ORAL HISTORY
ANDREAS BECHTOLSHEIM &
WILLIAM JOY

COMPUTERWORLD HONORS PROGRAM INTERNATIONAL ARCHIVES

Transcript of a Video History Interview with
Andreas Bechtolsheim
Vice President, Gigabit Switching Group of Cisco Systems

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William Joy
Chief Scientist & Corporate Executive Officer, Sun Microsystems

Recipients of the 1999 MCI WorldCom Information Technology Leadership Award for Innovation

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Interviewer: Daniel S. Morrow (DSM)
Executive Director, Computerworld Honors Program
Location: San Francisco, California
Date: March 18, 1999

DSM: It's March 18, 1999, a Thursday; the place, the Crocker Room in the Huntington Hotel on California Street in San Francisco, California. We are interviewing for the permanent research collection of the National Museum of American History, Andreas Bechtolsheim, Vice President, for Gigabit Switching Group of Cisco Systems and William Joy, Chief Scientist and Corporate Executive Officer, Sun Microsystems. This interview is part of an ongoing oral history program conducted on behalf of the Smithsonian Institution's National Museum of American History, in partnership with the computer world's Smithsonian awards program. The interviewer is Dan Morrow.

This series of interviews is made possible by a grant from MCI WorldCom, and Mr. Bechtolsheim and Mr. Joy will, in June 1999, join Erich Bloch, Ken Olson, Gordon Moore, Seymour Cray, Gordon Bell, Vint Cerf, Bob Metcalf and Tim Berners-Lee, as co-recipients of the MCI WorldCom Information Technology Leadership Award for Innovation.

Gentlemen, without objection, this video biography/oral history will become part of the permanent research collection of the Smithsonian Institution, and thus part of the public record. However, you may stop this interview at any time and request that your remarks be embargoed, that is, withheld from public access for up to 25 years, and in any case you will both have an opportunity to review an unedited transcript of this interview and make appropriate changes and corrections before it's made public. That's agreeable to you both?

AB: Yes.

WJ: Of course.

DSM: Great. We'll begin. I'm going to try to alternate questions between the two of you, and let's start with Bill. For the record, please state your full name and tell us when and where you were born.

WJ: William Nelson Joy, and I was born in Detroit, Michigan in November of 1954.

DSM: Tell us about your parents, Bill.

WJ: My parents were schoolteachers who met at Wayne State University when my father, on coming back from the war, took a class from my mother.

DSM: And your parents names?

WJ: My father's name is also William. My mother's name is Ruth, Ruth Nelson, which is my middle name.

DSM: Brothers, sisters?

WJ: I have a younger brother, Bob, and a younger sister, Linda.

DSM: How would they describe you, your parents, how would they have described you as a child?

WJ: Oh, that's a good question. Probably "studious" is the single word answer to that. I started school early, and at the time was skipped a grade, which is a difficult thing for socialization as a child. So perhaps I retreated somewhat into the world of books. I started reading when I was three so I'm very interested in the world of books, and very prone to ask a lot of questions.

DSM: Andy, if we could ask you to do the same thing? State your full name and where you were born, and tell us about your parents.

AB: My full name is Andreas von Bechtolsheim. It's actually Andreas Maria Maximilian von [indistinguishable] Bechtolsheim, but I'll spare you the explanation for that. I was born in a small town in Bavaria, Germany, close to Ammersee, which is close to Munich. I basically grew up this little farm, which was far away from any other town or village. My dad is a schoolteacher, similar to Bill. My mother's a homemaker. I have an older brother, a younger sister and a baby brother, so I was the second child.

Similar to Bill, I also got to school early by a year and I ended up skipping a grade. So I also faced some of these socialization issues in school, particularly high school. The effect was, I became very interested in computers and engineering things, and I spent a lot time building things in my hobby basement.

DSM: Andy, describe this place in Bavaria where you grew up. What was it like?

AB: Well it's called the Fochs Farm, which belongs to my family but we don't actually run the farm, it's leased to a farmer. What's nice about it is that you can't see another house from the farm so you're completely surrounded by meadows and woods, and you see the Alps in the distance.

DSM: Had you lived there until...

AB: Well, when the children reached school age it was really not practical to go to school from there because it was just too far away. So my Dad applied for a position at a German school in Rome, Italy. So we actually lived in Rome for five years. When we came back to Germany we decided to settle on the Lake of Constance, which is also in southern Germany.

DSM: When did you go to Rome?

AB: I was age seven, seven through twelve.

DSM: So that would be in 1961, 1962...

AB: 1963 to 1968.

DSM: Bill, how about for yourself--

WJ: I've never lived in Rome.

DSM: You never lived in Rome?

WJ: No.

DSM: Michigan sounds a lot like Bavaria.

WJ: It was, a hundred years ago, maybe. My father was a teacher in the Detroit schools and there was a decline in the physical environment of Detroit that started in the sixties. So he left and went to teach in a community college, and so forth. So we moved to the suburbs of Detroit and I lived there until I went away to college in the University of Michigan.

DSM: The people who are going to be watching this, we hope, two or three hundred years from now are going to have no idea what a suburb of Detroit looked like. Can you describe sort of what it was like, what your house looked like, what the neighborhood was like, the neighbors, the kids?

WJ: Well at the time they were taking large undeveloped tracts of land and making subdivisions. They would take a rectangle of land, cover it up in streets and build colonial style two story houses. They'd dig out a basement--they were very lazy--so they'd take the dirt and dump it in the front yard so that you'd have a mound in front of your house--and build a two story house with three or four bedrooms in the second story and a living room, family room, kitchen on the first story. Then a back yard with still the remnants of the trees, because it's a wooded area, Michigan is a very wooded state. It was all working families, kind of a middle class neighborhood, lots of trees, cold winters, humid, hot summers, lots of mosquitoes...

DSM: Were there lots of kids in the neighborhood, lots of neighbors?

WJ: Yes, exactly. Most of the families about the same age, two or three kids typically, lots of riding of bikes down the streets, playing hockey in the streets with hockey sticks and tennis balls. People would flood their back yards in the winter and make ice skating rinks and you could play hockey, occasionally hitting the puck through the window of the house.

DSM: Bill, who were your heroes when you were a kid. Who inspired you? Guys on the radio, guys in the early days of TV?

WJ: We lived on the street with one of the baseball players for the Detroit Tigers. And Jim Bunning, who is now a senator, lived in our neighborhood. And Mickey Stanley, who was an outfielder for the Detroit Tigers, also lived on our street. They were the local media types. Actually a future Miss America lived in our neighborhood too, but we never knew her.

DSM: Andy, would you do the same, just describe the place where you grew up? What did it look like?

AB: I grew up in three different environments. The farm was very remote and isolated so it was something special if somebody actually came by and visited. We didn't have a TV. I grew up without TV, in fact I still don't watch TV even today. I read a lot of books starting at an early age and some of my fascination was with the sciences and physics in particular. Einstein was actually my biggest hero because he could take these very complicated things and explain them in such simple terms that even as a ten-year-old I could basically understand what he was saying. It was only later when I really got involved with the computers.

DSM: Andy, tell me about your first school experiences, especially teachers that may have meant...

AB: The first two years of school I went to, the village was so small that the entire nine grades was just one classroom, and there was one teacher for all nine grades. So he did an amazing job in multiplexing his attention to the different grade levels. I think there was one other kid in my grade level, but you could basically listen in on what the older kids were being taught and it was kind of fun actually.

DSM: Do you remember the teacher's name?

AB: I'm afraid I don't, and he died a couple of years later, but it was an interesting experience because the room was just so small there.

DSM: Bill, tell me about going to school for the first time and teachers that made a difference.

WJ: Apparently when I was three years old, my parents took me to the school to sit in the Principal's lap and demonstrate that a three-year-old could read. It was kind of a circus curiosity.

I had a pretty influential kindergarten teacher when I was five, Mrs. Parker, who took some special time with me and gave me books to read and did things that stimulated my curiosity at the early age. So I have vague memories of that and also making a plaster of Paris turtle in her art class and eating most of it, but not very complete memories of the early years in school.

DSM: For either of you, did your teachers notice that you were special guys early on, or was it your parents or family?

WJ: Well having parents who were schoolteachers created a school-ish environment, at home as well. So there was a lot of encouragement, stimulation, help and so on, lots of books around.

You go to the modern American household a lot of times and- if I go into a house that doesn't have bookshelves or books that's just-- It sort of takes you aback. Probably back in the fifties was television was already pretty prevalent, they were starting to penetrate, but any TV we would have was very tightly controlled. It was more of a book kind of environment.

DSM: Do you remember the first TV you saw?

WJ: No. I remember watching the coverage after Kennedy was shot, on the TV. That's the oldest memory I have.

DSM: Where were you when that happened?

WJ: I was at school. We were sent home, as I remember it.

DSM: Sixty-three? And you had just moved to Rome in sixty-three. Was this a big change, going to Rome?

AB: Yes of course, you go from the farm to a very big city. But what was even more unusual was that my Dad, who is was a teacher at the time, was in fact my class teacher for the next two years. I think it's against the rules today, but at the time that was okay. The other kids always thought he gave me all the answers because I had an easy time in school. I didn't know how to study; everything just was pretty easy. Then later in high school, there are certain teachers I remember. Particularly the science teachers who talked about the subjects I was most interested in. I would say they had a certain influence on my level of interest and stimulated it further.

DSM: One of the questions that I've asked everyone I've interviewed is their earliest technology experience, and they ranged from electric trains to messing around with, I guess, the generators on T Model Fords, to rigged screen doors to kill flies. Was there an early experience with technology, Andy, for you that--

AB: Yes, of course. [laughter]

DSM: That gave some hint of what you were going to be doing in the future?

AB: Well I was always extremely curious how to build these magic devices and I think my Dad helped me to start taking apart radios when I was age four. I do remember them giving me this little electronics kit, one where you can do like your science experiments. This was before I could really read the instructions, but I sort of figured out what you could do with it anyway, and it was a lot of fun. There was also some electrician kind of person who came by our house to fix the wiring, and he knew how to solder things together. To me this was like black magic, that you could actually connect two pieces of metal with this hot soldering iron. And then there was electric trains and so on. So I was, I would say, preoccupied with all these things that I could get my hands on and try to build.

WJ: I guess at the same period that Andy was doing that I was more interested in playing hockey and baseball. Actually I really didn't do a lot of electrical, electronic kind of stuff. The first memory I have of seeing what we'd say is computer technology, was when I was in tenth grade. I was a long-haired kid in the school, kind of a misfit kid was lying on the floor in the hall one day writing a Fortran program and I tried to ask what it all meant. But it wasn't really until high school in electronics class that I got exposed to any of this kind of stuff.

DSM: When you were in high school did you have personal friends that really meant a lot, or rivals that you remember from your high school days that had an effect on your life?

WJ: Not that I was aware of at the time. I had some other friends who were very good at math and we in fact tried to get a math prize. We had a teacher who had us after school and would teach us additional little things about math, interesting number theory kind of things, and we tried out. It was called the Michigan Math Prize, and so that was kind of fun. No, it was a pretty diverse environment. It wasn't really technology focused. I was in advanced English and read a lot of literature and history. It probably wasn't clear, other than obviously an ability in math, it wasn't necessary to go into a technological field for me.

DSM: You were much younger than most of the people you were in school with. Couple of years?

WJ: Well, an average of a year and a half probably because I was at the younger edge, plus a year ahead.

DSM: Andy, what about for you? Was there a close best friend or an intense rival that you remember from your pre-university--

AB: No, not in high school. In fact I was sort of considered a nerd in the class. I was the youngest also by about one and a half years. So physically I couldn't keep up with these older kids anyway, and quite frankly I wasn't really interested in any of this. I was interested in the electronics and the computers. But I did participate in this German science fair competition three times, and the final time I actually won the German prize. At that competition I found a lot of people that were more interested in the kind of things I was interested in, which was similar to my later experience at college--that I was not the only one interested in physics or electronics problems, but there was actually a set of people who liked this subject matter.

DSM: What were your projects?

AB: Well the first year I did an experiment in chemistry, which wasn't really my forte but was an easy thing to do and I wanted to get a hint of it. The second year I tried to build an electronic scale that actually worked quite well, but it didn't get me to the final round. And the final time it was sort of a slightly computer-based method to measure fluid flow with ultrasonics in like a water pipe running by, and people thought that was pretty neat. In fact it was pretty neat.

DSM: We're on the verge of going to university now. How did you choose your university, Andy?

AB: Well there's an important period in my life in between, which is the invention of the microprocessor. I was very curious about the computers, but at that time in Germany, you really couldn't get your hands on any computer, certainly not at the high school level.

I read in the paper that Intel invented this thing called the 8008, which was the first eight bit microprocessor and the basis of the Altair, the first microcomputer. In the same village I was living in, Lake Constance, there was a small electronics company building machine controllers out of discrete logic parts. I was friends with the owner and I thought it would be much easier to build these machines based on a programmable computer rather than building a separate logic device for each design. So I convinced them that they should fund me doing this kind of microprocessor development to solve their own problem, and they did.

DSM: How old were you when you--

AB: I was sixteen when this started. The funny thing is there were no tools whatsoever, so we started off keying in the instructions in binary with binary switches and just memorizing all the op codes and so on. We had to write our own math libraries and floating point routines and so on, but we basically built this whole thing ground up and we invented things on the way. We figured out if you make all the wires the same on the back plane then it was much easier to wire it up. Of course this was called a buss, but I didn't know. The company subsequently did quite well. The deal I made with them was a royalty deal where they would pay me for each unit they would sell and that actually paid later all my studies, and I could afford to come here. So it was a very positive first experience with microcomputers.

DSM: So this is about 1970 and you came to Stanford when?

AB: 1973 to 1975.

DSM: And you came to Stanford in '75.

AB: No, I applied for a Fulbright Scholarship, which I got, and that was at Carnegie Mellon University which is in Pittsburgh, Pennsylvania. I got my Masters in computer engineering there.

I really wanted to come to Silicon Valley. Should we talk about this story right now? So what happened was I met this gentleman from Intel who offered me a summer job in Silicon Valley and I came out here. But literally the week I arrived here, he was transferred to Oregon and I didn't want to go to Oregon. I wanted to be in Silicon Valley. So I was here and had nothing to do.

I was staying with another friend of mine who I met over the Internet. At that time they shared an Internet in 1975. It sounds hard to believe but it worked back then. It was called the Arpanet. He was the computer operator at Stanford. So he showed me around Stanford, and then on the blackboard at Stanford was a summer job for somebody who was willing to work on some computer-aided design package. I figured, well, I can do this, I'm here, I might as well work on this. So that's how I ended up coming to Stanford. It was a complete chance kind of event.

DSM: So you were seventeen, eighteen...

AB: No I was nineteen at that time.

DSM: Bill, how about you? You went to the University of Michigan.

WJ: Right.

DSM: How did you decided to go there?

WJ: Well it was in-state and we didn't have a lot of money, and I got a small scholarship. It's a very large university, land grant kind of university, and had a very diverse academic program. I got into the Engineering School actually, mostly because there were fewer requirements. Even though they had a fairly unrestricted set of courses, if you were in the Arts School, if you were in the Engineering School, you could almost take any courses that you wanted. So that was very attractive to be able to not be required to do any one particular thing.

In fact I got in the advanced math program for math majors as a freshman, which is normally only taken by people who are in the school that has the math department in it. But I could take more math courses than they could if I decided to take math. They were actually restricted as to how much math they could take. Whereas coming from the Engineering School you didn't have the restrictions, so it seemed like a good idea.

DSM: Any teachers and courses at Michigan that really stand out?

WJ: Yes, the hardest course I ever took was the freshman introductory advanced placement math course. It was called '195.' Sometimes they would assign problems on a two-hour test that were unsolved. You know, they give you six problems. If you solve two of them you're doing good. Which is really a quite stunning thing if you've been going through high school and have been acing all your courses essentially and had no trouble getting 98s or 99s on your tests. Then you go into a class where the best you can do is get answers to one third of the problems, and those might not even be complete answers. That gave you an idea of how hard it was. If you really worked on the hard stuff you weren't always going to solve it, which was a really interesting concept that I really didn't have in my vocabulary.

DSM: Teachers. Do you remember any particular teachers that really had an effect on you?

WJ: Well the guy who taught that class, his name was Ramanujuan, which is also the name of a very famous Indian mathematician, so he was quite stunning. Another math professor, who is actually quite a famous collaborator with Paul Erdös, his name is Frank Carrari, who was a graph theoretician at Michigan. He was most famous because he was talking at the time about Erdös numbers, which are some form of the "six degrees of separation" idea. You know, who knows who, and you know somebody who knows the Pope, so your Pope number is two. In math it was your Erdös number. How many co-authorships would you have to go through to get to Erdös? If you were a co-author of a paper with Erdös you were one.

So the whole idea that the world was spanned by very few sets of "I know you. You know them. Everybody knows everybody." Very, very interesting to think about the implications of these very advanced graph theory kind of things, topology basically. To take a class from a world-class person like that in any field….he would get up at the start of the class and open his mail and just read you correspondence from people in the world who were on some problem he was working on. It was really interesting to see the flow that he had of ideas and collaboration.

DSM: When you think mathematically do you think visually?

WJ: No, I like to doodle. It's fun to doodle. And back to this professor, he'd say, "I'll solve this problem by writing down the answer." So he'd start with a guess and sort of fix it up. He'd sort of scribble something and just… it's a very immediate medium, when you try to do the stuff in a very fluid way. It's almost like doing watercolor, like painting alfresco. You don't have time. There's a limited amount of time, and if you lose the flow of the thing it falls apart. So he'd try to integrate something and he'd start to write it down, and if it got off course it would just melt. But if he could get it all the way through, quickly and with some inspiration it wouldn't. So I was really inspired to watch this whole class.

DSM: Bill, what was your experience?

WJ: I had been a winner of the Michigan Math Press so I had to apply to get into the math class for math majors, which they wouldn't normally let someone from the engineering school into, and we got into it.

They would give us homework. We would actually work on it in teams. I don't know if we were supposed to, but it was so difficult. We'd stay up all night working on the homework assignments trying to get even an approximation to getting them finished. They gave us exams where they would give us problems, which we could only do a small fraction of. Even collectively with 10 or 15 people in the class, no one would get the correct answer to number five in this test, or even know how to start. That's even if you scribbled down some approach to the problem.

There was a famous story…at Berkeley, there was the Field's Medal, the very famous math prize, and somebody had just put a list of unsolved problems outside the professors door but without a title on it. A very, very brilliant student walked by and thought this was the homework assignment. He took it home, and he came in the next day and said, "Well I solved one of them, but they are really hard. The other two, I only solved them half way." This is a famous story. So occasionally you do get people who can solve the unsolvable. Our problems weren't unsolvable. They were just at the edge of possibility.

DSM: Again, the University of Michigan, that's huge university.

WJ: Twenty or 30,000 students, I think.

DSM: Talk about that because that's going to be, I hope, perhaps a strange phenomenon in another 200 years just the size of the university.

WJ: Well, universities haven't been around forever. So if they still exist in 200 years, which certainly you can hope, as physical environments, the smaller classes, the more specialized classes would have 10 or 15 people in it. Then the larger classes would be 30, and sometimes a lecture hall size where you'd have 100 people with a professor and then a breakout into a lab, like a physics lecture.

DSM: Andy describe your university experience.

AB: At Stanford? Stanford is obviously a wonderful place. It's very idyllic, very relaxed, a very beautiful campus.

I used to be the best kid in high school, and I didn't really learn or study very hard. It was just very easy. But coming to Stanford there's a lot of smart people there both in the faculty and the student body. I sure enjoyed that experience--to see there's a lot of people that were a lot smarter than me. That was a big motivation, basically, to really learn and get to know more about this computer stuff.

I stayed away from the math because I was more interested in building things. Usually it was an issue of learning, what I needed to learn to actually build the next project. I have to admit I was interested in artificial intelligence for a while, but we concluded it was kind of an unsolvable problem. So at that point, I decided the heck with AI, and let's go back to building something interesting.

WJ: I got into programming by getting a job doing programming for the Anthropology Department. We used a computer to keep a database of where the artifacts were found in digs. Which is actually quite important because if you don't know where something was, and you often don't know what it is when you find it, and you have to kind of disturb it to collect it because you have to see what's underneath, you lose track of what you've learned.

So the computers of the time at Michigan, you were charged like $3 an hour. It was interactive, which was cool. It wasn't just punch cards, but you were charged like $3 an hour to be on, and you were charged for CPU time, disk IO's. Every little thing the computer did, it would keep counts and charge you. So the Anthropology Department had an account with several thousand dollars so we could get some reasonable computer time. And we figured out how to get free time very quickly. There was a bug in the system where you could tell it when you logged in, you'd say you wanted time, and time equals seven seconds, or time equals five minutes, some limit. You'd sign up for a block of time. You'd say T equals K, which was not a number, but that would give you free time, and then we had as much time as we wanted until they plugged that loophole, which took several years.

DSM: I haven't asked you yet about your first computer. What was the first computer that you actually owned, that was yours? Can you remember?

WJ: The first computer that I had to myself was a washing machine-sized VAX computer that was donated by Digital Equipment Corporation, to the research program that I was working on at Berkeley. VAX was subsequently bought by Compaq, who was subsequently bought by someone in the future, before you see this videotape. The industry is always in flux--but this machine was quite large and pretty slow. But we had several of them because we were networking them together on a very early computer network, which was really a new concept in 1978 probably.

DSM: Andy?

AB: Well the first computer was the one I built myself in high school for this little company in my hometown. It wasn't really a general-purpose computer. It was the one where we wired everything.

Later, I had access to timesharing computers, but that's not quite like having your own computer because when everybody gets busy, it gets very, very slow, particularly if you try to do anything interactive. So part of the motivation for what became the Sun

Workstation was to take the 32-bit microcomputer technology and build a machine that was for each student, or was for people for their own use.

WJ: The timesharing systems we used at Michigan were very advanced for the time. They had several processors in them. This was in 1970 more or less, and there would have 150 or 200 students logged in at the same time. And if in the middle of the night, before the end of the semester, you would ask it to do something, you'd need 10 or 15 seconds of CPU time. You could probably get it in a minute. When your homework was actually due and you were procrastinating at the very end, it could take you an hour to get 15 seconds because everybody was trying to do it at the same time. And the machine kind of keeled over from the load. So it's almost hard to imagine how slow that is, and how frustrating it is to sit there and wait forever.

AB: Yeah, in fact I'm an early morning person. What I found out is you get much better computer service on these timeshare systems when you come in at six o'clock because all the people who stayed up all night finally went home.

DSM: We're working towards 1982 when…

AB: Oh, there are important things prior to 1982.

DSM: When you guys met, but tell me about the other things that you were doing at the university.

AB: Well I was fortunate enough to be what they call a no-fee consultant at Xerox PARC. Which means they didn't pay me anything, but I could basically do whatever I wanted there, and just look at their Altair computers and play with them.

WJ: He got to get into the Emerald City.

DSM: How did you get to do it?

AB: Well I think Lynn Conway, who was writing a book about chip design, and she thought I would be a good student to try out her chip design sort of theories. I was working actually on a magic chip at the time, but what I was really thinking was that it would be really useful to have these personal computers with a network connection and a big screen for each scientist. I was back at Stanford then, it was obvious that this was like a great idea, and I began to work on that.

DSM: Who was with you?

AB: My advisor Forest Basket, who also had sort of the same idea--meaning he saw the vision. I remember one time he was teaching this class at his house on the Stanford campus, and he was pulling out these pieces, and a big screen, and sort of Ethernet plug-ins. And he suggested that we could build a machine here. He was wondering who was going to work on this, and I said, "I will work on it." And that was it.

WJ: They had personal computers that were like the machine Andy described at Xerox, but they were built out of mini computers. They took a Nova actually, a Data General mini computer, which had been what, 10 years before, and reworked the insides of it to be a personal computer. But you were talking about building something that mere mortals could build.

AB: At the time, 64 kilobytes of memory was a very large memory. They didn't realize that in a few years that would not be very much, but the whole environment was completely proprietary. They wrote all their own compilers, and languages, and software, and they also, of course, invented a lot of what today we think is graphic use interfaces. And Xerox did all this to save for the day when people would stop using paper and copy machines, which still hasn't arrived. But at the time, they made this big investment in computer technology to basically get ahead the starvation of paper.

But different people who went there saw different things. Steve Jobs went in there, and he saw the GOOEY, and he took that idea to Apple. And other people saw the laser printer, and they took that idea to make a laser printer company.

What I saw was the power of this work with the personal computer and how useful it was because I could actually see it. And then when we looked at how we would build such a thing, we just got the first 32 bit microprocessors from Motorola, the 60,000, which we really needed to program a scientific program, and we started working on the hardware. Of course, what was missing was the software. In the meanwhile…

WJ: When I was at Michigan, I got involved in early super computing actually. I guess you've interviewed Seymour Cray or talked to him?

DSM: Yes.

WJ: A man whom I unfortunately never had the chance to meet before he died. But I got to program one of his early computers, the Cray 1, and the CDC Star computer up in Minnesota in the early days of Cray and CDC. I was an assistant to a professor, and we were working on large codes to simulate mechanical systems using what were called finite element methods. So we did programming on these computers, which were very, very powerful at the time, very, very large machines.

So that was really how I got into writing quality software, to write these large, difficult, numerical codes for sparse matrices, actually was what we were writing them for.

I did that before I came out to California to go to graduate school at Berkeley. In fact on the way out to California in my car, my girlfriend was driving, and I was writing code by hand on paper. They were paying me for this code. So when I finished, I checked it over by hand. It was never compiled or anything. It was just all written out, and I paper mailed it back to them, and they paid me an extra $1,000 for the code I had written as I was driving across the country. Which paid for the fact that the car broke down, because it was an old car, and the gas, and everything, I think. I got my deposit for my apartment at Berkeley.

DSM: Speaking of girlfriends, this may be a good chance to ask about the families. Are you married?

WJ: I have a son, Hayden, who's five, and a daughter, Mattie, who's three. My wife, Sara, is an artist and school teacher and is now an artist and a mom.

DSM: Andy?

AB: I'm still single.

DSM: You share an award for your work and innovation. Where do you think innovation really comes from?

WJ: I think it occurs everywhere. People have bright ideas, and bright people are everywhere. So there's always people with ideas, and attempts to concentrate it can be very frustrating.

What Xerox did is they created a time warp by creating an infrastructure in an environment where they built these machines that let them have what people would have had many years later.

Time warps are expensive. I mean if you want to build a computer like it's going to be in 2005, that computer today—that's five or six years from now—is going to be 10 times more powerful. So you have to spend 10 times more money assuming you can build it.

If you wanted to build something that's 10 times as fast as the fastest machine we can build, you can't do that. But you could take a very expensive machine, pretend it's very cheap, and give everybody one, and Xerox did that. They had built extremely fast computers, which they then tried to put in people's offices. They were so noisy they had to put like this giant cone of silence around them. They called them the armored personnel carrier. Finally, they had to put the computers downstairs and run the video up to the offices.

The computer was called Derado and was built out of the fastest possible technology. They had machines that were as fast as any machine we had in volume in the computer marketplace for probably almost a decade later, because of the combination of the money and the fact that people were very smart. So they used the technology to do almost as good as you could do, and they had software, and the whole system put together with a network and disk.

So you can create these places where innovation can occur, if you have a vision of what the future might be like. If you spend enough money to make some of it true. Then it's like a telescope into the future, but it's a very expensive thing. It's not practiced in our time right now. It isn't practiced as much because there's so much easy stuff to do to go make money. That long term research has been in fact under funded, I'd say, for the last 10 years.

DSM: Andy?

AB: Most of what I am working on, and since we started Sun, was focused on this two-year horizon. You know something you can predict, something you can complete in a bounded amount of time. But Xerox PARC and Stanford were really incredible environments. There were just a lot of smart people around. That stimulates discussion, and you get exposed to a lot of different areas that you normally wouldn't see if you just worked on your own projects. So my sense is innovation does have origins in the individual, but it is very sensitive to the environment. And having a critical mass of a lot of smart people all in one place makes a huge difference in terms of coming up with new ideas.

WJ: Most of the stuff I'm doing takes far longer than two years. I have things I've been trying to get to happen for 20 years that still haven't happened. So some of the things that I'm working on now, people are still not sure whether they are going to work. We had the idea 10 years ago, and we're still struggling.

I'm not sure progress is really any faster than that in reality for a lot of the new ideas. You can implement things better, but if you have a new idea, like you want to do a new programming language, and you have some idea of what you want it to be. If you can actually get that to happen, and get it to be widely successful, and displace the previous thing in 20 years, I think you're doing very well.

DSM: This is a question for both of you. Is there a particular problem that annoys you, that sets you off with this creative thinking? Or is it an insight that comes out when you're working with a problem, and you say ah, here's something?

WJ: In the case of the better program, we're writing the software in a low-level language. The language is already 20 years old, essentially. This is 1980, okay, and so if we don't get a better way of writing this, there's this general nervousness about we won't be able to write things that work well. So you start looking for the better language. You know that you need one. You don't know how, but it focuses the mind then to look for it, and it takes a long time. For it to achieve commercial success, you don't always get it on the first go, and you just have to keep trying.

For me in that case, I tried four or five times before I actually participated in providing what I was looking for. It doesn't always happen that way. You know you have a sense that you want a better user interface. It actually came out not of Xerox but of Apple. We all knew that there were more human factors that could be improved, but we didn't end up participating really in that. Steve Jobs and the Mac project ended up doing that.

AB: My sense is that if you have a deep understanding of the problem you're trying to solve, whether it's a shorter term or a longer term problem, and you also know that the technologies or the methods of how you can solve the problem, and there's sort of a market need or a reason to do it, that tends to be the vicious circle that drives innovation. Obviously, the available technologies change continuously, so every year now we have a new type of chip technology where you can do different kinds of things. But I would like to confirm that the very first time I met Bill he told me about this need to improve the C program language. At the time, he called it the D language, the one after C. This was in 1982, and that was the vision that eventually resulted in Java.

WJ: So that was 13 years from then. 1995 was when we announced it, and it's not really still not completely what we wanted it to be. So I would say maybe by 2010 it will be done, which would be then from about 80 to 2010. So it would take 30 years.

The C programming language was a very, very major technology, which was incubated starting in 1959. Through various incarnations, it finally came out and became widespread in the '70s. So that was 20 years to widespread use, but widespread only because computers became more widespread.

The next generation you would assume would be incubating in somebody's brain now, and it might be 20 years away. The person is likely to be frustrated for 20 years if it's one person working on it.

There are limits basically from physics that you can't make a decision with less energy than noise. And at a given temperature, there's noise in the system. It's the motion of the particles, and if you tried to make a logical operation of the computer take less energy than the noise, it would be masked by the noise, essentially.

So there's a physical limit to scaling of the amount of energy used in a non-reversible computation, which intersects. And also when we think that the equations are going to break down is probably in 2010 and 2020 sometime. So we'll probably slow down also because the economics of making the future size smaller and smaller gets worse and worse, and plants become more expensive. But we've recently discovered Quantum, at least the theoretical possibility of Quantum computers, which work in a completely different way because they are not based on Boolean and algebra. At the bottom, they are based on a Quantum entanglement, which is Quantum theory, which is so weird that essentially Einstein didn't like it. But it's been proven by experiment. It's very strange. It's exponentially more powerful than traditional computing, and that may be a technology which becomes practical in the 21st century.

AB: There is another limit as well. As these chips become denser and denser and you have billions of transistors per chip, the current CAD tools that we use today to design chips are not sufficient. You can't just throw more people on the project because you would never finish it. So most importantly, we need to fundamentally change the methodology on how chips are being designed and how to design them correctly. It's difficult to imagine what you can do when things go a thousand times faster or more.

WJ: That's about how much we have left from Moore's law. My estimate today would be about another factor of a thousand, and then the free lunch ends.

DSM: The free lunch being you've got a lot of wiggle room.

WJ: Things keep getting better. So if it isn't quite possible, just wait, and the medium you're expressing the thing in will improve. And it may be possible, but that isn't always the case.

Somebody who wants to design a plane, which travels at mach 1.7 will encounter certain friction in the atmosphere which heats the surface of the plane to a certain temperature. That's a harder limit to escape. You know you can't make the air disappear. The air isn't getting thinner exponentially.

So for us, the ability to compute is getting exponentially easier and has been, and that's really a free lunch. It covers up a lot of bad designs and makes it really easy to do things. If the set of materials we were working at were steady, the industry would feel very different, and it will I think sometime in the next century. It will slow down, and different things will become important.

AB: You see the laws of physics are not changing where as [inaudible] has changed how close we can get to these laws of physics.

DSM: When you guys were growing up in the late 60s, the early 70s, the Civil Rights era, and Vietnam, and Watergate, and here in the United States, they were actually blowing up the computer centers. Were either of you touched by any of the politics of that period in which you were growing up, or were you pretty much isolated from that?

WJ: The anti-war movement in the United States, the students for democratic societies headquarters, were Berkeley and U of M. So you were very aware of that. Although a nerdish math major engineering kind of existence didn't intersect highly with the kind of people who were more into that were in the literature science and the art school, more in the different departments than I was in. We were perhaps just unaware.

DSM: Andy, were you touched by any of this turbulence?

AB: No, not at all. I was aware of these events, but I never really cared about politics. I think people remember these news events because there was a picture in the newspaper, but it really didn't mean anything.

What was a little strange to me was that people thought that technology was like dangerous, or that it would make the life worse in some way, which I never understood why people could believe this. But definitely in Europe or in Germany at the time, there was an anti-technology trend, which I would say was one reason why I came here.

DSM: What I want to do is work towards your meeting and work together. Maybe we could start, Bill, with your move to Berkeley and just talk about what you did from sort of the time you arrived at Berkeley up until the time you met Andy, and then we'll ask Andy to do the same thing from the Stanford side.

WJ: I applied to graduate school at MIT, Stanford, and Berkeley, and Cal Tech. MIT and Stanford admitted me, but without real financial aid. So I would have been a big debtor when I left, and that wasn't very attractive. And Carnegie lost my applications. I actually read it to them again over the phone, but that was kind of depressing, and I wasn't sure I wanted to live in Pittsburgh. Then Cal Tech offered me a fellowship, and Berkeley offered me a teaching assistantship.

I think the decision between Cal Tech and Berkeley was a hard one. Cal Tech is really more of a hard science kind of a place, and I think I'm interested in other areas of science certainly than engineering and technology. But in the end I decided I really didn't want to live in Los Angeles area because of the air quality. So I decided to come out to Berkeley. And both Berkeley and Cal Tech didn't really have programming kind of computer science as their focuses. Berkeley was much more of a theoretical department. The math department at Berkeley was very strong, and Cal Tech had this more science focus. This was opposed to going to Stanford or MIT, which were much more the hot beds of programming and AI, you were going into a more theoretical environment, but that soon changed.

Berkeley had no programming. It was in the process of getting it. So the fact that they didn't have it was the reason not to go. It's unintended consequences I guess is what they call this now. So I ended up being the person who helped bring programming back to Berkeley.

When I arrived in Berkeley in '75 with the hopes of not programming, and in fact, doing theoretical computer science, the math department had built a new building, Evans Hall. And one of the things they had done in building the building is they traded an elevator for a computer. In other words, they had taken the money that would have paid for the elevator and instead bought a mini computer. It was like giving your kidney for some money or something here. Twenty years later, they finally put the elevator in by lifting it to the top of the building and dropping it in, and they needed like the world's biggest helicopter. The first three helicopters they bought out to put the elevator in weren't big enough. So it was a major, notable omission.

But this computer was a P1145, which ran UNIX part of the time, and I got heavily involved in UNIX years later. But at the time, Derek Laymer, who is a very famous mathematician, was programming and had been involved in prime numbers and stuff in mechanical computers even going back to the second World War. He was quite old at the time and very, very famous. I ran into him because on the second floor of the building, they had some terminals, and we would program and ILIAC super computer, which was down at NASA. Actually, they only built a quarter of it. It was a parallel computer. This continued the work on parallel computers that I had done when I was at Michigan. So a few years after that, I got involved in writing some new software for another UNIX machine that we had got to do education in the department.

DSM: So you were working on UNIX, and your career as far as actually being in the business of computers and making money started with some tapes that you were selling for $50?

WJ: Right. What happened was, Ken Thompson had been at Berkeley a number of years before that. Then he went to Bell Labs and did UNIX, which was an operating system for DEC Computers, and at the time, a PDP11. He never got his Ph.D. He only had a master's degree, but he came back at one point to teach again.

Around the time that he came back to teach, the department got a PDP1170, which was a mini computer which could run maybe 20 or 40 screens that students could sit at and learn how to program.

When Ken left, a friend of mine, Sharkaley, and I took a program that he had started writing, which was a Pascal compiler. Pascal was a programming language, which was thought to be very suitable for teaching. And we worked on improving and finishing his implementation of a compiler for that language. Subsequently maybe a year later, I took the Pascal compiler and some of the work that we had done on programming tools that we had improved in the process of working on writing this Pascal compiler, and put them on a tape. And we put up a notice through a mailing list I got from somewhere, that if people wanted the software, they could send me $50. I then would send them a tape of the source code and the binary that would run on their UNIX computers. So through the informal UNIX community, of which there were a few hundred universities at the time, it became quite successful. The money that I collected was $50 each minus the $12 or $15 it cost me to buy the mag tape, and I franked it with the department frank so I didn't have to pay for postage. But the first time the universities below the top tier in the country had a common platform.

The top tier universities like MIT, Stanford, and Carnegie all had PDP10s, and research communities, and shared programming language. They had different operating systems, but they would share list implementations, and they could use the R [inaudible] to move their code around. But when the smaller mini computers came along the next tier of universities, maybe another hundred or several hundred universities, some fraction of them could get this UNIX system. They could now get their hands on something and start to do computing research using UNIX and the freely available, what you'd now call open source kind of exchange of software. This was, at the time, a very, very early example of that.

DSM: So the distinctions between what became known as a Berkeley UNIX and a traditional UNIX was this networking underpinning?

WJ: Initially we sent out a tape containing these programming tools. Shortly after that DEC came out with the 32 bit mini computer called a VAX, which was large enough to run LISP and other large AI kind of programs that we wanted to run to do the research in the department. So we got a prototype UNIX operating system for that and added virtual memory to it so we could run very large LISP programs. We tuned it up a bunch and actually made a complete distribution tape that we would send to people. That gave them virtual memory in a more stable system. Then the next version after that, we added support for the Internet, and so that became very powerful.

That was in 1979 or somewhere around there, maybe 1980, but the ARPANET was making a transition from an older protocol to the protocol that's now the Internet protocol. The VAX and running UNIX was extremely popular. And for the universities, and research labs, and companies who wanted to connect to the network, and who wanted to run these large software applications, this was a very cost effective way in a the days before personal computers and workstations. It was definitely the most popular academic system for the leading departments who weren't timesharing off a mainframe or something.

So for that operating system software, and those tools, and the whole organization of that distribution, we were charging them $300. And I think at one point there were 500 of them or something so that's what, $150,000. That's a lot of money. I don't actually know what happened to all the money. But we could call anybody in the world and talk to them as long as we wanted to on the phone. It's kind of fun to be able to make phone calls. Normally, the university phones you can't do anything.

DSM: So you were still a student working on what?

WJ: On UNIX. Eventually what happened was it got institutionalized. Bob Favory got a grant from DARPA, which is the research arm of the defense department. The grant was to make our target more specifically doing a system for a couple of their constituent research communities and knowledge representation image processing, and so I actually got an appointment as a California State government employee - as a principle programmer to work on this. But before that, I had been just doing it as a student by neglecting my studies.

DSM: What studies were you neglecting? I mean obviously you got sidetracked in a great way.

WJ: I was going to do theoretical computer science, and actually I ended up fixing the Pascal system. I had been trying to write a parser for general context free languages. That was a programming algorithm that someone had published in trying to think about a way of doing a better parser. It's a theoretical kind of thing. And when I was trying to write the theoretical parser as a program, the programming language implementation wasn't good enough. So then I had to go fix the programming language implementation. Then I needed a better editor to do that. Then the operating system was not stable enough. You never get back to where you started. You just recursively descend fixing other things. So I ended up kind of stuck at the lowest level fixing the operating system.

DSM: Andy, tell me about what you were doing while Bill was changing UNIX and this whole operating system. You were at Stanford working on what eventually became the Stanford University network. Tell that story.

AB: Right, so Stanford was not one of these DARPA Department of Defense sponsored research sites. DARPA tended to focus their investments into fewer places, which meant you had enough resources to actually get critical mass.

So Forest Basket was the principle investigator on this project, which we simply called the Sun Workstation. It was for the Stanford University network, to build a computer for every researcher and student at the university. DARPA gave us—I guess it paid my research assistantship, $400 a month and the tuition so I could work on this all night long. We had to build the graphics card, the Ethernet interface card, and the CPU card. Luckily, we had a CAD system that was left over from a previous project that DARPA also had funded, that was running on the PDP10 computer at the time. So because I had this CAD tool, I could actually do all this work by myself in a fairly short amount of time. About a year after we said we'd do all this, we actually had this thing up and running.

There was another professor, VonPratt, who wrote a little software module that would allow it to act as a terminal on the network. It was clear that what we really needed was an operating system where we could run standard little programs, not just a terminal function. The obvious solution was to take the Berkeley UNIX operating system that Bill had developed, and move it over to this very inexpensive desktop machine. I'm not sure it was really DARPA who pushed it, but it was just the obvious thing to do.

WJ: Andy working on hardware by himself is like Thomas Jefferson dining alone.

DSM: I'm going to ask you a question about Thomas Jefferson dining alone at the end of this. Did you guys know each other at this time? Had you heard of each other?

WJ: No, not until the day that he came with the other Sun people to visit Berkeley. I didn't really know where Stanford was. I knew it was south on the peninsula somewhere. I was going to consult one day for Hewlett Packard on UNIX, and I was driving down the peninsula to meet their shuttle to fly to their location in Colorado, which I was supposed to go to. But I drove down 101, and I couldn't find the San Jose Airport and missed the plane. So I had no concept of what was South of San Francisco.

AB: Maybe history would have been different.

WJ: If I had made the plane, it would have saved a day. They didn't listen to what I said anyway, so they probably still wouldn't have listened if I had gotten there a day earlier.

DSM: So tell the story of how you two guys met.

AB: I actually knew of Bill because he was famous. It was basically this guy from Berkeley who did this whole UNIX compiler pretty much by himself. Everybody was waiting for the next release of the 4.1 and 4.2 tape that was supposed to be the production release, and here we were having this piece of hardware but no software, and here was the perfect software.

So what happened on my side was that Stanford, obviously, was not a place to build or manufacture computers because it's a university. For a while we tried to license the design to a whole bunch of other companies. There were actually eight other companies that build these Sun boards under licensing arrangements, but none of them saw the potential for building a workstation. And still, even today, I can't quite conceive why that was, because if I had been in any one of these companies, that's what I would have done. But the conclusion was, this is not happening. We need to do this ourselves. I met Vinod Kholsa, who was best friends with Scott McNealy. The three of us sat together, wrote a business plan, and showed it to show venture capitalists. Very quickly, after a weekend or so, we had a check in our hands and became funded. But again, the problem was we had no software. So the first order of business was to call Bill Joy at Berkeley and ask him whether he would like to join our company.

WJ: Well for me, at Michigan, we had this interactive timesharing system called MTS, which was much more advanced than what IBM had. It was done in the university, and so our computing was done on this large-scale computer.

We went to Berkeley, where the PDP11 and the VAXs were roughly of the same scale. So in the phenomenon of micro computing, and personal computing, and the Apple came along, and it seemed that what we were doing really wasn't very interesting. We were trying, in fact, to run these difficult problems to solve certain scientific problems, to solve certain research problems, how to do symbolic mathematics or do image processing. And the computers, even the large ones we were using, weren't really adequate. We were working on networking the computers together with higher performance so we could gang several of them together to break up the work. So almost all the companies that came by and showed us their microprocessors were just useless. They wouldn't begin to run. They would be like three steps backwards. When Andy, and Vinod, and Scott came along, Andy's notion of what a terminal was at the time was as fast as my mini computer. So he was very aggressive in the kind of design that he did. The hardware was interesting enough to really get my attention.

It was one of the first microprocessor-based systems that could run real applications, because he didn't use the chips that the Intel machine did, which were very poor architecture. He used a Motorola chip that had a very linear address space, and it had the promise very soon of virtual memory so we could run the large kind of apps that I was interested in. So that got my attention.

DSM: Tell me about how you got in touch with each other. Did you get a phone call or a letter?

WJ: Vaugn Pratt, a professor from Stanford, whom I knew, called me. I had maybe met him once at a seminar at Berkeley. These guys Scott, and Andy, and Veno piled in a car and came to see me. Scott and Veno arrived first looking very young, and I thought, kind of confused. They came into my office, and I was working on fixing a bug in something. I was waiting for the adults to show up, so I sort of sat them in the corner, and I just kept working.

Vaugn and Andy came in, and there's a story about Andy about how he liked to cram all the chips on the board and stuff. I had heard this story. Someone had told me so I said "Oh, I'll just show Andy the computers that I have." I had this room that was very noisy, a room with a raised floor and all these big, washing machine type VAX computers, and I just went into the room. I just turned one off and took a board out and handed it to him. Now you just don't walk up to a mini computer. It's like walking into a hotel and shutting off the phone system or shutting off the lights without any warning. But I had six of these to myself, and it was just one I wasn't really using for anything. It was called Matisse or something. They were all named after Impressionist painters. So I just turned it off and pulled the board out, which I think Andy thought was pretty cool, because most people who were software types weren't that brutal to their hardware.

AB: You usually don't even touch the hardware.

WJ: Well we always would take it apart. If the thing wouldn't work, we would just swap the boards to see if we could fix it. We treated it as kind of an experiment in progress.

Then we went to a little café, the Three C's Café, coffee, cappuccino, and crepes, and sat down and just chatted. They all piled into this little tiny car, all four of them. I don't know how. It seemed like they all left in the same car, but they didn't arrive in the same car. They must have been dropped off, and people were parking or something. It was like they drove away.

DSM: What do you remember about the first time you saw Bill?

AB: It was just like. I mean he was typing away on his console, and…

DSM: And the office looked like what?

AB: Well it was the machine room. It wasn't really an office, right? You were in the middle of...

WJ: I had an office across, but yeah, I had the kind of plugs that pilots would wear. There was a bag of those on the door so you could go in there, and you could put the earplugs in and the headphones over.

AB: So you seemed in deep concentration, and I was actually wondering how we should tell him that we were here.

WJ: Well you get very busy. There's this thing now that's very popular called Linux, but that's just a kernel. We weren't just doing like the DOS part. We were doing the compilers and all the application software. So it was a system plus all the applications, and there were like three of us doing it. We had a list of 150 things that people wanted all the time, and we were never going to finish.

There's always something that's burning important that you're working on, and sleep and normal life are things attempting to get in the way of you finishing getting some problem solved. The graduate student existence, you know.

DSM: Tell me about some of the projects you worked on together.

AB: Well in the early days, the company was quite small. I was working on the next generation boards, and Bill was very busy getting the next release out. What surprised me was that Bill suddenly took a very serious interest in hardware both on the graphic side on the microprocessors, and just every aspect of hardware, which I didn't really expect. We had a lot of discussions about that. We also lived in the same house for a couple of years. It was like in the mid-80s.

DSM: And this was when you working on what eventually became the Spark Station.

AB: Well actually Bill did the architecture of the Spark chip with some other people. Where as I was sort of waiting for them to finish the architecture until I could like put it down on a board and actually build a system with it. It worked out pretty well.

WJ: I remember one time we had some devilish problem in the memory of one of the computers. The memory boards appeared to not work. It turned out that the memory chips themselves were defective. In other words, they didn't do what the data sheet would say because it's really analog inside it. It only appears to be digital. So I remember I stayed up all night one night and wrote my first timing analyzer. I typed in the datasheet for all the chips. So take a RAM chip. I didn't know the first thing. It's got all these numbers. So, "Andy, what does this number mean, TRC? What's that? What's this?" So he started explaining how it works to me, and so I go back to my office. I had the circuit drawing, and I typed in some more numbers about how long it took the thing to get from here to here, and what the various constraints were. After about a day, I said well Andy, this number should be zero, and it's negative three. What does that mean? He said, "Oh, don't worry about that." It was quite interesting.

AB: So we actually worked on some CAD tools at the time. Even though the Sun workstation was originally designed to run CAD software, it took awhile to get this CAD software from commercial companies.

WJ: You used to do the stuff at Stanford. You'd go back and use the…

AB: I was still using the Sun CAD environment for a couple of years even after the company started.

WJ: On these old, storage tube, vector graphics displays that would flicker. And if you put up a simple drawing, it would look okay, but once past the threshold it would go every other frame. And the drawings he put up, it would go like this. Just looking at it you would get an epileptic seizure. So you have no idea unless you knew what was on the screen…

AB: We were hoping that they would last until we had our project finished because if they were going to break, they would never be replaced.

WJ: They were ancient. All the designs only worked on one computer at Stanford, which had been custom modified. It was a digital machine, but…

AB: It was running the Stanford operating system.

WJ: Stanford guys had taken it apart and rewired the back plan of the machine. The DEC guys probably wouldn't even service this thing, and it was probably 10 or 15 years old.

AB: It was amazing. It was called the dungeon, and it was in the basement of [inaudible] Hall at Stanford.

DSM: I've heard that there was environment in which a lot of pranks and things were plentiful?

AB: Oh, that was at Sun.

WJ: Yeah, the April Fool's joke teams got quite creative.

AB: Elaborate.

WJ: They took a car that I had. It was a Ferrari. They put it in the pond on a platform so that it appeared to be floating on the water. They did car in pond, pond in office, car in office. They did a sequence.

DSM: Car in office?

WJ: Yeah, it was Eric Schmidt. They took a VW, sawed it into pieces, and put it inside the office. Then the next year, they took his office, and they floated it in the pond. So they did all combinations of pond, office, and car.

AB: And one year they put the little pond with the fish in my car, in the office.

WJ: And then they took Scott McNealy's office and the guy next to him and took the guy next to him and took the interior walls out and made a dog leg golf course inside his office, things like that, but it was a way of letting off steam because it's such a high pressure environment.

DSM: This is a question for both of you. When did you realize that this new company that you were doing with Scott McNealy was going to really make it?

AB: It was clear from the beginning.

DSM: Clear from the beginning, never any doubts.

V: Because we were doing a very interesting product that people actually wanted. When we started, we actually had a backlog of people who had heard about the product, and they were ready to buy one except we still hadn't built them. So it was a very unusual situation, because the product development was nearly finished in sort of the first version when the company go incorporated. In most start-ups, you start building the product and ship it two years later. We were shipping a product within three months of incorporation.

WJ: For me, I was happy just to be out of Berkeley. The Berkeley campus is landlocked in the city of Berkeley and has no space. So even with $150,000, that doesn't mean you can get 100 square feet. There was no way to get any space. I had money. I could have hired somebody to help, but because you can't get any office space for them, you can't get anybody. So you become a success disaster because the more successful you are the more demand there is, and there's no way to provide any people to help fix bugs or anything, or answer the phone even.

So when somebody came along that had a machine that could still run the kind of programs I cared about. Someone who could also get out of the Berkeley campus to a space where we could hire people, so if we had people who wanted to use a machine, we could have someone to help them. That really solved a problem for me. So it didn't really matter to me as much whether the company was successful or not, as long as I continued to work on the kind of things I wanted to work on.

DSM: Space is pretty important to you. You moved to San Francisco and then to Aspen.

WJ: I really wanted to get away from just all the Silicon Valley types at some point, and it's gotten worse since I left 10 years ago. It's hard to have dinner in Palo Alto without overhearing a business plan being discussed at the next table, and that almost to the exclusion of a lot of other kinds of things. So coming to San Francisco in a more diverse environment was very attractive. After the earthquake in the late 80s and the freeway overpasses and everything fell and the traffic became unbearable, all of a sudden it took forever to go from San Francisco down the peninsula. So I decided to move to an environment which was far enough away that people wouldn't be able to so easily invite me to meetings, and I had less traffic. It gave me an environment with more creative thinking without interruption. It's hard to think when you're being interrupted.

DSM: How would you choose Apsen?

WJ: They had a good bookstore. They had culture, and they had skiing, and they had a summer in the winter. Being from Michigan, it's kind of nice to have seasons. California only has climate. So the seasons are a nice thing to measure the passage of time and stuff.

DSM: What do you read? I know you're very interested in Shakespeare, yes?

WJ: I'm on the board of a Shakespeare festival. I read a lot of history, science books. I like biography.

DSM: I'm prejudiced. What history books do you like?

WJ: Well Guns, Germs, and Steel is a cross genre. It's not exactly history, but that's a really good one. An example of a really good science book is a book called Growing Young. It's kind of an anthropology book. But cross-disciplinary stuff is the most interesting stuff for me.

DSM: Andy, how about you?

AB: Oh, I love to read except I don't have time lately. When I was in Germany, I typically read about a book a day actually. The lady at the library kind of wondered. I went in there every day and got a new book and returned it the next day. But I sure like living in the Bay area because it does remind me, of all things, of Italy where I kind of grew up. So when I came here, I felt right at home. And there is a lot of beautiful nature in California.

DSM: You left Sun in 1987.

AB: Nineteen ninety-five.

DSM: No, but in '87 you left for the first time, right?

AB: What happened there was the company was so busy doing all these other products, that there were no resources left to do the one project that I thought we really needed to get done, which was a low-cost Spark workstation. In sheer frustration, I said, "I'll just do it myself. I'll pay my own way." I went off for about three months doing this. What was clear, of course, was we needed all the Sun technology, the Berkeley operating system to make it a real product. So we had this big meeting, at which point it was decided that this shouldn't really be part of Sun after all. So basically I never really left Sun officially. It was more a way to get a product kicked off. We called it the education product division because I kind of knew what Steve Jobs was doing at NIX, and I was getting a little worried about this. He was focusing this low-cost UNIX workstation. And by saying we're going to focus on the education market, nobody else worried about what I was doing. But it actually did become the most successful product launch for Sun as a new product when it was finished. Obviously, it was just a standard Sun Spark workstation.

DSM: When Jobs was at NIX, he did the Zilla network that you can run with the NIX machines which was really quite something.

AB: Well it was kind of funny because when Jobs was at Apple, Bill actually you know, really tried to get him to do some UNIX work. In fact, I remember we dropped him off a UNIX machine just to try to get him interested in UNIX. And he said, "No, no, no, this doesn't make any sense." Then he goes off doing this company. And the first thing he does is start with UNIX, but he sort of started with the wrong UNIX. He made a lot of mistakes in that product development so they never finished the system.

WJ: One of the things that didn't happen probably in Silicon Valley was Sun and Apple getting together. I first tried to make it happen probably in '85, actually '83, and '85, and '87, and in '89. I mean every two or three years I'd try to make something happen. In fact, I gave a talk at Apple on Tuesday of this week, but Apple is a pretty independent, almost an island company. It was always very difficult. I think Sun always had a really strong desire to do something with Apple, and it just never happened to date.

DSM: You had left Sun to start Unison, but you hadn't really left Sun. We talked about that. We talked about the development of the SPARC Station. Granite. Talk to me about your founding Granite.

AB: Yes. What happened in 1995? I guess I was a little--I shouldn't admit this--but I was a little bored working all of a sudden next generation workstation kind of project at Sun. It became repetitive, basically, and I was doing more or less the same thing. I did see that there was a major opportunity in making networking go faster by a factor of ten by changing the Ethernet from one of megabyte to a gigabyte.

That sounds like a simple idea, but it had significant economic implications in the sense that it can run your whole computer data center much faster. And even though I was quite happy at Sun as a founder, and working with Bill, especially, I just wanted to do something different for a change. And Sun was not the perfect place for doing this networking project because we would have to hire new people and give them stock options, and so on. So, I decided to do that. And that company was acquired by Cisco in September of 1996. And ever since, I'm at Cisco Systems.

DSM: Well, Andy was talking about Ethernet, switching. You were thinking about something called Oak or Java?

WJ: Well, actually, after the earthquake, and after a failed project with AT&T, since about 1980, I'd been frustrated that the software, the operating systems were getting too complicated. And I'd looked for many years to try to make it simpler. In the late '80s, we were trying to get all the various versions of UNIX. Because we'd had this academic atmosphere, we gave everyone the source code. People had made lots of different versions and so we tried to fold them all back together. AT&T owned the trademark, and was the original source of this technology. So, we did a deal with them to try to merge our version and theirs together.

Ours was the leading scientific UNIX and theirs was the leading commercial UNIX. We tried to put those together. But in the context of that merger of those two systems, I wanted to also create a project to rewrite the system using more modern technology, so it would be more reliable. And that was called Phase Three of our contract. The project was a failure because we couldn't find a suitable programming language to rewrite the system in. And shortly after that, the earthquake happened and traffic became unbearable.

So I decided that the best way to do a new system would not be to try rewrite UNIX, which was the large system, but to start small. And systems that are designed, and are big when they're first designed, generally fail. Large systems that are successful, if you look, they usually were small, successful systems to start with. So, we made a very small facility in Aspen called "Smallworks" because it was really what we call a "skunkworks." But that's a trademark of Lockheed. I didn't want to have a trademark of Lockheed on my business card. We started a small activity to think about how we could do a simpler kind of re-invention of the way software was done. And a few years later, that came to become what's known as Java. And we were involved with getting Java going, in various points of time, starting the projects that it came from, which became Oak.

My specific intent in going to Colorado and then bringing Mike Cleary--who was my main collaborator there--to Colorado, was that if we were going to do something new that was big and successful, we had to create some things that were small and successful and let them grow. And so, Java and Genie and some of these other technologies that we worked on, we kind of incubated in a second foundation kind of wave. If people still know the Asimov Trilogy, that the Sun is the first foundation. It's the very open opposition to the mule, which I guess would be Microsoft. And the second foundation, hidden opposition to the mule, was the skunkworks, called Smallworks in Colorado, which then became Java and Genie.

DSM: A few minutes ago, Bill dropped a line about Jefferson dining alone, which is from John Kennedy's quote when he gathered the Nobel Prize winners at the White House. To paraphrase it: "It was the greatest assemblage of brainpower since Jefferson dined there alone." Well, as a result of that remark--and simply because we had the opportunity to do it then because it was going to be fun--we did a similar gathering at Monticello of some of the leaders of this revolution. And one of the questions I wanted to ask both of you--and I'll ask Bill to answer this first because I've already told him I was going to ask him--is if you could put together six or eight people around the table at Monticello who were representative of your revolution and we could record their conversations for the sake of people who are going to be looking back at this time from the perspective of two or three hundred years, who would you like to have around the table?

WJ: Well, if I can cheat, I guess in a Steve Allen style, he got to mix people who were living and dead, and who would never have had a chance to be together.

The classical inventor with the most unrealized inventions, would be Leonardo. He would be a very interesting person to have. The American who was the greatest inventor, probably, is Edison. So that he would be a great person to have.

I think it would very interesting to have Turing, who really invented the modern notion of computing. More contemporary, I think Steve Jobs is a very interesting person. Great insight into design and also the way individuals think about the computers. And I guess I would look for some more contemporary people. But I think invention and design, to me, are the most interesting aspects of it. So, I'll have to think for a minute, perhaps, while Andy answers with a couple of more contemporary people.

AB: Well, I would like to have Bill there, for sure. And I would die for meeting Einstein, or could have met him. But that's not possible. I think Von Neumann also was an interesting person. So was Shannon, inventor of the information theory. But today, Bill Gates makes for interesting dinner conversation. He's a little off in his corner of the world, but he has a lot of insights as well. And down here in Silicon Valley, there are a lot of people now in the midst of the Internet revolution and leading certain Internet efforts. And there's Jeff Bezos at the Amazon company, Steve Case at AOL. And that's really shaping what a lot of people see today, is the computer network or what can they do with the computer. So, that would be fun. Who else?

WJ: The other three people I would have would be Murray Gelman, who was an associate of Feinman, who was a Nobel Laureate. But he's working on two things that I think would be 21st century sciences, basically, quantum computing and complex adaptive systems in the Santa Fe Institute. Danny Hillis, who is a computer scientist now working for Disney but is a broad-ranging thinker. And the last person would be David Gelernter, who is a professor at Yale University. He is a writer, who has written and anticipated a lot of things. He wrote a book anticipating the whole Web and, in fact, beyond the Web, a number of years before the Web happened.

I think the idea of having people who had visions of the future at different times together at one place would just be staggering. And maybe some day we can take the text that they wrote, put them in a computer and write a kind of a jazz music improv thing on their ideas and re-animate them, breathe life into their thoughts in some way, that could maybe partially reconstitute these people's ideas. I don't know if that's even possible but it would be a really incredibly eclectic group.

DSM: Maybe this dinner is possible. This could be great.

WJ: The last few are possible. Gelernter, in particular, and Danny, are really incredible people.

DSM: Speaking of the Web, there are some who have the perspective that you really can't tell how revolutionary the revolution is until we've got a 100 or 200-year perspective of it. How big a revolution is what's happened on the Web?

AB: No, I think you can really witness the revolution while we're in the midst of it. And it seems to me that this is the biggest change ever in the history of mankind, in terms of changing how we experience daily life and how people do the things they do. So, my sense is it's going to be a bigger impact than even the industrial revolution because it transforms the way we work, the way we play, the way we learn, the way we meet people even, and so on. And it's just at the very beginning of that. So, a lot of people are still getting connected. And it's just amazing. We've been on the network since the early days of Sun. In fact, one of the benefits he had was we had this internal network. We always had electronic e-mail and ways of communicating. Adding the rest of the world to this kind of network was really a mind-boggling experience, seeing that happen.

DSM: Outside of the technical community, the IT community itself, and that natural networked community, what are some of the most exciting things that you've seen spin out of the Web? I mean, you mentioned Bezos and Amazon.com in retail. But what really turns you on?

AB: Well, E-commerce always has a very huge economic impact. But the one thing that I get pretty excited about right now is that I don't have to worry about my CDs or video things any more in the future, because I will be able to download them from the 'net. And being able to simply find my own life, because I don't have to keep all this estate around that can get lost or misplaced, seems like a huge benefit that the 'net could offer.

WJ: Yes, houses are the place where we keep all of our things. If we didn't have to have all those things, we could just wander around. It'd be much nicer. There have been many advances in communications: the invention of the written, the transition from the oral to the written word, which was the issue in Socrates' time. The next big, probably, communications thing was Gutenberg.

The next big things that probably impacted our ability to travel were things like trains and then planes. Those affected our perception of the world. The existence of the trains forced us, around the turn of the century, to set everybody's clocks the same, which affected people's notions of time. That made a huge change in our world.

I think the Web, from a couple of hundred-year perspective, will probably get lumped together with radio and television. From a long distance, these things occurred very close together as forms of electronic communication, which kind of shrank the world culturally and let everyone see everyone else, to the destruction of a lot of cultures, but all to the enabling of diversity. Also it gives people forms of expression and new ways of history and all sorts of things. But it's probably the biggest thing since Gutenberg, in terms of the written word.

But I'd say jet transportation as an impact on the world has as much impact as the 'net did. It used to be the notion of a port; you're on a river and everything. And all of a sudden now, any place you can land a plane can become a center for other reasons. So, it really changed our notion of the world a lot, the jet plane.

DSM: In every one of these revolutions, from the oral to the written tradition, there was someone of significance. There was Socrates, who was absolutely convinced this was the end of civilization as we know it. Print, of course, undermined all of religion and the faith. It was the end of civilization as we knew it. More does the industrial revolution mark the alienation of man from man, man from his work, man from each other. Is civilization going to come to an end?

AB: Humans are amazingly adaptable. It's hard to believe that the same people, 10,000 years ago, would have worked with stone hammers and were barely melting metal, whereas, here we are 10,00 years later and we have a lot of tools to our disposal that were unimaginable even a few years ago. But we're still people.

WJ: The industrial revolution yielded this kind of attempt to design a better society, which was very destructive for a lot of people's lives, the isms, totalitarian and whatever. It's hard to think if we'd had some of this network technology, if it couldn't have been abused by some of these societies--who certainly had science fiction written contemporaneously --that suggested that it could. I hope that the 20th century was the century of the isms and the attempt to over-design society. And we'll work on more of our own personal state.

I think ascendance of the interest in Buddhism in the West reflects some of this, that we worrying more about ourselves and getting control of ourselves than trying to design the perfect society. The 'net is a tool and can be used as a blunt instrument to disseminate pornography, to disseminate hate speech, which fortunately isn't protected. Technology is a neutral-to-negative thing, I think. It has more abuses more than uses. But Arthur C. Clarke anticipated that communications technology would be the instrument for opening up the freedom.

In some sense, it's funny. We face this week, even, this whole political issue: what about giving technology to China? The long-term argument would be the more computers they have the worse off they are, in terms of trying to control what's going on. Fax machines, phones are good, communications satellites are good, if we really want our society to open up. That's certainly what happened since the invention of the communications satellite. That communication technology acted as one of the strongest forces for freedom. So, in that sense, the 'net should be a force for freedom. But it's also got the dangerous edge to it.

DSM: One of the founders of this program, as a matter of fact, 15 years ago said to me that what we should put in the B52s and be dropped immediately over the Soviet Union and China was not bombs, but Sears catalogs. The communication has that effect. Do you think the Web makes it very difficult for people who are evil to hide, as well?

AB: Well, I'm not sure about that aspect, specifically. But what I do see very clearly is the empowerment of the individual on the Web and the increase of personal freedoms and access to any kind of information for everybody at any time versus the ability of any government or any society to set rules on that. And I think, effectively, what it does is it reduces the power of government, which--even though you still need the government as an institution, certainly--may be a good shift of the balance of where things are. So, in a political process, this could be much more dynamic and interactive on the Web than they could have been in the past. Instead of potentially electing officials to vote for you, you could vote yourself on an issue.

Of course, that also has the potential for abuse. So, I think in the meanwhile, though, every government organization is getting on the Web and has a Web site. And it certainly allows the citizen to access information that is legally theirs and they should be able to access. In the past, they had to go to Washington, to some building, and find it. So, there's the tremendous benefit of that information available on the Web.

WJ: Someone said something to me this week. He said that the people are beginning to realize that the Web is not a mass medium. It's a medium for the masses but it's not a mass medium. And I think that really reflects its difference in character from radio, even print. There are so many little rivulets. It's not the Amazon. There's tens of thousands or hundreds of thousands or millions of different places and interests that can be supported. Just go to EBay and look at how the breadth and depth of the collectibles is stunning.

I showed the network first to a friend of mine who is a fan of the quarterback of the Denver Broncos, John Elway. And the first thing I showed him on the 'net was EBay, and went and just typed in "Elway" and there were like 75 things for sale in the next 24 hours somebody was selling that was memorabilia about it. But you can do that, type in keywords and see that you can find a community of interest. And people have been lonely, if they have certain interests, who don't know how to find other people that share their interest, that's in no sense a mass media.

DSM: I'm going to ask two more questions. We have about ten minutes. And then I want you to tell me anything that you think I should have asked that I haven't. The first question, I asked you about, who your heroes were when you were little and who inspired you. Now, at this point in your life, who inspires you? Who do you depend on?

WJ: My children, their creativity and energy. I have a lot of trouble with the word. I think the word "hero", and even the word "genius", have been debased in our society. The astronauts are heroes for having gone into space. They might be brave, but I don't see any sense in which that's heroic.

And I think even the word "genius", if you do something that's slightly creative, people say it's genius. So, to say it's my hero then, I have to decide what definition of hero I want to use when I'm answering the question.

I admire people who try to do great things. Always stuck in my mind was a definition excellence. I believe it was in the title page of Women's Room, by Marilyn French. It said, "According to the Greeks, excellence was the exercise of vital forces along lines of excellence in the life affording them scope." That was a definition of happiness, rather. But I think that kind of captures it.

I mean, you have things that you can do. You want to find a life for yourself where you can do those things and do them in a way that's great. And it doesn't matter what level you're doing it, whether you're in a caring profession or a creative profession. But we made a lot of mistakes in the industrial age of trying to reduce people to automatons. But if you give people the ability to be creative, you give them some scope to exercise their creativity and let them find the thing that they can do. So, my hero is anybody who has achieved that kind of balance in their life. Steve had his opportunity at Apple and cared more about the products and bringing them to people than making money, which is what most people in business tend to do. And so, that's heroic in a way, to focus on exercising vital forces along lines of excellence.

DSM: Andy?

AB: It's similar. My people have great creativity and real insights in what they're doing and who can reduce very complex problems to very straightforward thinking. So, one of my heroes, of all things, is Bill Joy. [Laughter]

DSM: Last question from me. Given the wonders of this technology, we all may live another 50, 60 or 70 or 80 years. So, I'll have a chance to ask this question again in half a century, perhaps. What do hope will be your legacy in this revolution? When people say, "Oh, yes, Andy Bechtolsheim, I remember him," what do you hope they'll say about you?

AB: You know, I don't think I ever really did what I did to create a legacy. I do enjoy working with young people who come straight out of Stanford, who sort of remind me of what I was like, say, 20 years ago, and who stay up all night and work really hard, working on some start-up idea. So, that's a very rewarding part of being in Silicon Valley and being connected to the flow of new ideas here. So, I do enjoy that very much. But I never look at myself in the historical setting or in historical terms. So, I don't know how to answer your question.

DSM: Bill?

WJ: Well, if I was remembered as having a few things I really wanted to do and having done them in a company, with a group of people, in that sense of a company, where we stuck to it and things mattered in the end. And did it in an honest and ethical and dignified way. Which is not always the way people in our industry have been behaving, recently. There's so much money around, it's clouding a lot of people's ethics, I think. So, it will be interesting whether this is viewed as a gilded age, or how people look back at this time.

I described the reason I left Silicon Valley was because of the kind of monochronicity (if that's a word) of the place, with the focus on money. And I hope it doesn't get to the level of New York, as chronicled by Wolfe and others. But there's that risk here--for those of use who have been working for a very long period of time to achieve certain things. I've been working on trying to find ways to have software that's more reliable. And I've done that by trying to make Java. I did that by being co-chair of a presidential commission where we recommended that--trying to get the government to fund research in universities towards reliable software--on the theory that it's like public health. Generally, we improve the public health system only when there are public health disasters. I mean when there was sewage open in the streets in London until really bad things happened.

So, similarly now we're facing Y2K because we--someone said at a conference that the technical guys have been running around without adult supervision--we've built a lot of very complicated systems. And the whole notion that complex societies can collapse because they built things that are too complicated. Whether it's a desert civilization that dies from the salinization of the soil or the pipelines get too long for some critical thing or disease vectors find their way in complexities that you've introduced in your beef system, or whatever, because things are too complicated. So, the thing I've cared the most about is trying to get the software to be more reliable. Because software is in part of everything. And if we take something that's a mechanical thing and replace it with some software and we knew what the mechanical did and we don't understand really what the software does, we've introduced a risk. And accumulation of these risks could easily get us. None of us really knows what will happen December 31 of this year. There's some small chance that something really dire could happen. I'm not necessarily a believer in that. But it's at least, I think, raised our level of awareness of it's not always good to build things that are this complicated.

We should take more responsibility. Just as if we build buildings here in San Francisco today, to build them without building them to be earthquake-safe, to have sheer walls and stuff, would be malpractice. So, in technology, a lot of the software we've been building is essentially malpractice, because we don't do appropriate test and design. And people's lives come to depend on these things in unintended ways. So, I think it's something we have to take more responsibility for, going forward. And if I can have contributed towards the solution of this more reliable software, that would be a great thing.

AB: Actually, I would like to answer that question again in a different way.

DSM: Yes.

AB: So, what really motivated me was trying to build better products that are simpler and work faster and more efficiently than what was available. And even though each one of these products only had a lifetime of a couple years, I think, in the aggregate, it did make a significant difference in industry. The other thing is the most important use of these products--actually was when people use them--were as tools that would allow them to design yet better products, whether that was in the genetic area or the computer design area. So, having created an environment where people can build better things and build really great products and accelerate innovation was something that was pretty close to my heart.

DSM: How do you think Bill Joy will be remembered in 200 years?

AB: Well, Bill certainly created a number of lasting legacies. One was the UNIX at Berkeley. And then at Sun, the network file system, the SPARC architecture, the Java language, the Genie environment. And many of these are going to be around, the next century.

DSM: Bill, how is Andy going to be remembered?

WJ: Well, this is my personal memory of how he'll be remembered as--that he taught me how to make things simpler. I think Andy is one of the most elegant designers of this era, in terms of really understanding how to put together systems that have an essential simplicity. He is also one of the kind of serial entrepreneurs of which there aren't many.

Jim Clark is another, who is famous now for having started several companies. Andy, if you go back to the one he started in Germany, essentially, with the first microprocessor that he got the royalties for. They sent him to school. And all the companies he's seeded out of his Sun project at Stanford. And then Sun. And then Unisun, I guess, and then Granite. He's a person who is continually re-inventing and creating and starting from small and simple. And we're going to come to appreciate much more as time goes by and these complicated systems continually overwhelm us, the beauty of simplicity. And what a great man once said, "I would have written a shorter letter but I didn't have the time." Andy has designed the simpler systems because he took the time. And it's hard and it's an art and it's something I learned from him. And I'm grateful for that. I think he'll be remembered for that.

DSM: I think that's a generous and elegant way to end this interview. I hope we will have an opportunity to redo it in 50 years. [Laughter] And we'll see how we do. Thank you both for--

AB: That will be 2049.

DSM: I'm going to write that down, going to make a date. 2049.

WJ: My friends in college, we printed out a 100-year calendar in the mainframe, but I've since lost it. The paper yellowed. It wasn't acid-free paper, so it wouldn't make it.

DSM: Well, thank you very much. And we'll see if we can't get these guys around Jefferson's table and invite you both to come and talk.

[Laughter]

WJ: Well, if Leonard is there, I'm coming.

[Laughter]