somehow or other.

QUESTION:

07:05:32;22 That's pretty interesting. Now, when you were at Fairchild, what was the, was there like one major breakthrough thing that they did? I mean you mentioned the planar transistor, but everybody was in this sort of semiconductor business, but did the invention of the integrated circuit happen somewhere in there? Or was that...

GORDON MOORE:

07:05:48;08 Yeah, well, that was a, I won't say a logical follow on, but depending on the planar transistor technology, the extrapolation to the integrated circuit was relatively straightforward. So, you make planar transistors, you could start making integrated circuits soon after that invention.

07:06:12;02 There were a couple of other bits of technology. There was something called epitaxial growth, which was a new way

of growing silicon that contributed greatly to making integrated circuits practical. Before that, you could make them, but it was a messy operation. Requiring high temperature treatment of very thin wafers. Ended up looking like potato chips when they came out of the furnace.

07:06:39;05 But, with epitaxial growth, you could take a wafer, and grow a layer on top of it. Grow a thin layer of the kind of material you wanted. And that made the whole integrated circuit process a lot easier and made much better devices. But there were a lot of things along the way, a lot of innovation required as we went from a single transistor to hundreds, thousands, millions, billions, along the way.

QUESTION:

07:07:10;13 And was it just a pure exploration process that drove you, or the fact

that we could drive down costs, that competition, what people, what was the mode of force to keep people being innovative in that?

GORDON MOORE:

07:07:22;23 It's a peculiar industry in that the next generation of technology improves everything. It makes things faster, lower powered, more reliable systems, but it makes them cheaper. So, if you fall behind the industry trend in this technology, you become non-competitive very, very rapidly. So, everybody fights, everybody who's still participating, which is a small subset, fight to stay at this leading edge.

07:07:58;03 And this is something that Moore's Law either chronicles or drives, I'm not quite sure which. But everybody knows these exponential expansions we've been on, and realizes they have to go that fast or they get left behind. So, it requires pushing the innovation to make

sure that we can keep moving at that rate.

07:08:20;22 The industry even banded together and set up a research corporation to support research in universities. To be sure that the research is done far enough ahead of time, that by the time the technology is required, we have some kind of track laid ahead of this locomotive to keep it going. And that's been very useful.

QUESTION:

07:08:44;29 And what, that's an organization, or...

GORDON MOORE:

07:08:45;29 Yeah, an organization called the Semiconductor Research Corporation, I think. SRC. And it collects dues from the various participants, pushes university work, oriented principally towards silicon. The problem was, universities were tending to do their research off on weird compound semiconductors of much less practical

importance but fine for research. The SRC kind of keeps it focused on the problems that the silicon industry sees down the road.

QUESTION:

07:09:21;00 Let me jump in with some more personal questions here, for a moment. Do you have a...

QUESTION:

07:10:06;24 Let's talk about some personal things. Do you have a favorite kind of music, a favorite song, an artist, something that...

GORDON MOORE:

07:10:12;09 I like classical music, actually.

QUESTION:

07:10:17;28 Favorite piece?

GORDON MOORE:

07:10:17;24 Yeah. I've got several of them. I like Beethoven's Third Symphony, Scheherazade.

QUESTION:

07:10:29;09 Good stuff.

GORDON MOORE:

07:10:30;26 Yeah.

QUESTION:

07:10:31;22 Let me ask you this one, I mean, we didn't talk about you, about how you got started in this business. Were you inspired by historical figures or were there people in your life, family members or something that sort of moved you into this scientific...

GORDON MOORE:

07:10:42;23 No, not much. You know, I'm the first in my family to go to college. My father had to quit school in seventh grade because his father died and he had to support the family. He was, at one time, I won't say upset, but concerned, he would have much rather have had me be an MD than a PhD, I think. Because he at least knew what MDs did. So I haven't really had a someone that I was emulating. A mentor along the way.

QUESTION:

07:11:22;17 What drove you? Just an inner voice,

or...

GORDON MOORE:

07:11:27;14 You know, what got me in the technical area was when my neighbor got a chemistry set when I was about eleven years old. And, I found out you could do some really neat things with that. In those days. You can't get those chemicals anymore. And I decided very early I wanted to be a chemist, not necessarily knowing what they did.

07:11:48;18 I had a home laboratory in which I did such things as turn out small production quantities of nitroglycerine, which I made into dynamite. A couple of ounces of dynamite makes a fantastic firecracker. So, I kept my interest in chemistry, in that way. Then gradually got into the more technical aspects of it.

QUESTION:

07:12:15;12 But, it was just there's always just been this sort of, "I have to

discover." I mean what, I mean you didn't sit around thinking if Thomas Edison or Enrico Fermi or some other scientist inspired you? You just...

GORDON MOORE:

07:12:27;06 No. How to make a bigger bang was more nearly my motivation.

QUESTION:

07:12:32;05 Well, that's interesting. You've made a couple of big ones, haven't you?

GORDON MOORE:

07:12:38;19 Mmm-Hmm

QUESTION:

07:12:39;12 What about, let's talk about some of the people you've worked with, and some of the important things about them. Like talk about Noyce a little bit. Tell us a little bit about what people should be thinking about him.

GORDON MOORE:

07:12:45;03 Well, you know, Noyce is one of these people who everybody liked the moment they met him. Just a marvelous personality. Very bright, very full of

ideas. Almost too full of ideas. He'd throw them out and it would be good enough, you couldn't not consider them. But he seldom followed up to see if you did. He just threw out these ideas and some worked and some didn't. But in fact, he made some really important contributions to the development of the industry. And then gradually, he got away from the technology and the products and got much more interested in the health of the industry overall, and so forth.

QUESTION:

07:13:32;12 What were some of his big contributions in the industry?

GORDON MOORE:

07:13:36;14 Well, obviously the invention of the practical integrated circuit was. I could go back in the early days of Fairchild, we split up the technology and I in particular had a couple of areas where we had problems. For example, in our diffusion area, where

we were putting impurities into the silicon, the electrical properties of the devices weren't coming out right. And we were struggling to find out what the heck was causing the variation and the like.

07:14:10;11 He suggested one day that I de-plate nickel on the back of the wafer. For no good reason I could think of. But I'd run out of ideas, so I said, "Okay, I'll risk putting nickel in one of the furnaces." I put it in and the electrical properties came out perfect. It completely solved that problem. And you know, I didn't know why at the time, I'm not sure he did. But his suggestion solved that, in particular.

07:14:43;09 Another thing had to do with the metal we use for interconnections on the transistor. We wanted to find a metal or alloy that would make good contact at two different kinds of silicon, the

P-type and the N-type that are necessary to make a transistor. But this requires metals that have different electrical properties when they get dissolved in the silicon. So, I was working with complicated alloys, the silver and gallium and one thing or another. Kind of going up and down, not making much progress.

07:15:18;15 Bob came by, and said, "Why don't you try aluminum." Well, everybody knew aluminum interacts with silicon to make P-type alumin…, P-type silicon. You didn't want a P-type contact to the N-type silicon. So, not having anything better to do, I tried it. And lo and behold, made good contacts to both the N-type and the P-type.

07:15:44;03 I think it was five years after that before I understood why, and before the industry understood why. But switching to aluminum made the thing practical.

So, there were two major problems he solved by a couple of suggestions he threw out. Neither one of which I thought was a good idea, I'll have to admit, before I tried it.

QUESTION:

07:16:06;14 Well, how much of it, this business, is just you get lucky, or it's an accident? A lot of people...

GORDON MOORE:

07:16:11;08 Well, he probably had reasons for suggesting those things, but he never got into them with me. There was a period of time when the technology got significantly ahead of the science. As we did things that worked, but we had no idea why they worked. And that was a significant part of the research laboratory's job, was to find out why these things worked so we could figure out how we could continue to improve them.

QUESTION:

07:16:41;25 What's an example of something that

worked, that you didn't know, that we might relate to? Or was it really technical chemistry, sort of?

GORDON MOORE:

07:16:51;11 Well, the aluminum one is probably a pretty a darn good example.

QUESTION:

07:16:54;12 Yeah, that's a good one.

GORDON MOORE:

07:16:54;02 From what I knew of the physics of these devices, it shouldn't work. In fact, it turned out working fine.

QUESTION:

07:17:04;20 What about, you mentioned Shockley a little bit before. What, tell us a little bit more about him. I mean he invented, he was credited with inventing the transistor?

GORDON MOORE:

07:17:12;23 Yeah, he invented the junction transistor and several other devices. He had tremendous physical intuition. One of my colleagues claimed he thought Shockley could see electrons. But you

know, the lack of continuity on his original goal was one problem. Where he started out to make a transistor, which was a general purpose device, and then for some reason or other, decided to make this four-layer diode, which was a very special purpose thing that has never become important.

07:17:51;00 So, there he lacked the insight into really where the market was gonna develop. But, the real problems with him was that he was extremely competitive, and he didn't really appreciate how people reacted to his competitiveness. I was lucky. I was classified as a chemist, so he didn't think he had to know everything I knew, because he was a physicist. But the, my colleagues who were physicists, found this particularly tough.

07:18:29;17 But, he did such things, for example, he asked some of them what they had

liked to do, you know, in the laboratory. And these were young scientists. They would like to be able to publish some papers. So, he went home that night. Worked out the physics of an effect in semiconductors. Came back the next morning, and said, "Here, flesh this out and publish it." You know, it took all the creative insight away from the people doing the job.

07:19:00;06 And one of the things that turned out to be a major problem, is we had an incident where one of the clerks cut her hand on a little point sticking out of her door. And Shockley decided this was malicious. And he was gonna find out who put that there to hurt this lady. And he was ready to go through the whole staff with a polygraph test. And we disabused him of that.

07:19:36;06 And he had his favorite candidate,

which was our metallurgist, who had an unusual personality himself. The metallurgist, took this pin, went out, looked at it through the microscope, discovered it was the metal part of one of these glass-headed tacks, where the glass head had been knocked off. And somebody just pinned something on the door. And somehow or other, the head got broken off, and that's what she hurt her hand on. You know, it was, you know, a couple of weeks there, near as I can recall, it was a major problem around the lab.

QUESTION:

07:20:17;07 Strange, isn't it?

GORDON MOORE:

07:20:18;01 Yeah, it was. Yeah, he was paranoid.

QUESTION:

07:20:19;23 What about, did you know Kilby?

GORDON MOORE:

07:20:21;12 Oh yeah, I knew Kilby quite well.

QUESTION:

07:20:22;23 Tell us a little bit about Kilby and

what he did and what your relationship with him.

GORDON MOORE:

07:20:28;22 Kilby kludged together a circuit in showing that you could use semiconductors for all the elements. Resistors, capacitors, and transistors. And it was really a laboratory kludge but it demonstrated that was possible. The contrast of that was Noyce. Noyce took the planar technology and pointed the way to a practical integrated circuit. So, the two of them kind of had complimentary contributions.

07:21:02;21 I was on a government committee with Jack for several years. We used to get together in Washington every six weeks or so. Or in New York, typically, every six weeks or so. I never felt uncomfortable walking down the street with Jack in New York. He was about 6'8" and weighed over 200 pounds. A big, husky guy. I don't think anybody

was gonna tackle him while we were there.

07:21:32;18 Very self-effacing, quiet kind of a person. Really an inventor. He had, he tried inventing several other areas, too. You know, ahead of his time. He was trying to make a solar-to-hydrogen converter using silicon, heck, 30 years ago, at least. And had some clever ideas for that. I guess they never quite panned out.

QUESTION:

07:22:04;08 How did it turn out that you and Noyce decided to leave Fairchild and be partners and start Intel? Were you good buddies? You were working on the same thing, or...

GORDON MOORE:

07:22:11;28 Yeah, we were. He was my boss. In fact, when we left, he was my boss once removed. There was another person in between us. We got along pretty well together. You know, we, he was a much

more outgoing personality than me. But our interests were kind of complimentary. I could filter through his ideas and decide which ones I wanted to try.

QUESTION:

07:22:44;23 But when you came over here, to Intel, did you become more managerial and less a scientist? Or, did you walk both paths? Or how did, tell us how that worked?

GORDON MOORE:

07:22:57;02 Yeah, I guess I did. One thing the, we decided in the beginning, is that we would essentially share the job of running the company. He was president, I was executive vice president. But he said, "You know, one thing he really wanted was somebody he could talk to as an equal." And we were, that worked out fine. He would kind of worry about the outside stuff, I'd worry about the inside stuff. I'd worry about the products and the technology. To some

extent, the marketing.

07:23:30;21 He worried about financial arrangements, major customer contact, that kind of stuff. I didn't like the government saying he seemed to enjoy it. It was things split up fairly naturally.

QUESTION:

07:23:48;16 And so that was in '68?

GORDON MOORE:

07:23:50;05 Yeah.

QUESTION:

07:23:50;29 So, about 30 years, Intel's been around.

GORDON MOORE:

07:23:53;07 40, isn't it?

QUESTION:

07:23:54;23 Probably 30 or 40. '68? 40.

GORDON MOORE:

07:23:57;20 40.

QUESTION:

07:23:56;10 See, I can't even add. Why am I doing this? In those 40 years, what, tell

me, what are some of the breakthrough moments that you remember at Intel. I mean there's been so much, but there must have been four or five or maybe three or four just eureka moments that you guys shared. What were some of those big things that you said, "Man, did we ace it!"

GORDON MOORE:

07:24:12;23 Well, getting our first memories to work was, we started out, we set ourselves, I think it was, four technical goals we wanted to achieve in the, by the end of the first year. Which was only six months. And we kind of chose sides. Who said we could do it and who said we couldn't. And New Year's Eve, we actually made the last one. So those of us on the side that said we could do it, had to throw a party for those who said we couldn't, was the way it worked out.

07:24:49;19 Getting that, those things done that

soon I think was important. But then when we started trying to make products, it was almost an accident when one came out and worked. And we would announce, you know, six good memory chips or something. So, we celebrated several of those early things with the champagne parties in the little room we had there.

07:25:23;05 Those were kind of just the startup things then. We invented some of the new memory devices. I remember particularly one called an EPROM. Erasable, programmable, read-only memory. And it was an idea that was based on the physics of the semiconductor oxide, silicon oxide. And that turned out to be a very important product in Intel's history. The guy that developed that, in fact I just saw him last week, over the weekend, in Quebec City. He was getting an award from the IEEE, and I

was as well, for this invention that happened in the early '70s.

07:26:17;15 He made this product and demonstrated it and it was just spectacular. Got a standing ovation at a technical conference. We showed what the thing could do, so that was certainly one. And then it gets kind of fuzzy. A lot of things are happening. Clearly you know, we're progressing, making new products. Tend to remember the negative ones more than the positive ones.

QUESTION:

07:26:50;07 What's something that was just an absolute failure?

GORDON MOORE:

07:26:55;03 Well, our watch business.

QUESTION:

07:26:58;00 Your watch business?

GORDON MOORE:

07:26:58;16 Well, again, as with calculators, watches were something where you could

make a chip, and sell it in large volume. And we were the first company in the liquid crystal watch business. One of the first ones out, too. We acquired a very small startup that had the liquid crystal technology. And started trying to make watches.

07:27:25;12 And the first one we were selling for 150 dollars. And we thought that the watch could be expanded into a much more complicated device with a lot of additional functions. I think we were viewing an iPod or an iPhone on a watch. Not very clearly. But something that did a lot of different things. And we were wrong at that time. You know, all people wanted was time, day, and date.

07:27:56;29 And by the time we got out of the business, the chip was costing us less than the push buttons on the side for setting the time. So, that was, you

know, a failure as a business. I kept one of the latest model developmental watches, which I referred to as my 15 million dollar watch for many years. But, it's too sensitive to moisture, so I, there's a waterproof one now made by a company that stayed in the business.

QUESTION:

07:28:27;08 Okay, also when you came to Intel, you did some things like you let engineers deal directly with suppliers, I mean things that weren't normally done in other companies. What, tell us about some of those things and how they encouraged invention.

GORDON MOORE:

07:28:41;11 Well, for...

GORDON MOORE:

08:00:00;28 You were asking me about some of the things we did in the beginning.

QUESTION:

08:00:02;12 Right, right. Yeah. The manage, yeah, there's a, I've read there's a whole series of things. You know, management

layers that, don't book the money until the customer buys it as opposed to the wholesaler. Maybe I'm saying that backwards. Some things I got more from the management innovations that they can tell.

GORDON MOORE:

08:00:21;04 Well, some of the ones right in the beginning one of them was in setting up the initial budget technology and the like. We gave the engineers purchase order books, not requisitions, but purchase orders. And let them decide what equipment they wanted and negotiate with the vendor. Write out the purchase order and hand it to them.

08:00:40;27 You know, most of the salesmen weren't used to that kind of thing. They were expecting a purchasing department to get in the way. But, we wanted to get going as fast as we could. And giving the engineer a complete responsibility really made them think what they needed

and what they didn't. They were much more careful, I think, than had they just written things out and let somebody else do the actual purchasing. That worked very well getting us going.

08:01:08;01 Another thing we did was eliminate a problem that had bothered Fairchild in that they had put a lot of products and distributors, had a competitor cut the price, been unable to cut the price on theirs without taking a big hit to the P&L, so they let their competitor get market share. We decided that since we protected our distributors for price decreases, that we shouldn't count anything as sales until it actually moved off their shelf to the final customer.

08:01:44;09 Now, this was a bit of a tough sell to our accounting firm. But we convinced them of the validity and it had become kind of standard practice in the

industry now. It was actually, I think, spread to some other industries, although not as completely as it should have. These were examples of the things we did to get going in a hurry. And we had a rather egalitarian society. No reserved parking spaces. If you wanna park close to the building, get to work early. That kind of thing.

QUESTION:

08:02:20;04 So, it was almost a thing that everybody was sort of working together on the same team and there weren't big hierarchies, and that seemed to make things work better.

GORDON MOORE:

08:02:28;21 Yeah, that was certainly the case. We've tried to prevent hierarchy developing in the company. Free-flow of information is extremely important. There's so many technical decisions, they have to be made by the people that understand technical problems. You

can't have administrative people who don't understand the problems making technical decisions. And we pretty well avoided that. And I think Intel still does pretty well. We try to put decisions down to the level of appropriate technical confidence.

QUESTION:

08:03:07;04 Yeah, tell me a little bit about the growth. You started in '68 and then you take off, you go public, so take me through that quickly. The whole...

GORDON MOORE:

08:03:13;15 Well, we thought in the beginning that the, we had to get fairly good sized in the first five years. So, by the time our competitors started seeing us, we'd be far enough down the road that we could survive. Our original goal was to get to 25 million dollars in sales in five years. Which these days doesn't sound like much. But, it was pretty aggressive at the time. We actually got to 63 million in five

years. So, we did pretty well on that.

08:03:55;01 In my view, it was a relatively smooth startup. But, it's interesting, the different way people felt about it. Andy Grove, who came with us from the beginning and ran the company after me, was here during that time and he considers it the most trying time of his life. He was afraid we were gonna go broke every week, I think. And I was pretty relaxed about it. I thought things were going especially well for a startup. So, either I didn't understand the problem or he didn't get a complete picture of it. But we sure had different views of that time period.

QUESTION:

08:04:30;28 And was the sense of change very rapid? Were things moving quickly and...

GORDON MOORE:

08:04:36;00 Things were moving quickly, but I think his expectations for some things were

greater than mine. For example, our first memory products were kind of mundane. I didn't expect to sell an awful lot of them, but it got us going. And he was disappointed that the world didn't beat a path to our door when we first got a product out. It wasn't until we made the first dynamic memory available that our market really started to explode.

QUESTION:

08:05:08;00 At what point did you go public?

GORDON MOORE:

08:05:10;17 We went public in 1971 at a time when we still were not profitable, but our business was growing pretty rapidly.

QUESTION:

08:05:27;29 We went public...

GORDON MOORE:

08:05:30;22 In 1971, at a time our business was growing rapidly. Even though we weren't yet profitable. Interestingly enough, we went public on the same day and the same price as Playboy

Enterprises. And several years later, one of the analyst conferences, one of my colleagues who was then an analyst. Actually, he was a student of mine. I was a grad student, I'd known him for a long time, got up to give a talk. He looked at this and he says, "The market has spoken. Memories over mammaries, ten to one."

QUESTION:

08:06:09;06 Wish I'd thought of that story.

QUESTION:

08:06:21;27 What about, I mean, this whole sort of information and high technology business seems very American in some way. It sort of was born out here. And of course, you know, 30, 40 years ago, is there still something about America that makes this a great place for innovation, even though we're in a global economy now?

GORDON MOORE:

08:06:38;03 I think there is. Some of the things we talked about, I think lack of fear of

failure is an important part of it. People are willing to try things. They figure if they don't make it, they can do something else. The availability of venture capital is important; people with a good idea can generally get it financed. Or at least under more circumstances can. I hope that continues to be the case.

08:07:13;09 And there are a lot of successful examples where engineers with no previous business experience have succeeded in setting up major companies. And there continue to be examples being created. So, I think as this has developed an entrepreneurial environment that's not matched anyplace else in the world.

QUESTION:

08:07:32;11 And why do you think that is? What is it about America that makes people feel that way?

GORDON MOORE:

08:07:39;00 It's hard to say. I don't know. It just has worked out that way, certainly. It's not being an American. And a lot of the entrepreneurs are born in other countries, particularly now. Both China and India create people with very strong entrepreneurial urges. But they've been able to exploit them, they've been able to develop them, best here in the US.

QUESTION:

08:08:10;03 Just maybe the way the markets work here or...

GORDON MOORE:

08:08:12;17 Well, the US market being as large as it is and monolithic, was certainly important in the beginning. In Europe, each of the countries, in the time Intel was getting started, kind of wanted its own view of the world and you didn't have a uniform standard sort of thing. Well, the US did. I think that was very helpful to have this integrated market. We've had some

other advantages. At one time the military market was important, for example, to the semiconductor industry. Gave it a boost at a time when it needed it.

QUESTION:

08:08:51;09 Let's talk about some of the things, I mean all these things you've accomplished and places you've, what are some of the things you're most proud of in your career?

GORDON MOORE:

08:09:02;00 Well, I think generally, just the fact that Intel has developed to be such a major corporation and has continued to succeed. It's hard to pick subsets under that. I guess I ought to be proud of Moore's Law but I'm almost embarrassed by the fact that I got such traction from such a relatively trivial article.

QUESTION:

08:09:28;03 Well, it's a good thing to be held by, I guess. It's been true for, it's not

gonna continue to be true, is it?

GORDON MOORE:

08:09:34;10 Well, for a while. It's gone further than I ever imagined it would.

QUESTION:

08:09:39;00 Let's pretend we had a bunch of, like school kids here, young kids, and they were contemplating what they wanna do with their future. From your perspective, what would you tell them would be important things that they should look for?

GORDON MOORE:

08:09:51;01 Oh gosh. Find out, find something that they really enjoy doing and pursue that. Things are changing so rapidly, that the first thing they ought to do is get a good education with a strong basis in the fundamentals. The details you learn you're probably not gonna use for very long. But the fundamentals don't change.

08:10:18;03 And during your career, you'll probably

have three or four really different jobs. But you won't depend upon exactly the same thing. So, you gotta be in a position to be flexible.

QUESTION:

08:10:35;08 And what about, where do you see this industry going? I mean, as you look down the road, are there big breakthroughs coming? Are we sort of getting mature here? What's gonna, what's happening in this [industry]?

GORDON MOORE:

08:10:46;19 Well, you never anticipate the big breakthroughs. Those are the things that really surprise. You, if you'd asked me in 1980, I probably wouldn't have predicted the importance of the personal computer. And in 1990, I wouldn't have seen the Internet. These things just become important kind of out of the blue. I hope there are more of those. The industry, in a lot of respects, has matured. Its growth rate has changed dramatically.

08:11:20;03 It had to. If it hadn't, it would have exceeded the national gross national product by now. It was growing so much faster. But it is a basic industry utilized broadly across modern society. So, I think it's gonna be around for a long time. But, it gets harder to enter the mainstream. It's gonna be a very expensive business to operate in the mainstream. So, there will be fewer and fewer companies that are able to do that.

QUESTION:

08:11:58;03 And what about if somebody wanted to get in the business, they wanted to be an engineer, what should they look for? Is it gonna turn out to be a great career or is it getting more, you know, are we just filling holes or what?

GORDON MOORE:

08:12:12;21 It can still be a great career. There are opportunities to do new things. On the other hand, it's harder for the

individual to do something great anymore. It tends to be done by fairly large teams. The complexity of the products is so great now that no one individual can really span it. You know, a development team now for a typical product is several hundred people. With a broad range of experiences and you know, each doing a[n] important part of the whole. It requires a management of much bigger groups than it did when Intel got established, for example.

QUESTION:

08:12:58;07 So, you think like a small company that's starting up and sort of the semiconductor, the hardware end, would have a tougher go now? Because of the big giants that are...

GORDON MOORE:

08:13:06;15 Well, it's never been an easy go. A lot of them have failed along the way. I think it requires having a good idea for a product or technology. You know,

a few years ago, I go over to Stanford and everybody in the business school was planning on a startup or was going to a startup. With the idea that you decided you were gonna do a startup, then you went out and found out what to do. My view is different. My view is you e come up with an idea that requires being separated or allows being separated. And then you decide you're gonna do a startup, if it makes sense. I've only seen a few ideas in my career that I would have considered sufficiently different to start a new company with.

QUESTION:

08:13:59;02 And what were some of those?

GORDON MOORE:

08:13:59;09 Well, the transistor, the silicon transistor. The integrated circuit at the right time. You know, I think the one Intel exploited in semiconductor memory, changing the leverage in the business. Those don't come along every

day.

QUESTION:

08:14:19;21 What about people who don't even know what a semiconductor is? What do we, what do you tell them it is? If somebody said, "What is it?"

GORDON MOORE:

08:14:28;28 The semiconductor is a material whose electrical properties could be controlled by putting in impurities. And, in particular, you can make these things called junctions, where one impuritiy dominates in one place and another one in another. They only conduct electricity in one direction. Using this, using a bunch of these, you can make switches and amplifiers and that's what modern electronics depended on.

QUESTION:

08:15:00;25 And then you shrink those all down? You...

GORDON MOORE:

08:15:03;16 We make them smaller and smaller and

they get better and better.

QUESTION:

08:15:06;26 Are they really gonna be made out of a single atom soon? Is that really a...

GORDON MOORE:

08:15:12;09 We're not far from there in some of the layers now. But when you get down to that point, quantum mechanical effects can actually cause you problems. So, we're limited in how far we can go with our current technology. But, it's a very flexible technology and it's being exploited in a lot of other directions. For example, the biotech industry uses technology developed in the semiconductor industry, to do some of their most rapid sequencing. They can make these gene chips that allow that to be speeded up and the cost reduced by orders of magnitude.

08:15:56;04 Medical devices with tiny little chemical laboratories built on a chip, also to take advantage of the same

technology. And things like the sensors for air bags in your automobile depend on little mechanical devices, made again with the same technology. So, it's a very versatile way of making microstructures that are important in a large number of applications.

QUESTION:

08:16:21;03 Let me ask you this: when people look back at you 100 years from now, when they read about Gordon Moore, what would you like them to, the message you'd like them to take away to be remembered for?

GORDON MOORE:

08:16:29;15 Gee, if I just am remembered, I'll be happy.

QUESTION:

08:16:34;09 Obviously the joke is obviously not Gordon Moore's Law, you told us that. But I mean seriously, I mean, of all the things, what would be the thing you'd like most to be remembered for?

GORDON MOORE:

08:16:48;13 I've never really stopped to think much about that. You know, I think that 100 years from now, really, if I'm remembered at all, it'll be enough.

QUESTION:

08:17:00;29 But, is there anything that you've done that it might be, I mean everybody's gonna remember Moore's Law and they're gonna remember Intel, but maybe there's something else that...

GORDON MOORE:

08:17:10;27 Well, I know there will be the principle things. Now, hopefully my foundation will still be operating then. It's set up in perpetuity. So, maybe some of our philanthropic things will...

QUESTION:

08:17:21;10 Tell me a little bit about that.

GORDON MOORE:

08:17:24;24 My wife and I set up a foundation a half a dozen, no, eight years ago now, I guess. Where we put half of our Intel stock into the thing. And set

them off in a couple of directions that we thought were important and interesting to us. That you know, it's an interesting business. You hope you're doing some things that are gonna have a permanent impact, but you're never quite sure. A lot of our effort is going into the environmental areas.

08:18:04;00 We also have supported scientific research in a variety of ways. My wife has been very interested in nursing, so we have a significant nursing program. You know, we think we're doing some things that will have lasting consequences in 100 years somebody will know.

QUESTION:

08:18:25;02 Let me ask you something, we had a bunch of managers here, just starting out their careers. They wanted to know how to keep their people motivated and happy and get rid of all this folderol that discourages creative agreement.

What would be your message to them? What would you tell, what lessons could we pass on from you to them?

GORDON MOORE:

08:18:42;07 Well, encourage the people that are doing things you think are in the right direction. Give them sufficient flexibility that they really have intellectual contribution to make to their projects. And hire the very best people you can. Don't hire your assistant, hire your replacement.

QUESTION:

08:19:10;14 What about making people feel they have a sense of ownership with a...

GORDON MOORE:

08:19:14;23 Well, as much as you can, absolutely. That's what I was trying to say a little earlier, not quite in those words. But they have to feel that they own their part of the project, their part of the problem. So, they can feel they've accomplished something when they're done.

QUESTION:

09:00:00;09 Be innovative and want to experiment and discover now, when there are so many restrictions around.

GORDON MOORE:

09:00:12;07 We have to come up with ways to motivate the kids go into science, and technical activities, in general. You can't make that your glycerin in your backyard anymore. That would be frowned upon. But there are a variety of other things. Certainly electronics is an area where kids can still experiment.

09:00:36;12 You can still build crystal set radios. Learn from that sort of thing. And seeing what the kids do in science fairs these days there's a tremendous range of things that can be done at home. I'm impressed to find out that high school kids can do gene sequencing.

09:00:58;04 The techniques are not that difficult, and are generally available. I saw an example recently where a couple of high school girls examined fish samples from New York restaurants, and discovered that many of the fish being sold at these restaurants were not what they were advertised to be but were some much cheaper variety. Just being able to do things like that is spectacular. So things have moved to different areas since I was a kid. But I think there's still a lot of opportunities that they can dig out and kids can be really resourceful. They can find these things where I couldn't begin to think of them.

QUESTION:

09:01:38;11 Is there anything, does Intel do anything for kids? Are there any programs or...

GORDON MOORE:

09:01:41;17 Well, we run the science fair these days. The one that used to be

Westinghouse. And another one. We run two major science fairs. So, those help a lot.

QUESTION:

09:01:54;25 And what? Kids enter it, and it's like they win blue ribbons like the science fairs of old that we all remember?

GORDON MOORE:

09:02:00;06 Well, they win scholarships, and you know, $100,000 scholarship, I think, is the top prize. And...

QUESTION:

09:02:07;07 That beats the blue ribbon we used to get.

GORDON MOORE:

09:02:09;12 Yeah, no kidding. And...

QUESTION:

09:02:10;14 The other thing, let me, hand you, remember, we talked earlier about some of these famous quotes. The ones that we've checked. I thought maybe you could just read us a quote, and then, and just give us your reaction to each one.

GORDON MOORE:

09:02:22;27 "There is no need for any individual to have a computer in their home," according to Ken Olsen in 1977. Knowing what digital equipment was doing in those days, I can understand Ken's feeling completely. Again, it's an example of a company having a successful operation at a particular level.

09:02:44;06 That case, the mini computer level, but not seeing the expansion of it to the next level. I'm not sure I would have said anything very different, if someone had asked me at that time. In fact, one of the engineers at Intel came to me with the idea of a home computer in roughly this timescale. And I asked what would he use it for.

09:03:05;16 And the only example he could come up with was a housewife having her recipes on it in the kitchen. I could imagine

Betty sitting there, looking at a computer, trying to cook something. And it didn't really resonate with my idea of where the business was gonna be.

09:03:20;05 So, I don't fault Ken for that. I think from his perspective it was a very sensible comment. The second one is from Thomas Watson, then chairman of IBM, in 1943. "I think there is a world market for maybe five computers." Obviously, IBM sold more than that in their history. Again this was not understanding the breadth of the applications that computers could undertake. He was looking at calculations of more or less the engineering or scientific type. Wasn't considering the fact that computers are useful in handling business information as well. And at least it didn't limit what he did at the company. IBM certainly was the most successful

computer company, over a long period of time, in spite of what their chairman may have said.

09:04:25;09 The next quote is from the editor in charge of business books for Prentice Hall in 1957, which is actually the year Fairchild Semiconductor was formed. "I have traveled the length and breadth of this country, and have talked with the best people, and I can assure you that data processing is a fad that won't last out the year."

09:04:50;13 I don't know how to justify that one. It, but, you know, you see what you think at the time. He didn't quite get it right. An engineer at the advanced computing system division of IBM in 1968, commenting on the microchip. "But what is it good for?"

09:05:17;27 Well, a few things. IBM had an alternative technological approach at

that time. And while they were successful it took 'em a while to get onto the real winning technology.

QUESTION:

09:05:34;29 Two final, thank you for that two final questions...

GORDON MOORE:

09:05:35;28 Okay.

QUESTION:

09:05:35;28 Two final questions. One is, you know, this is an interview that's gonna be preserved and archived and last for a billion years, we hope. Are there any misconceptions or things you'd like to correct on the record? Something that maybe has been printed that's not true, or anythi[ng], a message to...

GORDON MOORE:

09:05:53;08 Yeah.

QUESTION:

09:05:53;07 ...somebody that, I mean, you know what I'm saying.

GORDON MOORE:

09:05:54;09 Nothing in particular. You know, I

never read an account of what went on unless it was directly a result of an interview with me, that I think is right. But different perspectives. People can live through the same history and see it from different angles. And they get dramatically different stories. All of it has to be somehow or other incorporated. But I don't have anything in particular that I'm going to...

QUESTION:

09:06:17;15 There's no big misconception.

GORDON MOORE:

09:06:18;21 No.

QUESTION:

09:06:18;25 ...that you've seen written, or a story that...

GORDON MOORE:

09:06:21;07 I don't think so.

QUESTION:

09:06:22;02 Hmm. Well, what about this? I mean, again, this is gonna last for a long time. If we kind of looked out in the

future. Maybe it's 100, 200 years or whatever. What kind of message would you want to give to the scientists or the entrepreneurs of the future?

GORDON MOORE:

09:06:35;09 I have no idea. Come up with a good idea, if you're gonna attempt to establish a company to exploit it. It's the ideas and the products, the technology that's important. Not the idea that you want to set up a company. Okay?

QUESTION:

09:06:56;15 Okay, very good.