CRAIG R. BARRETT, PH.D.
ORAL HISTORY

COMPUTERWORLD HONORS PROGRAM INTERNATIONAL ARCHIVES

Transcript of a Video History Interview with
Craig R. Barrett, Ph.D.
Chief Executive Officer, Intel Corporation

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Location:	Intel Headquarters Santa Clara, California
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DSM: Today is Thursday, October 24, 2002. We're interviewing Dr. Craig Barrett, the author of *The Principles of Engineering Materials*, and Chief Executive Office of Intel Corporation, the world's largest chipmaker. This interview is taking place in the Robert Noyce Building, Intel Headquarters on Mission College Boulevard in Santa Clara, California.

Growing Up in San Carlos

DSM: To begin, Dr. Barrett, we'd like you to tell us a little bit about when and where you were born and a little about your family, your parents.

CB: I was born in 1939 in San Francisco Children's Hospital. My mother was a nurse for a doctor in San Francisco. My father was a chemist for Shell Oil—he worked in their development labs in Emeryville, California.

DSM: Did you know your grandparents at all?

CB: I knew my grandparents on both sides, although most of them died when I was very young. But I did have some interaction with them.

DSM: You were born in San Francisco, did you grow up there?

CB: I grew up mostly on the San Francisco Peninsula. I moved out of San Francisco in about the fourth grade to Hillsdale, which is kind of sandwiched between San Mateo and Belmont. Then after about two years moved to San Carlos, California, where I went from about the sixth grade through high school.

DSM: Do you have brothers? Sisters"

CB: An older brother and a younger sister.

DSM: What are your earliest memories of California? You are born at the beginning of World War II, at least as far as Europe was concerned.

CB: Obviously, I was seven years old when the war ended. I remember in San Francisco, there were still some vacant lots near where we lived, near Mt Davidson. I remember Victory Gardens there in that time frame. I remember rationing that went on in that time frame. When my mother would cook bacon, everyone saved the bacon fat. So I remember those lean times associated with World War II.

DSM: It is very unusual to have one parent who's had even a high school education. Only ten percent of the country had a high school education. Was your Dad a college graduate?

CB: My Dad graduated from the University of California. There's a real long story here. He actually died when I was about ten years old of cancer. My mother remarried and then my stepfather legally adopted my brother and me. But my father left his belongings to someone where they were in storage for about fifty years.

About two years ago I got a call from a lady who had my Dad's belongings. She had been searching for me or my brother for about five years and finally found us on the Internet. She basically said that she had these cardboard boxes of my Dad's belongings and would I like to have them. The obvious answer was, "yes."

It was a lot of my Dad's stuff, his college textbooks, some of his work at Shell while he was working there as a chemist, photographs of him as a young man, and even some cards and things that I had sent him when he was in the hospital before he died. This was some fifty years after the fact, which was kind of interesting.

DSM: Was your Dad responsible for your interest in science and chemistry?

CB: Yes. He was a very methodical engineering type, and he got me interested in two things— the science background and also the outdoors background. He was a hiker and fly fisherman and he got both of his kids interested in those activities.

DSM: An ongoing passion of yours.

CB: Absolutely an ongoing passion.

DSM: When did you start grammar school and where? Did you know how to read when you started grammar school?

CB: Actually, I haven't a clue. I do remember that I was pretty good in school (in grammar school) especially in math and in the other topics that you study—geography and English and other topics. I don't know if I learned to read before Kindergarten or not. I can remember going to Kindergarten on the first day. There was kind of this traumatic shock.

DSM: Did your Mom take you?

CB: Of course. My Mom took me and then kind of said "goodbye" and left me there with all these strange people.

DSM: Another question we've asked all our interviewees is about early friends before the high school level. Were there kids that you hung out with that were great friends?

CB: There was a group of friends that I grew up with in San Carlos from basically the sixth grade and on through high school, and then even a few of them on through college. Those have been friendships that have lasted over the succeeding fifty years or so.

DSM: Are there stories that your family used to tell about you that gave any hint when you were just a child of what you were going to become later on?

CB: I had set in my mind early on and I think probably convinced my family as well, that I was going to become a forest ranger. I had this love for the outdoors and fishing and hiking and just being outdoors. Being a forest ranger was a very logical extension of those interests.

In fact when I got to the state of deciding to go to college, I applied to two schools: Oregon State, which has a forestry department, and Stanford. And I really didn't think that I was going to go to Stanford for it was exorbitantly expensive, even back in those days in 1957 when I started as an undergraduate. I was accepted at both schools.

I got a scholarship to go to Stanford, and there's a funny story with my application form to Stanford. I was sitting in my fourth year math class at Carlmont High School, where I went to high school. My friend Tom Hessler was sitting next to me. I was filling out this application form during class, which I probably shouldn't have been doing, but I was. I got to the point where it said "perspective major" and I knew that Stanford didn't have a forestry department so I needed to add some other major to put down. I elbowed Tom and I said: "What are you going to major in?" Tom was going to go to San Jose State University. He said: "I'm going to major in metallurgical engineering." And I said, "What's that?" He said, "I'm not sure, but I think it has something to do with metals." I said, "How do you spell it? Is that two "L's" or one?" He told me it had two "L's", so I wrote down metallurgical engineering and received a scholarship from International Nickel Company. I was probably the only incoming freshman at Stanford that had ever said that they were going to major in metallurgical engineering. I don't think they had ever given out the scholarship before. So I was at the right place at the right time.

DSM: Otherwise, you might have been a forester.

CB: I might have gone to Oregon State and been a forest ranger.

DSM: You might still be, I gather from your interest in forestry.

CB: We still have a lot of interest in forestry and we have some property up in Montana. Actually, the last couple of years I have been doing resuscitation or reforestation work on it. We had a lot of damage in the big fires in Montana in August 2000.

DSM: What about teachers in high school? You described yourself elsewhere as an "Okay" student. Were there teachers that made a difference that you can remember?

CB: My math and science teachers, I think, made an imprint on me, especially chemistry and physics and math teachers. But probably the teacher that had the biggest impact on me was my English teacher, Barbara Fracisco, who was a—I'm almost embarrassed to tell you this—she was a very attractive young lady in her early twenties. I know that every senior in the high school class was in love with her, as was I probably. We always used to love to be in her class. But she had a way to get you to think and do things in the area of English and English literature and such. Being an athlete and an engineering type person, I wouldn't have thought I had any interest in English. But she got us all interested in studying English and pursuing things that were far outside of our normal realm.

DSM: What about sports, summer jobs, that sort of stuff when you were of high school age?

CB: In high school, I played basketball and was on the track team. When I went to Stanford, I was on the track team for four years there and then participated a few years in my graduate years at Stanford on the track team. From a job or work standpoint, I think I was probably the normal California kid growing up. I mowed lawns. I delivered newspapers.

DSM: Which newspaper did you deliver?

CB: Oh this was the local paper in San Carlos. Probably the *San Mateo Times*, or whatever it was called in those days. My relatives on my father's side were involved in the Dinwiddie Construction Company in San Francisco, so when I was about a sophomore in high school, I started working as a laborer in construction jobs during the summertime, then as a stock boy at Macy's and things like that during the school year to make money. I think it wasn't until my sophomore year at Stanford that I finally got an engineering job. I worked for a brazing and heat-treating company in San Carlos, called Pyromet. I was a lab technician for them during the summer, but it was engineering work associated with brazing and heat-treating of metals.

DSM: I didn't ask about your uncles and Dad and the war. Was your family directly touched by the war in any sense?

CB: No one was killed in the war, though several of my uncles fought in the war. My Dad was not active in the war.

Catching the Research Fever at Stanford

DSM: We talked about your decision in 1956—sometime during 1956/1957—to go to Stanford. Interesting time. In 1957 you have the Sputnik launch. In 1961, when you get your BS, John Kennedy enters the White House for the first time. For graduate students two or three hundred years down the road, can you describe what it was like entering college as a freshman? It's a lot different at Stanford now than it was in 1957.

CB: Certainly the physical plant is a lot different! They have co-educational housing in the dorms that I lived in and things like that. So there are a lot of differences.

It was an incredibly exciting time for the very reasons you mentioned. It was in that Sputnik era, the National Science Foundation was pushing a lot of money into basic research and a lot of that going into the universities. The Department of Defense was also putting money into research. The Department of Energy was putting money into research. Materials—metals—what I was majoring in, was getting a lot of financial support for research because new materials were labeled as one of the important items to not only to win the space race, but important in the military race as well. So it was an incredibly exciting place to be. It was really "basic research was it."

Stanford had built up its engineering department under Fred Terman, who had been the dean there, in a pretty clever way. He was able to grow the faculty by having them signed on as half-time teaching, half-time research people. Essentially, all the engineering faculty were devoting half of their time to doing research, and only half of their time to doing teaching. This way he could amortize their salaries with research monies to supplement the budget from the university.

So, the entire school of engineering was an exciting place to be. I was obviously swept up in that as many other people were. Then I got my bachelor's degree, then my masters and Ph.D. and, I'm not sure if "brain-washed" is the right phrase, but by the time I graduated, the only thing I wanted to do was basic research. I wasn't interested in applied research. I wanted to just study the fundamental nature and properties of materials and make that my life's career.

DSM: Who were some of the teachers that really made a difference? First of all, in your decision to go on and finish, to become a basic researcher, to go on and finish your Ph.D., because that was unusual at that time and place as well.

CB: You have to know the entire environmental setup at the time. I married my high school sweetheart at the time and was, in fact, working part-time my junior and senior years, and working in the laboratory helping some Ph.D. students. So I was getting my taste of what Ph.D. research was like from the experimental side while still an undergraduate.

It was kind of a logical follow-on to just pursue that activity by going for a master's degree then a Ph.D. But there were a couple of faculty members in the department of material science that really were role models to me. Oleg Sherby, who is still a professor emeritus at Stanford in material science, was one. Bill Nix, who is still on the faculty, was another one. Those two gentlemen ended up as my thesis advisors, whom I worked for several years in that time frame. But they were good role models of doing research, the excitement associated with it. Both incredibly enthusiastic about what they were doing and that enthusiasm seemed to rub off.

DSM: Do you remember any of the other graduate students that you worked for when you were an undergraduate?

CB: Oh sure. I primarily worked for a guy by the name of Jack Litton, who had been a—let's call him a "late return" to get his Ph.D. He had graduated, then worked, had been in the army for a while, then had come back to school. He was in his thirties at the time, which seemed very old. Doesn't seem quite so old now. But I worked and helped Jack do his Ph.D. research for a period of time.

DSM: And what was he working on? You obviously loved it.

CB: Those days we were working on high temperature mechanical deformation of metals. You know, when you hang a load on a piece of metal at high temperatures, it slowly deforms and we were trying to relate the microstructure characteristics to the mechanical strength of materials at high temperature.

DSM: Right in the middle of your progress from freshman to doctorate, Jack Kennedy was killed. Do you remember that day?

CB: Absolutely. I was in the second floor of the Peterson Building. Somebody had a radio turned on and we just were frozen in place listening to that whole scenario.

DSM: What was your disertation topic?

CB: You don't want to know! Something esoteric about the role of stacking vaults and grain boundaries in the high temperature mechanical deformation of metals. Don't ask me what stacking vaults are, I've forgotten. But it was really exciting at the time.

The Road to the Fulbright

DSM: Immediately after you got your Ph.D., and my chronology may be a little messed up here, did you go to England as a post-doc just after you got your degree and before you started teaching at Stanford?

CB: Correct. I left Stanford, I guess, in the fall of 1964. I had finished up my Ph.D. work. I had a NATO post-doc fellowship. NATO at that time was giving fellowships to promote scientific interaction between the NATO countries. I went to a place called The National Physical Laboratory in Teddington, England. It's about halfway between Windsor and downtown London.

The National Physical Lab is the equivalent really of the National Bureau of Standards in the U.S. They do research in a wide variety of topics. There was a renowned scientist in the area of mechanical deformation of metals, Don McLean who was there, and I went to work in his group for a year. With my wife and two young children at the time, we lived on the princely stipend of $7, 000 a year.

DSM: A "princely" sum.

CB: At that point in time with the exchange rate in the U.K., I was effectively making more than the lab directors at the National Physical Labs. So I went from being a poor impoverished graduate student to a very, very, royal salary in U.K. for a year.

DSM: And you had two children then? Girls? Boys?

CB: My daughter is a year older than my son and they were three and four at the time.

DSM: You do a year of post-doc research at Teddington. Tell me about the decision to come back to Stanford.

CB: While I was at Teddington, one day I received a letter from Stanford saying that Professor Macris, Vic Macris, who was the professor in material science that worked on electron microscopy and x-ray diffraction and characterization of defects in solids, had decided to pursue a commercial career, building basically an electron microprobe, a device that takes a focused electron beam and shines it on the surface of materials and then you analyze the emitted x-rays for chemical composition and such. So Vic Macris went off to do that and they had a faculty opening and they asked me if I was interested. I didn't have any other job prospects at the time and I said sure I'm interested.

DSM: That's not too shabby a job.

CB: It wasn't too bad, no. So I came back from the U.K. in the fall of 1965 and got a pay raise. I was now up to $9,000 a year to start to teach at Stanford for a year.

DSM: Was it unusual for Stanford to hire its own Ph.D.s?

CB: There were two unusual aspects to it. One, it was rather unusual at the time to go straight through bachelors, masters, and Ph.D. at the same school. That was a little bit frowned upon. One should go off and explore new pastures and get different perspective on life. You have to imagine though that I was married, I had two young children and I was interested in getting my degrees as rapidly as possible. I knew the system at Stanford. My grades were good enough that they were willing to accept me as a graduate student there, so I stayed and blasted through in three years. But then to get an invite to come back and teach after having been so ingrown was perhaps a little unusual as well.

DSM: Obviously the work you were doing was much appreciated. In 1969, you were awarded the Hardy Medal. Tell us about that.

CB: That is an award given by the American Institute of Mining and Metallurgical Engineers for someone who shows great promise under thirty years of age. So I guess I just barely made it in 1969, being under thirty.

DSM: In 1972 you became a Fulbright Fellow and went to Denmark.

CB: To the Danish Technical University, Lyngby, Denmark.

DSM: What can you tell me about that?

CB: One of the benefits of teaching is you get sabbatical leaves. Sabbatical leaves are designed to allow you to go off and do something new, refresh and, perhaps, to pursue new ideas. The Danish Technical University had a materials department that was run by a gentleman who's still there.

Rod Cotterill was doing some very, very interesting computer simulation work on atoms and solids. Very simply, he was modeling an array of atoms with vacancies or imperfections in them, and seeing how those imperfections or vacancies might move under thermal vibrations as you raise the temperatures. I went there and did some teaching and did some research for a year.

"There Has to be Something More to Research"

DSM: Do you like teaching? Are there students that you remember because they were particularly good or particularly difficult?

CB: Teaching was exciting for two reasons. One, it was a great learning experience. Anyone who tells you that they don't learn more teaching a course than taking a course is crazy. You have nightmares about all the possible questions you will be asked if you are lecturing on a topic. Therefore, you learn the material really well if you are going to stand up in front of a group of bright graduate students like Stanford had and try and teach it. That aspect I found enjoyable because I learned a lot.

Another aspect I found enjoyable was when you saw the light bulb click on in somebody's head, when you're explaining some complex business about electron diffraction technique with an Ewald sphere, and a reciprocal lattice, and you put this together with that, and you can predict what the diffraction pattern is going to look like. There are some very abstract concepts. But all of sudden you would see two or three people who's eyes would light up and say, "Gee. I understand that." And I really feel good when that happens. It's just the same way a teacher in elementary school feels good a child learns mathematics or fractions or learns to read. Just recognizing that you've helped somebody understand something is a wonderful feeling. I enjoy teaching because of both aspects.

DSM: You enjoyed teaching. You enjoyed research. Stanford's a great place to do it. 1972 you a Fulbright to go do some more research in Denmark and do more teaching. And two years later you make this very strange decision. Can you talk about getting there?

CB: Well, it wasn't a strange decision. Remember that I grew up at Stanford doing basic research. I joined the faculty doing basic research. After awhile I began to recognize what it was like to do basic research from my perspective. What it was like was very interesting challenging topics, working with very bright graduate students, able to get research funds to do some very interesting things. You do the research, you write the paper, you publish the paper, six people from around the world would be interested in what you were doing. You knew all six of them beforehand; they knew what you were doing beforehand, so publishing the paper is an interesting exercise, but that was it. I just started to feel that there had to be something more to doing research.

At the same time, I was doing a bit of consulting. And some of the consulting was with some of the companies in Silicon Valley that were starting out. Fairchild was still around at that point in time. National Semiconductor was still around at that time. Some of the people that I had been working with in consulting at Fairchild, had left to join a new company called Intel. My interest had started to move from basic research to more applied aspects of research, wanting to see something come out of my research activities other than a technical paper. If you then start to move in that direction, and say, "All right. I'd like to see my work result in products which get into the marketplace in a finite period of time," you start to say, "What industry is moving technology most rapidly into the marketplace? Is it the classic metals industry, steel industry, automotive industry where it takes ten years to create a new brand of steel that goes into making bumpers or fenders or something like that? Or is it the semiconductor industry where they're introducing new products every six months?"

This concept of Moore's Law—Gordon Moore coined that law in 1965—so it was around at that time. This concept of doubling something every eighteen months or so was starting to permeate the industry. In the early 1970s, if your interests started to move out of basic research towards applied research, or towards products, and I looked at myself—seven years of University training, basically ten years of teaching, pretty good technical background, and I want to apply that background—let's apply it to the high tech industry that's moving fastest. And it so happens it's just right down the road a few miles. Why not go down to Intel and see what can happen?

DSM: It's a pretty extraordinary group of people.

CB: The absolute best part of the last twenty-eight years at Intel, was working with Bob Noyce when he was still alive, Gordon Moore, Andy Grove, and then just a host of other folks not just at Intel, but in the industry in general.

DSM: Is there a story or a conversation that led you to make this jut?

CB: There was a specific conversation. A gentleman who still works at Intel, Gene Meieran—he's one of our Intel fellows—he had been at Fairchild. We had both been interested in x-ray diffraction and x-ray topography techniques for looking at defects in semiconductor devices. He had gone to Intel. He called me one day and he was now working in packaging, electronic packaging. Ceramics were very critical in electronic packaging and he asked me, "Hey Craig, do you have any graduate students who know anything about ceramic engineering. We'd like to hire one." I didn't know of any graduate students at Stanford. We didn't have any that were in ceramic engineering. I said, "No Gene, we don't have anything. But how about a frustrated associate professor?" And the next thing I knew, I was down at Intel talking with a series of folks—Andy Grove, Ron Whittier, and Les Vadasz and the senior management of Intel at the time—about "Why don't you come down. Maybe take a year's leave of absence from Stanford. Come down and see what it's like and see if this is what you want to do."

Early Visionaries at Intel

DSM: To me 1974 is only yesterday. But it's over a quarter of a century ago.

CB: It seems a long time ago.

DSM: Describe what it was like to be at Intel twenty-five, almost thirty years ago.

CB: First of all, Intel was a tiny company. It was only six years old and our revenue wasn't even $10,000,000 a quarter, $50,000,000 a year, something in that range. The industry was terribly cyclical at that time. Every couple of years it was up, then way down. No one was sure that it would grow. No one was sure how big of an industry it would be. It was exciting as people were really applying science and technology to create leading-edge products.

You know, you talk to someone like Bob Noyce—the ultimate entrepreneur. Bob had a vision of where this was going. Gordon Moore had a vision of where it was going. But I think there were very few people who had that visionary capability at that time, to see what that industry could do, what it could become. For most of us, I think, it was an exciting place to be; new products were coming out every six months, new capability, and an immense amount of opportunity.

DSM: Correct this impression, but I have an impression of the period from 1974 when you joined Intel, until about 1984, as a period of intense growth. Then suddenly there loomed this huge Japanese challenge. Is that your perception of that period, or is it more up or down as a challenge.

CB: There's a bit of cyclicality thrown in there. But the cyclicality has always been this type, or it's always on an upward cycle with ups and downs. And it's a pretty accurate statement to say that it grew very rapidly through the 1970s and into the early 1980s.

At that point in time there was a challenge from an international standpoint. The Japanese semiconductor companies started to challenge the U.S. companies for dominance. They were technically very good. They were better at manufacturing than the U.S. companies. This was when the quality ethic really invaded the semiconductor industry. There was a classic paper put out by some engineers at Hewlett Packard who compared the quality of Japanese dynamic RAMS to dynamic RAMS manufactured by U.S. companies. There was a huge difference between the two. This, I think, gave credence to the Japanese companies to really invade the U.S. marketplace and challenge the U.S. companies.

DSM: You were given a really tough job when you became Vice President. You were to meet that challenge at Intel. Can you describe how you saw the problem and what you were going to do about it?

CB: It was an interesting time at Intel because we had been very successful as a technology leader. We continued to introduce new products—everything from the dynamic RAM to the static RAM to the microcontrollers, to the electrically programmable read only memories, to microprocessors. So we had a steady influx of new and exciting products. We were great at introducing new products. We were not great at manufacturing them or staying in the market when we had competition. Our forte was to be at the leading edge and being at the leading edge, we could command premium prices for our products. We had no competition. We didn't have to worry very much about customer service. So we had kind of a lopsided view of business. It was a one-sided view, which was technology leadership without a whole lot of substance behind it.

When the Japanese threat came in and threat from European companies and other U.S. companies, the threat was real. Not only do you have to be a technology leader, but you have to be a manufacturing leader. You have to have quality, reliability, capability built in. You have to be an efficient manufacturer, an efficient supplier, provide good customer service if you want to continue to grow and be successful in the marketplace.

So the challenge we had was to undo part of the corporate culture, which had been around even prior to 1968 when the company was founded, because Fairchild Semiconductor was founded back in 1960 timeframe by Noyce and Moore and six other gentlemen. And it had been kind of a technology leader without much manufacturing capability. Noyce and Moore left and Grove came and joined them. Les Vadasz came and joined them to form the cadre of Intel and it kind of carried on the same tradition, which was technology leadership, technology capability without a lot of manufacturing customer support substance behind it. By the time we got to the mid-1980s and we were getting to be a billion dollar company, the issue became how much can you continue to grow without having a well-rounded company and being able to compete with anyone on the planet.

Changing Intel's Culture

DSM: Where did you get good at doing this? You were seventeen years an academic. You'd been at Intel in the environment you just described for ten years. How did you get good at what you do so well?

CB: I haven't a clue! It's common sense. Common sense. I was an engineer and so you couldn't bullshit me about engineering topics. I'm competitive. I told you earlier, played basketball, was a track athlete; I played two-man competitive sand volleyball for bunch of years after I graduated for another twenty-five years or so. I'm a competitive athlete. I don't mind traveling, so I went around the world and saw what other people were doing. There was no magic to what they were doing. They weren't any smarter than we were.

I figured we could do that; all we needed to do was get ourselves organized, set the right goals, reinforce those goals with some tough management, make some tough decisions, and we could be successful.

Effectively, we started off to do that in the mid-1980s with great liberal doses of statistical process control, complex design of experiments, taking all the engineering fundamentals that you would expect a high tech company would know about. We knew about them, we just weren't applying them in the ways we did business. And when we went back in and started applying those engineering, mathematical, scientific fundamentals to how we did things, we got pretty good at it.

DSM: I've interviewed several folks about this particular period of time. And this is the part we can embargo, so you can be honest. Was there ever point during that period when you were really, really scared?

CB: Everybody was scared in 1984/1985. No one knew, regardless of what company you were in the United States, nobody knew if you were going to make it through that time frame. Intel started out in 1984 with about 25,000 employees. By the time we got to the end of 1985, we had laid off a third of our workforce. We were down to 17, 000 or 18,000 employees. I mean this was a major, major transformation of a company that had been growing rapidly for the previous fifteen years or so. It was a shock. It was a shock to the whole system.

DSM: First lay offs ever?

CB: Well, not the first lay offs, but I mean, these were massive lay offs, plant shut downs. A massive transformation of the way the company did business.

DSM: I'm from Chapel Hill, so when you're playing basketball sometimes there's a time in the game when you know you've made it through that transition. I'm sure it's the same in volleyball, if the tales I hear about your volleyball playing are true. Is there a point during that period when you knew?

CB: There was one absolutely great climatic point in the early 1980s and mid-1980s when we were in the middle of this; we made constant pilgrimages to Japan to see how the Japanese did business. To see how they did quality control. To see how they did management. To see how they elicited suggestions from their employees on how to improve things. Basically to see how they were beating our pants off of us. When we got to the early 1990s, there was a constant flux of Japanese executives to Intel to see how we were doing things. And I figured, when we had changed roles that we had made it.

DSM: Given the position of Intel, when you're talking about eighty percent of the chips in use in the world being Intel chips and the rest deeply influenced, there's no lack of critics as well. So you can't make mistakes.

CB: You do get a lot of people looking over your shoulder in this business. As Intel is by far the largest semiconductor company in the world and typically the most profitable and we're kind of the "bell weather" of the industry, people look at us for signs, and characteristics and trends, and there's no shortage of financial analysts who like to suggest how we should do things somewhat differently than we do. And because we're kind of the big brother, I think we are sometimes looked in the press a little bit like the Yankees who have a long winning streak who ought to be put in their place. So you are very visible. But in a sense you can turn that around to use that in your advantage. Yes, you're visible, but if you are competitive and you want to be successful, you can show the world how to win by being better than anyone else. Everyone's going to see what you do, so let's get on and win.

DSM: This question is a little bit like "what's your favorite job" question, but have there been customers that have been particularly helpful in that regard, in terms of staying on top of what you're doing and being very communicative of what you need?

CB: I think all of our major customers—the IBM's, the Hewlett Packards, the Dells, Compaq, the Japanese companies, European companies—all of our major customers are helpful at giving us feedback. Feedback can be good; it can be bad. What you hope is that it's constructive and that you can do something with it. I wouldn't like to single anyone out. I think they've all been helpful to us.

Following in the Footsteps of Titans

DSM: In 1998, you became—well the year before you became President—but in 1998 you became CEO (the fourth President and the fourth CEO) succeeding Robert Noyce, Gordon Moore and Andy Grove. That's a pretty extraordinary set of predecessors. How did you feel when that happened?

CB: Scared as all hell. These are the titans of the industry. These are the most significant people in the semiconductor industry, and to follow in their footsteps! First of all, to work with them has been one of the great thrills in my life. To know them personally, professionally, to work with them, be with them in the off hours is a great joy. You couldn't have asked for anything more. Then to follow in their footsteps at a time when Intel has risen to be this immensely successful company—not just in the U.S., not in just the semiconductor industry, but in around the world. It has a brand that's recognized everywhere. You can't go anywhere in the world and not see "Intel Inside", or tell people you work at Intel and they know who you are.

DSM: In preparing for this interview, I was reading the oral histories we have done with Gordon Moore and with Andy Grove and David Allison with the National Museum of American History, and I think the high compliment of one of the things he said was in that interview was that it's hard for him to think that you weren't there at the beginning, which I think is a real tribute.

CB: I just had been deeply honored to follow in their footsteps, but it is I think a daunting task for anyone to try and follow after those three. Bob Noyce would have been a Nobel Prize winner if he hadn't died because Jack Kilby—the co-inventor of the integrated circuit got the Nobel Prize. Gordon Moore has been the father of the industry, the technical father of the industry for his entire forty years of professional work in the industry. And Andy Grove is Andy Grove, *Time* Man of the Year, management guru, technologist, visionary. Along comes old Craig Barrett and you say, "these are big footsteps." And even though I'm a heck of a lot taller than Grove, he casts a really long shadow that I'm in, in awe of all the time.

DSM: Another question I've got to ask because after doing this for fifteen years, there seems to be something that all the folks who were chemists at heart have in common, and that was that when they were little kids, they either made really noxious things or blew stuff up. Gordon Moore especially. Did you do that when you were small?

CB: Can we embargo this part? No. Of course we all do that. We used to make thermite bombs, which were great. But the best one is nitrogen tri-iodide. Nitrogen tri-iodide is an unstable crystal that you form and it explodes on mechanical contact. What it does is it explodes and decomposes into iodide and a gas vapor. It leaves a purple stain. You can put this stuff on interesting places like toilet seats, things like that. Although I admit to none of the details, I do admit to having made nitrogen tri-iodide as a youngster.

Passing the "Red Face" Test

DSM: I'll ask you some questions that we've asked, tried to ask, everyone we've interviewed in the last fifteen years about things like honor, and innovation, and that sort of thing. I'd like to begin with, especially with what's gone on lately both in the corporate world and in our religious world, talking about honor and integrity. Some people say that honor is a kind of behavior you owe to people that you yourself respect. I would say that it's something that your parents, your upbringing, instill in you that you just can't escape. Where does your own sense of honor and integrity come from and what do you think about all the stuff that's been going on?

CB: First of all, I don't think that any American businessperson or international businessperson would ever condone some of the stuff that's going on. I think they're all abhorred by it. I'd like to think it's a minority that's been involved. It's been a very visible minority, a very public issue.

I've always ascribed to the simple philosophy that in the professional life, anything you do should be governed by the reactions of three people or three things: that you should never do anything that would upset your manager, that your manager wouldn't be proud of; that you should never do anything that you wouldn't like to be published in the media, so it has to pass the "red-face" test; and you shouldn't do anything that your mother wouldn't be proud of her son doing. So those are the three m's—your manager, media and your Mom. If you put anything that you do to that test, it is very difficult to imagine doing something, which doesn't reek of professionalism and integrity and honorable conduct.

This is the way the Intel environment, Intel culture, Intel value system works. I didn't invent those three m's. We teach our employees and tell them this is the way we behave. This is the way you should govern your activities at Intel. This is how you should conduct your professional life. I firmly believe that if you follow those—if you ask those three questions---follow where your heart leads you, you can't do the sort of thing you're reading about at Enron and World Com and other places.

DSM: And you work in an environment in which men and women, honorable men and women prevail. Is there a person from history, or fiction or literature that was sort of a hero when you were growing up other than the folks you work with?

CB: That's a tough question. It may sound strange, but I used to read all the Captain Horatio Hornblower novels and I think he as a character exemplifies the sort of things I'm talking about. If I come back to Intel for a minute, I have to give credit to Noyce and Moore and Grove for the culture and the style that put into this company. We have these characteristics such as we call "constructive confrontation" and we promote straightforward behavior. You promote clear identification in attacking a problem. You promote high integrity professional conduct. And it is really the atmosphere that those three gentlemen. I think, gave their personalities to and created the company around, that probably have created an aura here, an atmosphere here, that wouldn't allow these corporate misdeeds to take place.

Origins of Innovation

DSM: Tell me about innovation. Where does it come from?

CB: It comes from smart people and in the right environment. I don't think anyone can define where innovation comes from. If you go to the lobby of this building, there is a picture of Bob Noyce there. You have to consider Bob one of the greatest innovators of all time. And the saying we've captured under his photograph is one of his comments, "Don't be encumbered by history. Go out and do something wonderful." When you dissect that very simple statement, it tells you a little about innovation, which is you have to be a free enough thinker not to be encumbered by what's happened in the past, and you have to have some vision about what could happen in the future. But then you have to throw in the rest of the recipe, which is get people the best education, inquisitive minds, no fear of failure, no fear of trying something new.

I remember one simple example here at Intel where there was a young man working for me, named Tim May. We had a problem with our 4K dynamic RAMs at Western Electric. They were in small PBXs and Western Electric started to complain that these devices every once in awhile would lose their memory. They'd get a wrong bit in them. They claimed that there was something wrong with our processing because they had never seen this before; therefore the processing must have drifted. Therefore it was our fault, so come and fix it.

I was running the quality and reliability organization at Intel at the time. I reported all the data we had and we couldn't find any change in any process. I went back and had meetings with the Western Electric engineers and they showed us every twenty-four and forty-eight hours these devices would flip a bit. We went around and around trying to solve this problem.

Tim May, bright engineer, wasn't even working on this problem, but was thinking about it. He thought back to when he first showed up at Intel. He'd gone to a talk that Gordon Moore gave and Gordon was talking about "Moore's Law", and shrinking things smaller and smaller and that someday they might get so small that cosmic rays might come down and that would upset and impact on these devices. And Tim started to think, "Well gee. Cosmic rays. Well, maybe not cosmic rays. Maybe the packaging materials that we have, has some low radioactive content. And maybe we're getting alpha particle emission or something like that from this package material." So he did a classic experiment. He went over and grabbed a handful of the ceramic material that we made these integrate circuit packages out of. We used to do hermetic testing of our devices and you did that by pressurizing them with a radioactive gas. Then you'd put the devices into a Geiger counter, in a vacuum, and pump the gas out. And if you got any count, you know that one of the devices was leaking. It was not hermetic.

Tim didn't bother with that; he just put a bunch of the piece parts—ceramic piece parts—into this Geiger counter chamber and counted for twenty-four hours to see if there was any radioactive content count above background level. And there was. And then he said, "OK. Now maybe it's alpha particles. Where can you get alpha particles? And he said, "Smoke detectors basically have a little bit of alpha particle emitting device. That's what ionizes the smoke which makes it electrically charged, which gives you a current that makes the smoke detector work. Let me rip a smoke detector apart. Let me get the plutonium source out of it and then let me knock off the caps of one of these dynamic RAM devices. Let's put that alpha particle emitter right up next to it and see what happens." He does that. He's running pattern, electrical pattern through this device and he brings the alpha particle source over to it. This thing goes bananas. It's creating soft errors, just multiplying like rabbits. We're then able to demonstrate in a very short period of time that if you put these dynamic RAMS in the vicinity of alpha particles sources over a fifteen orders of magnitude of different intensities, there's a linear relationship between the soft error rate and the alpha particle source. It's pretty tough to argue when you have a fifteen orders of magnitude correlation, one-to-one.

DSM: But the approach—it's like Fineman dropping the seal in the glass of ice water?

CB: Creative, innovative, brilliant, all of the above. Tim May had imagination. He had a good technical background. Wasn't afraid to try something new; wasn't afraid to think out of the box. Wasn't encumbered by history. He went off and did something wonderful.

Knowledge: The Driving Future Force

DSM: Two areas I want to ask you about, your interest in things environmental, in forests and forestry. But before we get there, you're also very interested in foreign policy, foreign economic policy. When we began this program in 1988/1989, in a symbolic sense, the Wall came down that year. The Cold War, symbolically, came to an end. It looked like we were going to have an opportunity to remake the world almost in the same sense that it was opened to being, we made after the Great War in 1919. Now things don't look quite so good. You've got September 11, which had a profound effect. The economy is struggling. What do you think happened to it during that period?

CB: I'm not sure that it's moving quite as dramatically away from the direction of the early 1990s as you're suggesting. There are certain hot spots in the world. We can look at the Middle East. We can look at isolated events of terrorism. We can look at Iraq. And yes, there are hot spots. But if you look at the rest of the world, and the governments of the rest of the world, and the governmental attitudes of the rest of the world, I don't think you've ever seen such coalescence around a common theme as we're seeing today.

I visit about thirty countries a year and I do get to talk to business leaders, and government leaders, academic leaders. You talk to them and they all say the same thing. "We know what is going to drive our economy in the future. It's not oil, it's not agriculture, it's knowledge. What we have to do is educate our people to take advantage of this. We have to educate our workforce so they can be competitive in the world's economy." And you're seeing government policies by everybody doing exactly the same thing.

We could have a long discussion on whether the United States recognizes that this is happening, but it is pretty clear today that you could go to China, India, Vietnam, Malaysia, Israel, Australia, Russia, Jordan, United Arab Emirates. You can go anywhere you want in the world in the world and you see exactly the same thing happening. And those people are all competing for the same jobs, the same intellectual content-oriented jobs that created this place where we're sitting in today. Silicon Valley, Intel Corporation, the semiconductor industry. And they're crafting policies to let them participate. They're getting more competitive on a daily basis. You see this happening, real time, around the world.

So I don't think we're getting a divergence; I don't think we're getting a polarization other than a few unfortunate places where we have either despotic leaders or we the have the Middle East situation where we have Palestinians who have nothing, the Israelis who have a great economy and we have a "have/have not" relationship, which is inherently unstable.

But if you look at the totality of the world, I've never seen a greater coalescence and I think it's moving at light speed towards an open economic structure where information flows everywhere, and the success of your company, your country, your population is going to be totally dependent on education level and capability to compete.

DSM: Is technology making it better, easier, for people to succeed and harder for bad people to hide?

CB: Of course. The three great things that have happened in terms of democratizing the world in recent history have been: the fax machine, CNN and the Internet. One country outlawed the Internet, Afghanistan and the Taliban. It was a symbolic gesture; they didn't have any telephone lines anyway so the Internet wasn't any power there, but they outlawed the Internet. The Chinese, the Chinese government, even today toys with trying to restrict access to the Internet and search engines and things like this. But they recognize that they're not going to be effective by controlling this. The great democratizing influence in the world is knowledge; it's information. It's the ability for people to know things real time, things that are going on everywhere in the world. If that happens, then it is incredibly difficult to close down a society, to be a dictator. The Internet has opened up the world, but I want to give credit to the fax machine and CNN. They did it as well.

DSM: After spending fifteen years collecting stories of people who do great things with this technology, as a historian who is hopelessly prejudiced in favor of the technology and its power. But looking at the other side of that point, what do you see as the greatest obstacles to this technology really achieving its full potential in the world? Cultural, mechanical, economic?

CB: One of the obstacles is the probably the educational obstacle to take advantage of it, and this is why I think education is such an important fundamental in any society in any country. I think it's unfortunate if you look at the United States and its role in this area. We have been given by whatever circumstance, a huge lead in the high tech space, but if you look at the educational infrastructure, we're in danger of losing that lead. And educational infrastructure, I don't mean just the university infrastructure. The Stanfords and the Berkeleys, and the Cal Techs and the Harvards of the world are still the premier research universities in the world. You understand that by the fact that people vote with their feet. And all the foreign students in the world come to our great universities. They take that learning and increasingly take it back to their own countries.

But if you look at the K-12, the elementary education system in this country, I think it's a dismal failure. Standard international comparative tests of a twelfth grader in the U.S. to a twelfth grader in the rest of the industrialized world, we're ranking in the lowest ten percent, on average in terms of mathematic, technical, engineering and science comprehension. How can this high tech success story do such a crummy job educating its young people? This is the cobbler's shoeless children's story.

DSM: You're a product of public education, are you not?

CB: Absolutely. I went all the way through high school in public schools. But this is the biggest challenge that the United States faces going forward, because you can look at China. China today is producing more engineers than the United States. India is producing more engineers than the United States. And you go to country like Vietnam—you find a major program to produce IT professionals. You go to the three hundred million people who live in the Arab world and the gateways to the Arab world are Jordan, and Dubai and UAE. They are recognizing what's going on.

DSM: I couldn't agree more. Both you personally and Intel as a corporation, I know, is trying to do tremendous work to try and help address some of these issues.

CB: This is tougher than the 1984/1985 crisis in the semiconductor industry, though.

DSM: And if it is a crisis in the U.S., the rest of the world…

CB: It's tougher to solve.

Technology and the Environment

DSM: Another big interest of yours is the environment. You have a ranch in Montana; you're active in the National Forest Foundation. Is there a conflict between the success of this technology and the destruction of the environment as the rest of the world industrializes? Or do you think you will be able to reconcile this?

CB: I don't think so. You need to look at some of the features in the United States—the characteristics of what's going on here. When I grew up in the San Francisco Bay area, you couldn't put one toe in the water in San Francisco Bay. It was so polluted. You couldn't catch a fish out San Francisco Bay because it was polluted and you dare not eat that fish. They're growing shrimp in the South Bay now and they catch fish throughout San Francisco Bay. My wife grew up in the Pittsburgh, Pennsylvania area, the birthplace of the steel mills. You go to that area today and compare it to how it was fifty years ago and there is no comparison. It is vastly improved environmentally.

It's certainly easy to say that, OK, we have global warming, we have ozone, we have depletion, we have things like that. And yes, we should be very, very concerned about those things. But sometimes I have a general feel that the world is getting better environmentally as we go forward, and not worse. Now we could argue that the rain forest is being cut down. Much of the forest in the United States was cut down to do our development, so it is a little hypocritical sometimes of us to critique other people.

I don't guarantee that there are technical solutions for every environmental problem. I do think responsible companies like most of the semiconductor industry absolutely try to minimize the use of toxic materials. We absolutely try to minimize the use of water. And we try to minimize the use of power in our industry.

And if you look at Intel, which has been growing pretty dramatically through the 1990s and present day, we use a lot less raw materials today than we did five years ago, even though we've grown in that time frame.

So there are ways to conserve and still move technology forward. Are there unknowns? Certainly and people can always ask the question, "How do you know what's going to happen in fifty years?" And by golly, that's a tough question to answer when you don't know the environment, you don't know the boundary conditions and if you're an engineer, you kind of look and say, "I don't know."

DSM: And technology is making it easier, and in some cases possible.

CB: You can use the technology to police the system and to control the system and make the system more energy efficient, water efficient, and environmentally efficient.

Monticello Fellows & Legacies

DSM: Two more questions. One is my Monticello question. One of the things I have enjoyed in working with this program is bring people together to talk about stuff. Gordon Moore and Seymour Cray and Bob Metcalf, and Jay Forrester met once at Monticello as part of this program and sat around the table and talked about this revolution in that old revolutionary's house. One of the questions I like to ask is, if you could put together a table of folks in Jefferson's house or in any house that's your favorite place in the world—say Montana—to talk about this revolution, is there a group of people you'd like, that it would be a shame not to put around the table together with a recorder what they have to say?

CB: There are immensely interesting people in the world for sure. And again, one of the opportunities I've had is to meet a bunch of people that have, in their own right, changed the world. Whether you're talking about Ronald Reagan, or Margaret Thatcher, or one of my all time favorites from his ability to accomplish something with a vision is Lee Kwan Yu in what he did with Singapore.

DSM: Total transformation.

CB: I mean, he took a ten by ten mile swamp and turned it into a financial/shipping powerhouse. This stands out. I've been able to talk to many of these people one on one, but the thought of getting a bunch of them together could be really invigorating.

DSM: That's one of the things we get to do, bring them together if they agree to let us record what they talk about. It's an interesting thing, Lee Kwan Yu from Singapore, anyone from India? I was just thinking of the countries that you mentioned: China, India, Vietnam.

CB: I don't think you have the dominant personality in India other than the democratization of India with Gandhi and so forth. In modern times the government and technology have been kind of disjoint, and the government has been so democratic that it has been so constantly changing that it moves fairly slowly.

But certainly you could take some of the current Chinese leadership. There's Jiang Zemin or someone of that ilk, with a Lee Kwan Yu, with a Margaret Thatcher, and you might go and find someone who's from a totally different area of the world. King Abdullah, who is the King of Jordan, who along with probably Sheikh Mohammed, who's the Crown Prince of Dubai, are kind of the two Arab heir-apparents to the technology leader, or the technology guru of the three hundred million population Arab countries in the world. Doing that sort of cross-section of people, maybe with a few technologists—Gordon Moore, too, thrown in—I think would be really exciting.

DSM: It would be an extraordinary conversation. The last question I'm going to ask you is, from my perspective, is the hardest. We're doing this because we believe that from a perspective of two hundred or three hundred years graduate students and lots of other folks are going to look back on this time and be proud of the work that was done here. The people who did it. So, as an academic, industry leader, how would you like to be remembered three hundred years from now?

CB: You know what they're going to do when they look back on us in three hundred years? They're going to be like us folks today looking back at the vacuum tube saying, "Gosh those people were old fashioned. Why couldn't they have worked with better technology? What took them so long?"

Two hundred years from now, we're going to go through probably four, maybe more, major transitions. Let's assume that vacuum tubes ran for fifty years. Semiconductors, transistors run for fifty years. Two hundred years from now at a fifty-year transition rate, we're going to have four more cycles. Nobody even knows what the next one is. It's nano-tubes, it's quantum-dots, it's pushing atoms around on the surface. It's something like that. They'll probably say, "Gee, that was interesting." They'll say, "Moore's Law? Do you know for fifty years, those guys were able to double something every eighteen months? That's never happened before."

That may be the thing that sticks out most dramatically in this whole time period. It's not a physical law; it's Gordon's observation and the rest of us—thousands, hundreds of thousands of us—have worked hard to make it happen. That phenomenon is truly outstanding. I don't think anywhere in history have you ever seen anything even close to that. So they may be amazed by that, but they'll probably say, "Well, if they had really good technology back then, think of what they could have done!"

DSM: Thank you so much for spending this time with us and making this contribution to the collection.