NATHAN MYHRVOLD PhD
ORAL HISTORY

COMPUTERWORLD HONORS PROGRAM
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Transcript of a Video History Interview with
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Chief Technology Officer, Microsoft

Interviewer: David Allison (DA)
Curator, National Museum of American History,
Smithsonian Institution

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DNM: Today is Thursday, May 28, 1998. This is an oral history interview for the Smithsonian Institution's National Museum of American History with Dr. Nathan Myhrvold, Chief Technology Officer of Microsoft Corporation. I'd like to begin the questioning by having you talk to us about where you were born and some of your earliest childhood memories.

NM: Well I don't remember any details of my birth, fortunately. My mother tells me that from the time I was two years old on I said I wanted to be a scientist. I can't honestly remember saying it when I was two, but certainly all my life that I do remember; I wanted to be a scientist. I was very interested in science and mathematics. At various points I found one part of science or math or related fields more exciting than the other, but it was always something in that area that excited me.

DA: Please tell us when were you born, and where, and if you can give us your parents and your sibling's names, just for the record.

NM: I was born in Seattle, Washington on August 3, 1959. I have one brother, Cameron, my mother Natalie brought both us boys up. When I was about two we moved to Southern California and I grew up in Santa Monica, California from that point on. Well actually I should say I was young there. There are those who say I haven't fully grown up yet, so.

DA: And your mom was pretty special I understand.

NM: Well I sure think so. Everybody thinks his or her mom is special, but my mother particularly was. She was a fashion model actually, for Jantzen swimsuits, which you'd certainly never know looking at me. She was also a schoolteacher, and while I was growing she would teach for various private schools in Los Angeles area. Part of the reason she was a schoolteacher is that she got a break on the tuition for sending us kids, Cameron and myself, to school.

DA: Do you remember, is there any particular learning experience that you remember before you really started school?

NM: My grandmother taught me to read. She lived with us, and she had been a schoolteacher. So she taught me to read, and I think that was probably the single most important thing.

We lived right beside a branch library, which was great until I was about nine years old, at which point I had read everything I was interested in that library. So I had to take the bus to go to the main library in Santa Monica. Then after a while I talked my mom into letting me go to the main library downtown Los Angeles, which was like an hour-long bus ride. That library had books you couldn't get in Santa Monica. So I think learning to ready was probably the most important step in my education, because once you can read, the world's knowledge is really opened up to you.

DA: Is there a moment that you remember when you suddenly realized that you could read?

NM: I don't remember any specific moment of learning to read. I just remember reading a lot, a lot, a lot. Pictures of me as a child invariably show me and my little brother Cameron, and he's got some toy, and I always have some book. I look very serious, and I'll be pointing at something in the book. I was the most serious phase of my life I think.

DA: Were you interested in reading about science and mathematics at that time, or just anything that you could get your hands on?

NM: Most anything, but a lot of science and math. I've also always been into cooking. From the time I was nine or ten years old on I would cook at Thanksgiving and so forth. My mom would just let me take over. I'd get books from the library and I'd cook the dinner.

DA: Is this from your mom letting you help in the kitchen, is that where that got started?

NM: She was very good at letting me help and in letting me take over and cook things. So she deserves a lot of credit there, but I can't say I learned to cook from her. I went and got books from the library for that.

DA: So it sounds like you learned from books very early on as well as from people.

NM: Well books were way more accessible, especially to a child. Books wouldn't tell you that you were too young, or you didn't have enough experience, or you didn't have enough precursors. You could just dive right in.

DA: Do you remember having role models or people that you looked up to as a young boy?

NM: No specific ones. The various people who were famous in science and in other fields, I thought were great. I used to read biographies of famous people and great leaders in science, but also in politics and other areas. I remember when I was a kid about a quote about Winston Churchill. Since then my respect for Winston Churchill has grown, but this just made me so mad. Because there's a quote of his that says, "scientists should be on tap not on top." Well who the hell gets to say that? So although in retrospect he was a great world leader in many ways, but that always bothered me.

It also bothered me when I read about people that had invented things or discovered things and the world passed them by and no one ever realized. It was only retrospect that people realized that they had made a great invention.

DA: Who was the first real scientist that you ever met?

NM: It's a very good question. There are people that I met that were scientists, sort of with a small "s". I think the most famous scientist I met while I was young was probably Jane Goodall and Louis Leakey. There was a series of lectures at Royce Hall at UCLA, and my mother got me a ticket to them. I don't know old I was, I must have been only twelve years old, something like that. Some how we managed to get the good seats, so I was sitting fairly up front.

DA: So you were like in the sixth grade or…

NM: I was a little ahead in school, so no…

DA: When did you start school because you finished high school at 14 right?

NM: Yes, well I'd gone to a couple of private schools because my mother had been a teacher at them, and every couple of years I'd skip a grade. There's always great controversy about this, that it was going to completely ruin me, that it would be a devastating blow to my social development. Well, judge for yourself, they're probably right.

I remember having an argument with the school I think when I was in sixth or seventh grade, they wanted me to repeat a grade because they said that my social development was going to be horribly stunted, and this was terrible. And so I said, "Well how many kids of the right age are you going to fail because of social development?" And they said, "Well ah, it isn't failing." "Well what do you call it when somebody repeats a grade?" Normally when people repeat a grade, that's because they failed that class.

DA: So you never had any doubt that it was the right thing to do?

NM: It was absolutely the right thing to do. Frankly I was bored most of the time anyway. The idea was to make you less bored and I think it achieved that. I don't think it was fast enough, certainly at times I didn't think it was fast enough. Plus I was never the most socially inept kid in class. In Phys Ed I was always terrible because I was always two, three, four years younger than everybody else. So we'd go on a mile run and I'd be huffing and puffing, but I was never the only one huffing and puffing. There was always some kid that was hanging behind me, and I'd sort of pull up even with him and we'd go together.

The fact is there's a wide range of levels of social development and other things, and the notion that there's identical, perfect, right age that someone should be in a grade is just silly. And when you see that range of social development in a child that's the normal age for a grade, no one ever thinks, "Well, let's make them repeat the grade because they'll be less of a nerd if we do that." Or if they're uncoordinated and inept in PE, many kids are. Do you hold them back? The only thing that always used to bug me was that, intellectual achievement like that, if I can be immodest enough to say it, is treated very differently than say sports talent or musical talent.

You know if I was a twelve year old that was working on gymnastics or something for the Olympics, everyone would say that, "Boy isn't that great that this kid's really following his dream to be in the Olympics." Or if you were a musical prodigy, people can accept a musical prodigy. But if you're just damn good at schoolwork and you're smart, it's very disturbing to people and they have attitudes that they'd never present to somebody was great at sports or great at music.

DA: Did you find that your teachers felt intellectually threatened by you?

NM: A few.

DA: Did they generally support you? What was the relationship, it must have been different for you then your peers?

NM: I guess. I mean it's always hard to have completely objective notion because I've only been me, right? I know what I remember being like back then. I remember in fifth grade, when I was two or three years younger than you're supposed to be in fifth grade. The teacher was teaching us that bears hibernated in the winter. I said, "No, bears don't actually hibernate, true hibernation is done by small mammals, and bears actually go into a deep sleep, it's not true hibernation, in fact sometimes they'll wake up and get up. And oh, the teacher was so mad.

I remember because I was always very shy in class, but I spoke up. So the next day I brought this book in, and the teacher finally admitted that he was wrong, and I was right, and in fact bears don't actually hibernate. But it wasn't an experience that a fifth grade science teacher had had before that they were corrected.

DA: Tell me about your seventh grade science teacher, Mr. Kagle (ph.).

NM: Yes, Mr. Kagle. He was influential with me, in large part because he had such a great attitude. He was a good teacher, but he also wasn't anywhere near as strict and formal and rigid. So he was quite an inspiration to me.

DA: What did he teach, what did you learn from him?

NM: It's interesting because what I remember of him is his attitude towards life, and my wanting to do well in his class. I don't remember the specifics. What do you learn in seventh grade science? It's not that big a deal. It's good that kids have it. I don't mean to bemoan science education, but it's not like there was this single crowning fact that that was earthshaking, or some great technique. But he was a great teacher.

DA: As you got out of high school at the old age of 14, were you already committed at that point to a career in science?

NM: I knew I was going to go to college. I actually discovered part way through my junior year of high school that I'd have enough credits to graduate. So I could graduate that at the end of that summer. But I hadn't applied to universities, so I would have to go to Santa Monica College, which was fine with me.

However, I had one course, one requirement I had not done, which was driver's ed, which in California is a requirement for high school graduation, but that also require you to be sixteen. So I was stuck, it was the horrible catch 22.

So I went in to see the principal and I laid my case out. So he thought about it and he says, "Well, rules are made to be broken. I'll waive it." Well I said this is an interview on that was put on TV or somewhere, and I got a letter from him a couple of months ago. He'd seen it and he said, "Yep, I remember doing it." I also was telling this story to some group of people that included Willie Brown, who's the Mayor of San Francisco, and was at one point the head of the legislature. He came up to me afterwards and laughed and said that Mayor Alioto of San Francisco, he's dead now, but he was mayor at the time. His daughter had the same problem. The principal wouldn't over rule it, so Willie Brown put a bill through the legislature specifically for Alioto.

DA: Graduating from high school at 14 is one thing, but entering college at 14 is another. Talk about that and your math teacher and college.

NM: College was great. I went for the first two years to this junior college because as I said, I hadn't applied anywhere else, and it was very close, and my mother didn't want me to move away for college. So I went there and it was very interesting. It was different from high school. Particularly at a junior college you had people of all ages. I remember some of my classes there'd be people in their 70s or 80s who were going back to finish their college degree, and then there was me who was 14. No one really thought I was 14. Everyone thought I was young and I was a geek, but it's far more reasonable to think it's just an unusually geeky kid than they're actually that young.

One of the influential teachers I had was during my first year in college. I took the second calculus class. It was math 8B. I think I had had math 8A. The teacher was a guy named Mr. Crawford. He was a very boisterous guy, and he was very, very unusual. The first day of class he's taking roll, and he's making all kinds of crazy jokes about people's names. He called on a bunch of people and just asked questions. He called on me and I got a question wrong. And he said, "Whom did you have for physics 8, or for math 8A? I said I had Mr. Rose. He said, "What did you get?" I said, "Well I got an A." He said, "Well why don't you go down to the registrar and move out of this class because you're going to fail."

I was 14 years old in this class, and this guy has singled me out on the first day of class, and he tells me I'm going to fail the thing. And I said, "No I don't think so." And he sort of accepted it and he moved on. It was a very interesting thing, because it was right on the edge of me thinking, this guy's a lunatic. I should get the hell out of this class. Moving from there to, wanting to be challenged by it. He had done it in the right. He had gone right up the edge of that divide as to whether it was just being ass hole or whether he was actually being inspiring. I loved the class, and I did get an A in that class, and in the following class after that.

I think he was an inspiring guy, a lot because of his attitude. He emphasized people really understanding things, not just having a rote combination of facts. I'm sure I would have gotten an A in anybody else's class. I generally got A's in classes, but still it really made an impression on me.

DA: Did you have to study hard to get good grades, or did it seem to come naturally, or was it a combination of hard and natural ability?

NM: Mostly I didn't study hard, for some classes I would. There were some classes where I'd be scared and I'd study real hard, and there were others I didn't. In general school was never all that difficult for me. There are friends of mine who are brilliant people and incredibly accomplished people, who never did well in school or got disgusted with school and dropped out. As much as I have respect for them, I have to say I was the opposite. I mean I did very, very well in school. I always wanted to take more classes than I possibly could fit in a period of time.

I never met a course catalogue I didn't like. You could read about some course in anthropology, or art history, or some other damn thing that was way away from what I was supposed to be doing, and I would find a reason I could be interested. I also discovered that there are more interesting course catalogue descriptions than there are interesting courses. You know, it's much more interesting to write a single paragraph than it is to do something over a whole semester.

DA: As a boy did you play around with technology or are you more interested in the theoretical sciences?

NM: Constantly I played around with technology, and not just technology. I was very into cooking, so that was one theme I always did. I remember there was a point where I was very interested in biology. For some reason I got interested in taxidermy. So I was stuffing animals.

I would go to the pier in Santa Monica and catch fish and I'd stuff the damn things, and friends would have their pet rabbit would die, and so by god I immortalized it. Now there are a fair number of folks at the Smithsonian who are still involved in doing that. In fact I got a book as a kid that was by a guy name Vinton or Vincent Brown, it was called *How to Make Your Own Natural History Museum*. I just loved that book. It had all of these different things that you could get into. I collected insects for a long time and collect rocks. And this book sort of had a whole theme on all of this, because you could take all of these rocks and bugs and other things and you could lay them out and create a museum exhibit.

DA: Your mother must have been very supportive of you. It sounds like she must have been wonderful.

NM: Yes she was wonderfully supportive. I think tolerant might be another word. Enormous patience might be a quality she had to have.

DA: How about your brother? You were pretty close in age right?

NM: Two years apart.

DA: Were you close to him?

NM: Yes, Cameron and I have been close always. We weren't always close in school because I was way ahead. And although he's very smart guy, he wasn't ahead in school. So although it was two years apart, it stretched out to be more like six years, because I wound up being four years ahead, plus two years of age difference so only rarely were we in the same school at the same time. Generally I would have gone through school years before he did so we weren't always at the same school.

DA: So we've got you through junior college. You went to finish your college degree where?

NM: At UCLA. I went there and I got a bachelor's degree in math, and a master's degree in geophysics and space physics, simultaneously.

DA: And were you always thinking about going on and doing advanced degree work?

NM: Always but I didn't know quite what to do, which is part of why I like math, I like physics, I like all kinds of things. So I wound up getting the bachelor's in math and the master's in geophysics. Then I went to graduate school at Princeton.

DA: Why Princeton?

NM: Initially I wanted to go on in math. I talked to a professor at UCLA and they said the two best schools for mathematics were Princeton and Berkeley. I have been bad about procrastinating. So I put off applying, and I applied only to those two schools, which, if my kids do that, I'll kill them. Of course they should apply to many, many schools, and they should keep their options open. I only applied to those two, and I got into both of them. I decided to go Princeton and I decided applied math was more interesting than pure math. So I went into this applied math program that could let you do whole variety of different things.

So the next degree I got was a master's degree in mathematical economics. Then I finally got a Ph.D. in theoretical physics. A friend of mine said that I was trying to have more degrees than a thermometer. And they're all on different topics, which in a way was a mistake because I could have been out much sooner if I had concentrated and focused on just one area.

DA: You were still in your young, early twenties.

NM: I was 23 so it wasn't like I wasted that much time. And I'm glad I did because it was great to see all of these other fields and learn something about them.

DA: Were you considering spending your career as an academic?

NM: Oh absolutely, that was the only thing. I'm sure if you had interviewed me when I was in graduate school at Princeton, I would have been very full of myself about that. And I would explain in an enormous, articulate way about what else would one do? You know, what greater thing could one aspire to? But of course I'm not there.

DA: I'm just going to ask just a couple more personal questions. Tell me about how you met your wife.

NM: Oh I met my wife in graduate school at Princeton. She was in graduate school also, not in the fields I was in. She was working romance languages. Her particular expertise was a 17th century Spanish playwright, Augustine Moreto y Cabana, who is a contemporary of Shakespeare, and actually at that point in time, Spain was a very important country. He only wrote comedies, not tragedies, but Moreto at the time was considered a far more important writer of comedies than Shakespeare, because the Spanish-speaking world was larger and it was more competitive, and none of his plays have ever really been translated. As a result, the combination of that and Sir Francis Drake doing in the Spanish Armada, and a variety of other things, Moreto is under appreciated.

DA: So did you, were you taking classes together, how did you meet?

NM: No, we met at the graduate college, which was the graduate dorm there in Princeton.

DA: And you've been married for how long now?

NM: Boy, at least 14 years I think.

DA: I've asked this question of several of the folks that we've done oral histories. Which is harder, you're the head of a major research organization, which is more difficult running a research organization or being a dad for two boys?

NM: Well I certainly worry more about being a dad. There are many aspects of parenting that are irreversible. You know, I should have done something different when they were five, they're nine now, and that period of your life is gone, and to a certain degree it's fixed in stone.

Now you don't always know how much influence a parent has. Of course you don't always know how much a manager has in something like a research organization. But generally in a research organization you can fix things. If I got back to the office later today and I make a bunch of horrible decisions, chances are next week or even next year, I could reverse a whole lot of them. You don't always have that option, nor frankly does it grab you quite as viscerally as it grabs you to be a father.

I love my job, I love the organization we've built, Microsoft Research, but if it burned down tomorrow I wouldn't feel quite so bad as I'd feel if something happened to my kids, because we could build another one. You can have another child but that doesn't replace the one that you had lost.

The other thing is, that I can at least fool myself into thinking I'm successful at doing my job. Bill Gates who is my boss is, he judges what I do, and maybe he isn't a perfect judge, but if he thinks I'm doing a good job, and I think I'm doing a good job, I probably am. But you know, raising kids, how do you ever know if you did the right thing? Not only is the past irreversible, but you don't even have a good read on the present, you know. So if when my kids are twenty and they say, "I hate you. I'm going away from college. I don't want to see you again." Or they say, "Dad why didn't you do X?" What am I going to say?

So it's a very funny thing. It's not like any other activity you do, and I think in that sense perhaps it's the hardest thing. It isn't hard to actually do. It's very rewarding. I want to spend time with my kids. It's not difficult in the sense of, "Oh god I dread going back home to see my kids." But I think it's difficult in the sense that you only have one shot at it really, and you don't know how you're doing until much, much after the fact.

DA: I was going to ask you abut moving from Princeton and I guess you went to Cambridge next with to work with Hawking. How did that come about?

NM: I wanted to be a physicist, an academic physicist, and the path that you take is that after graduate school you apply to get a post-doc position somewhere. And usually you go through one, or two, sometimes three of these post-docs before you get an assistant professor job. Then you usually work there for five to seven years before maybe your get tenure, and then you get tenure. That's sort of the life cycle of a graduate student or an aspiring academic.

So I applied a whole bunch of places for getting a post-doc. I wrote sixty-three letters. I was a little more nervous than I was applying for graduate school. Then I went off to Japan because my wife was teaching at a university in Japan. She wasn't my wife at the time. She was my girl friend. So I went off to see her over Christmas and I expected I'd hear in a couple of months. Well at four in the morning the phone rang and she answers it and she gets me up an says, "It's for you. It's somebody in England." I remember this bad connection, and this woman with a British accent says, "I'm sitting here with Stephen Hawking." Right. My thesis advisor was British, so I really thought this was a joke he was pulling. I honestly thought that it was. But they convinced me no, it wasn't, it really was Stephen Hawking. I could hear this murmur on the other end of the line. It was Stephen talking to the person that was talking over the phone, offering me a job. So I said yes. That was my first, and it turns out only post-doc. And it was the best post-doc of all the jobs I had applied to. I had sent a letter to his research group but I didn't have any real hope of getting it. It worked out that I did.

DA: You were there for a year, is that it?

NM: I was supposed to be there for like three years, but I was only there for about a year. And I loved working with Stephen. He's brilliant. He has a tremendous sense of humor and he has a great attitude. Those are a very rare combination of things. Within the realm of British academics he was very, very prestigious guy. He had the Lucasian Chair of Mathematics, which was the chair that Isaac Newton once had. Despite that he was a very down to earth kind of guy. He was always doing things for the benefit of the graduate students.

I remember there was a conference he was invited to that was supposed to be a small workshop. They only had room for one person from our research group. Well the topic was right on the thesis of one of the graduate students. So Stephen tried to get him in, and they said, no they really have to limit it to one. So Stephen sent him with a note saying I'm sorry you didn't have room for me. And it was completely unheard of because no one had stipulated that the one person had to be him, but of course honor and prestige and rank would all dictate that of course the most prestigious guy would go. It never even occurred to someone that he would send a graduate student in his place, but it was more important to that guy's thesis then it was for Stephen to go the thing. He was always doing things like that, so that the students around and the post-docs, we all loved him.

After being there for a year, I decided to take leave of absence for three months, and I never returned from my leave of absence. I intended to return, but I went to work on a software project that some friends of mine from graduate school had done, and that kept sort of snowballing. We thought we would work for a couple of months on the software project. I had never been into computers, I should mention.

DA: Did they ask you whether you'd be interested in computers?

NM: I was interested in computers a little bit, but I've never had a class in computing. I never had a class in computer science. I learned to program computers, and did a little bit of work on my thesis with computers. I typed my thesis on one of the early CPM-80 machines. It was a machine by a company called Northstar. And I used a word processor called Magic Wand, which was one of the earliest word processors. One night I had typed and typed and typed and typed, which I was terrible at. I was terrible at typing. And the machine crashed. And I hadn't saved the stuff.

This was the middle of the night, but there was a guy named Bob Austin who is still a professor at Princeton, and Bob kept bizarre hours, as I did, and I went down and talked to Bob and I talked to another friend of mine who was into computing. And he said, "Well there's a debugger program that you might be able to use to extract, as long as you haven't turned the machine off. You could actually go and get this debugger to boot into the machine and inspect the contents of memory. " You can't do that in computers any more, but on the CPM-80 machines you could. So he gave me this debugger disk, which is this eight-inch floppy monstrosity, and this mimeographed instructions for the debugger. It took me like three hours, but I figured out how to use the thing and how to recover. Of course I would have been time ahead if I'd just retyped it. But by god I was going to get that stuff out. So I got it, and I saved it off disk, and that was my first experience with a mini, microcomputer.

While I was working on my thesis, a couple of friends of mine in graduate school decided that it would be great if there was a program to help us do equations on our computers --something that would let you use equations with the same facility you'd manipulate text with the word processor. At that time there was a couple of programs, something called Maxima that was done at MIT, and something called MSP that had been written by a guy Cal Tech, who was in the Institute for Advanced Study, named Stephen Wolfram. They were computer algebra packages, but they weren't made for little computers, they were made for big computers. They weren't made for casual use.

They were made for something like if you had an equation that was 10,000 terms long, in desperation you might turn to one of these programs. So you could do a calculation you couldn't do on paper.

We had a different goal. We thought if we had something that would help you catch every factor of two, or minus sign error, every factor of Pi, and all the other simple, dumb things that you made, while you manipulated equations, it would be vastly more useful than something that was used all the time. We wanted to create a program that would allow scientists to manipulate equations with the same facility that word processors would let you manipulate words. This program would work on a small computer so that everybody could have it. So we started working on this, and I worked on it a little while I was in Japan, in between graduate school and going to Cambridge. And I worked on it a little bit while I was in Cambridge. Finally we decided, let's get together and get this out of our system and do it. Then put it in the public domain or give up or sell it to somebody or something.

Well by the end of the summer we decided to incorporate a company and I was the president of the company. And for the next two years I kept delaying my leave of absence. To this day I've delayed my leave of absence. They don't really expect me to come back.

DA: So tell us about this company you had. How many people were in it?

NM: Well initially there were three or four initial founders. Then we quickly added a couple others. There were five or six guys that were all part of the team summer that formed the company. My brother was one of them. He was about to graduate from college. He had one semester left to go at Berkeley, but he decided this opportunity was too great so he didn't finish. He dropped out with one quarter left. He later finished it.

So we started this company, and we got very excited. We were going write this mathematics package. Only we decided you couldn't do it on a PC yet because the operating system wasn't advanced enough. So in our spare time we just whipped up a little graphical operating system for personal computers first. So we had enormous naiveté, which, really you need to be to be an entrepreneur, because what a lot of entrepreneurs start off doing isn't what they wind up doing.

Then we discovered while we were working on this graphical operating system that IBM was working on something similar. We knew Microsoft was working on Windows. There were other things, but this IBM thing was very close to what we did, because ours designed to be a real time system. You could use it for taking data and other things scientifically, and we just kept plunging ahead.

People have a lot of metaphors for entrepreneurship. I like two of those metaphors. One is white water rafting, and I say white water rafting because you have a skill in rafting that counts for something. I know a number of people that are great rafters. But you're also going on this wild river, and the current is going, and you're going to get splashed, and wet and thrown, and even the best rafters have been thrown out of the raft and capsized and everything else. It's partially under your control, and it's partially not under your control. And a lot of people don't realize that.

I talked to a lot of people when I first started this company. There was a venture capitalist who had been an entrepreneur, and he was full of sage advice. I remember I was in his office, which was in the Bank America Tower in San Francisco. It was on the 50th floor with this stunning view. And he says, "You know, having a company is like having a baby."

I said, "Okay." He says, "No, no, no, it's not like what you're thinking. You're thinking it's like the man's role in having a baby, a half hour of fun, and nine months later you pass out cigars and you're a proud father." He said, "No, it's like the woman's role in having a baby. It's nine months of incredible discomfort and pain and all this; and then the hard work starts." And I have to say he was right. You know at the time I listened to him. I heard him out. I didn't realize how true that was.

DA: So you had what, some venture capital and some PCs?

NM: We had a very shoestring operation. We were not a very well funded start up. We were funded mostly by enthusiasm. We rented an attic of a derelict house that was being renovated, and while they were renovating the basement, we were working in the attic. The walls were so bad that almost the plaster was gone. You could see through and see the outside. And at night there would be this wind that would clip through there. We finally bought tarps and nailed them up to try the keep the place a little bit weather tight.

We had a dozen or so PCs, and a bunch of employees who were mainly paid a nominal wage. We didn't really have a real salary. So people would be paid this stipend, and they'd also get stock options in the company, and that's sort of what kept us going. We wound up having a number of customers, people particularly in Wall Street who had built financial information systems. They wanted a multi-tasking, real time, Windows system for PCs before any such thing existed. So Standard and Poors, and Merrill Lynch, and ADP, and a bunch of companies like that were customers of ours, and they would buy licenses into the software. It didn't make us rich, just kept the lights on basically.

DA: Were you the salesman too, did you go out and work the company?

NM: In a little company you have to do everything. And that's one of the great things about being a little company is that you do get a very broad range of experience. I used to have this schedule where I would wake up around noon. I'd go into the office by around one o'clock. I'd do business all afternoon, return calls and have meetings with outside people if we had to. Then I would program until five in the morning. The reason for that was, if I did business all day, we couldn't afford to do that, because I was also one of the main programmers. And it turns out that because there's always a big lunch gap, there was no reason to come in. You could always explain why you were busy in the morning and you were out to lunch. So if you came in between one and two o'clock in the afternoon, it was great. Meanwhile if you work all night, the other eight to five, eight p.m. to five a.m., you get a hell of a lot of work done.

DA: And you taught yourself all this programming?

NM: Yes, I got a bunch of books. Actually, back while I was living in Japan, I bought a bunch of books. We took a trip to Taiwan, and at the time Taiwan had all these books, their copyright laws were not quite what they were anywhere else. You could get all of these books very cheaply. So I got a bunch of classic computer science textbooks, and took them back, and read them, and started the program.

DA: Sounds like you kind of fell in love with the computer at that point.

NM: Well computers are wonderful tools. In many ways software is the closest this world has ever come to magic. The traditional notion of magician is that somebody who by recanting a particular spell and putting words in a particular order, can impose his will on the world and make things happen.

Software is almost like that, because if you get an idea and you put it in the right words, not English, but a programming language, and you're picky about how you write it down, you write it down very carefully, it suddenly does become something tangible.

I used to do all these electronics projects as a kid. That was another thing I would do, is electronics projects. I was always burning my fingers, and getting solder and rosin on things, and with software all you had to do was have the idea. So the step from the intangible to tangible is smaller in the case of software than essentially anything else we do. Because you've created a program, it can be a very tangible tool that changes the world. That changes the way people work. It's as much a tool as anything wrought from metal, or as much as tangible a thing really as a jet, or any other piece of high technology. Yet all you do is think it up and write it down. That was very attractive to me.

DA: I'm fascinated by this switch in your life. I'm a Princeton PT myself, and the notion of finishing up your Ph.D. at Princeton, going to England and working with the leading academic, and then coming back and saying, the heck with that I'm going into software, is a fairly significant career change. You must have had some agonizing about the direction your life was taking or not.

NM: Well yes, but we're kind of getting to a stage where I either got to ask you to block it for 25 years or go on to something else. I had some personal reasons to do it, which, if it were just me, I'd say, go ahead, because it involves some other people. I hate to be weird about it but…

DA: For personal reasons you decided to make this career change and the name of the company was Dynamical Systems, is that right? Where did the name come from?

NM: Well it's a branch of physics. The study of systems with dynamics is called dynamical systems. It's been popularized quite a bit in the notion of chaos. People who study chaos generally study dynamical systems. Now there's nothing chaotic to dynamical systems, celestial mechanics is an example of that. The branch of dynamical systems that's gotten the most play recently in the last few years is the notion of chaos. But it's a part of systems; it's a part of physics. We thought that Dynamical Systems was a cool name. We were all physicists so that's what we went.

DA: When did you actually start the company?

NM: 1984.

DA: So how did you get to know Bill Gates and Microsoft?

NM: Well we were rolling along with our company, and we got a call from Microsoft one day. They wanted to talk to us about our technology. I later discovered that that was because I had given a presentation at IBM about our technology, and IBM and Microsoft at the time, were working together on a project. Microsoft didn't have one of things that IBM wanted them to have, and a guy at IBM told a guy at Microsoft, "Hey there's this company that I think has what you need." So I flew up to Seattle. We couldn't afford to send a delegation. I remember I had dinner that night in the Burger King on Northeast 8th. Everything we had had to go down to the penny.

So I came up and I met with a couple of peoples in the Windows group. Then after meeting with them, and giving some demos and stuff, they took me to see Steve Ballmer. I talked to Steve Ballmer for a while and he said, "Hey, there's somebody else you should meet." So I went over to see Bill. I think I spent an hour talking to Bill. At the time Microsoft want to license our technology. I said, "Look if you're going to license, there's only eight or ten of us here. If you license our technology, you've got to buy us, because if it's worth an anything to you, you're going to have to have us to understand it."

It took a couple weeks to come to terms, but we decided to be acquired by Microsoft. The thing that was funny about it was that we signed a letter of intent, but the deal would actually take another couple of months to close. So we came up here to Seattle in July, right after the 4th of July in 1986, and very shortly we learned that the original reason that Microsoft was trying to get this technology went away. So we were a little bit nervous, "Oh god, they don't really have to close this thing." But they did. In part because it was part of the process, I guess they thought we were part of the assets.

DA: Let's be a little technical here. What was the essence of what they wanted to buy?

NM: It was a couple of things. We had made this multi-tasking window system for PCs, which was a roughly similar technology area that Microsoft was working on with Microsoft Windows, but we'd taken some different technical approaches.

Also we had made that system compatible with a system that IBM had called Top View. Initially we were about to bring our system out when IBM came out with Top Vu that was similar, but different. So we made a compatibility layer, as the program was written for Top Vu it would work with our thing. That was the most important thing to Microsoft at the time. They wanted Top Vu compatibility, and we had it.

DA: And this was all programmed in a fundamental programming language? What was it written in?

NM: It was written in assembly language.

DA: So you wrote it all the way down to assembly language?

NM: Absolutely. Back then computers were a lot smaller in terms of memory, and most programs were written in assembly language, not in high-level language because you just couldn't afford it.

DA: Did the whole company go to Microsoft?

NM: Yes, well most of the company came. There were about 15 people who were employees, and a whole bunch of them were part time. The eight full time people all came, and we weren't sure how long it was going to last. We weren't sure whether we would like Seattle. We weren't sure whether Microsoft really would like us once they saw us up close. It turns out this group had an illustrious career at Microsoft. I'm still here. My brother Cameron is a Vice President here at Microsoft. He actually didn't join when we first came up. He was the only full time guy not to join. He went back to Berkeley and finished up that last quarter, and joined the following year. The guy who's the technical lead on Windows 3.1, Windows 95, and is now technical lead for natural language in the company, came from my company. The guy who is the technical lead for graphics and Windows NT came from my company. The guy who's the technical lead for multi-media for a long time at Microsoft, came from my company. These eight guys that came up, all had stellar careers. We sort of spread out throughout Microsoft and wound up in very senior positions.

DA: It sounds like they should have put you in personnel.

NM: Actually everybody at Microsoft is in personnel, in the sense that hiring and recruiting is a huge part of making a successful software company. So we're always looking for trying to hire the next wave of great people.

DA: What was your impression of Ballmer and Gates when you first met them?

NM: I went back and told the people at my company, "These guys both really need us, and could use us. They're very open to new ideas, and doing things a different way then they've done before. They're very smart and they're not stuck with one notion of how things should be done." So I told everybody I thought it would actually work for us.

There was a lot of skepticism of course because both some of the people in the company, and people outside our company, our advisors, would say, "Oh no, no, no you don't want to go to a big company. You'll loose your freedom." I said, "Well yes that's right, we're free to do anything we can afford to do which is damn near nothing." You make the whole list of constraints that were on us, and we would be way more free at Microsoft. So we hit it off very well with both Steve and Bill.

DA: I know you're now with the research laboratory, but that's not what you did at first. What was the first thing you did?

NM: My first title was Director of Special Projects. I reported to Steve Ballmer, and I did a couple of things. I was always involved in doing some new technical thing. I mentioned this IBM compatibility with Top Vu. Well shortly after we'd signed our deal, but before the deal really closed, Microsoft lost the business with IBM. IBM said, "We won't work with you anymore." So they didn't need us, but Bill and I, and a couple of other people went down to Boca Raton to have one last hearing to see if we would work together. I wasn't even really an employee of the company, technically, but it was important to go. So we went down, and Bill and I wound up being very active in this meeting. At the end of this two-day meeting, literally two day, all day, every day, reviewing various things, they decided maybe they should work with Microsoft after all. They would convene a two-week task force meeting. Microsoft at the time, in fact anywhere in the PC business, the notion of a two week task force was, where are they coming from, but that was the way things were done.

So, Bill sent a delegation of people, including me, in fact I was sent ahead of the delegation to go argue that we should still be part of the project. The deal still hadn't closed, and we went to England, because there was an IBM lab in England that they decided they were going to get.

We then had a two week long meeting arguing about things like, you get all the various parts of the technology, and what do we have to contribute, and what do they have to contribute? By the end of the two weeks, we had a deal that Microsoft and IBM would continue to work together. That was the first thing I did.

After that I was involved sort of two things in parallel. I was a development manager for graphics on Windows 2.0. That was the last unsuccessful version of Windows. They got me off boom, you know. So that was exciting. We changed the graphics algorithms for all of the things in Windows 2.0, but we had a goal of making every operation a factor or two faster even on the same computer. We actually did it without a whole bunch of patents, and making it faster was very crucial because Windows 2 0 was the platform on which a couple of the most successful windows applications launched, both us and other companies. It's the platform on which Ray Ozzie and a bunch of people at Iris Associates wrote Notes. It was a platform at which Ted Johnson and a bunch of people at Aldus, which is right across the way here in Seattle, wrote Page Maker for Windows.

That was also when Microsoft wrote Excel and Word. Those applications were very crucial to the future success of Windows. Windows 2.0 was never a very successful platform. I think Windows 1.0 came in 1985, and it was a joke cause far as most people were concerned. In fact there was a big thing at Comdex where they had a roast of the project and all these people came up to make fun of it. Windows 2.0 was more credible but it still was not our best seller by any stretch.

Windows 3.0 came out in 1990. So Windows was a product for five years before it was successful. Those were long, hard, difficult years for those of us that were involved in building it, but we believed so much in the technology. We believed that graphical use interface was the future, but we did things in retrospect. You'd say, "My God what were we thinking." As one example, in Windows 2.0 we couldn't assume that there was a hard disk machine because too many machines didn't have hard disks. So there was a card that came in the box with Windows 2.0 that had the instructions for how you should lay your floppy disks out on the desk, so when asked you to swap a disk in and get more things, you could shuffle them in and do this little shuffle to keep it straight.

In retrospect, you look now and the machines are at least a factor of 100 maybe 500 times faster than that. Machines have hundreds of mega bites of hard disk space. What were we thinking to try to do a system like that on that very weak machine? Yet it was the future, and if we hadn't built Windows 1.0, we wouldn't have built 2.0, and if we hadn't built 2.0 people couldn't have written the applications that made Windows 3.0 future version successful.

We run a research lab at Microsoft now. People will ask me how far in advance are you willing to do research, "Are you willing to do things five years out?" Hell, we'll have products that are five years out, and that's what the story of Windows is about. Never mind the research, which would have happened many years before and was largely not done at Microsoft.

We had tons of problems because there were hundreds of different kinds of PC's. Of course now there's thousands, and getting the graphical system to work on all those kinds of display drivers, and all those different crazy kinds of printers, and different kinds of mice, is a really huge, huge job, and it took the combined ingenuity of us at Microsoft working on Windows. People at Page Maker and Iris and whole bunch of other companies working on the applications would make it successful, and people at the hardware companies that would invent the great laser printers that would come out during that period would intently improve the processors. It was that whole combined effort that brought the PC industry to a level where the graphic user interface would take off and it could become the huge success it's been to the industry today.

DA: I can't let you cover this period without talking a little bit about the culture of market or something, just what you said a while ago when you first came here you were already running off with the head of the company without even being an employee, meeting with probably his most important customer, one of his most important customers and jumping into discussions when you didn't even have the badge on your shirt.

This is a different kind of time. It's a different kind of organization then most people even have an awareness of. How do you remember the culture in the working relationship as you went through this early period?

NM: Well, I'm very lucky that in some ways the company's never changed for me. I worked for Steve Ballmer for the first three years I was at Microsoft, and then for Bill for the last nine years. In many ways we've changed, we've matured. A whole variety of things have happened to make us different. The company is vastly larger.

I still work with Bill and Steve, and fundamentally they're still the same people, and I think I probably am too. I'm sure we were way more naive then. We were still rough around the edges in many ways. I remember one of these trips to Boca Raton where we had to stop and buy a tie for Bill. We were in a very real sense, still quite green at that point. But fundamentally today I think we're the same people.

DA: Perhaps it's a compliment that how the IBM's culture has become more like Microsoft for not being sedentary. Is that part of what this business is about, constant change?

NM: In order to be successful in our industry you can't stay in one place. To go back to this analogy of white water rafting, you're on this raging torrent of technology and nobody controls it, not us, not Intel. Not anybody controls it because there are unexpected twists and turns. Look at the Internet. That was a giant wave that washed over everybody in the boat. So you constantly having to keep moving, and when you have to move very quickly you've got to have a great sense of priorities and to know what things you should focus on and what things do you do not focus on. The thing that's made Microsoft so special for me is that Microsoft is a technology company run by a technology guy, Bill Gates. He has very direct hands on involvement in product design and technology strategy. He did back then, and he does today. There are companies that are run by lawyers, or by marketing people. Now if in fact they make soft drinks, or are financial people, that's probably okay in those industries. A lot of hotel businesses are run by guys specialized in finance. If you're going to play capital really well, that's super important for real estate. It is an essential part of that business. In technology it's not that way. In technology, the part that's essential is the technology itself, at least at this stage in our evolution. Maybe some day software will become a mature field and somebody who's a great people manager but knows nothing about software, or is a great financial manager but knows nothing about software could be successful, but not in a stage where you're constantly moving. So you've got to keep focused. You've got to keep priorities, and those are the things that Bill has been very good at.

You also have to learn to grow with the opportunity, and I think that is one of the things that is truly remarkable about Microsoft. Many companies are started by a charismatic entrepreneur of whatever background, and at a certain point the opportunity of that company outgrows the entrepreneur. Sometimes that's very sad because it leads to tragic results, or it's recognized soon enough, or it's recognized but people spend a long time being unhappy because they're not the right person for the company at that stage. There is no dishonor in that because people change and different personalities are required.

Well, Bill and some of the other people at Microsoft, like Steve whom I would say the same thing about, have grown with the opportunity. There's no better guy to run Microsoft than Bill Gates, and there's no better guy backing him up than Steve Ballmer. So, being able to grow with it over this long twenty-year period of time when the company has gone from being worth nothing to where it is today is really outstanding, and it's because there are great individuals.

DA: Certainly, one of the things that has changed at Microsoft is the whole incorporation of research territory. How did that come about? Why did that come about? Was it controversial?

NM: It was very controversial. When we first was involved in personal computers, the technical challenge was that they were little computers, and there's all this stuff that big computers did, and you have to find some way of making that stuff work on a little computer. The challenge is all about how I can fit 10 pounds of stuff in a five-pound sack. That was the deal. That's not entirely fair because there were aspects of personal computers that were different. You had more of a user interface focus. But coding an assembly language, and squeezing stuff down, and finding a way to make this big stuff work on these little pathetic machines was the name of the game.

Starting around 1990 I realized that a couple of things were going to be true. Prior to that I had been involved in the Windows strategy, as I said Windows 2.0, but then I was very involved in our whole strategy of extending Windows. I got the Windows MP Group started, which was hugely controversial, and that was the first major project that was going be written in C, a high level language rather than in an assembler, and written for multiprocessor machines and big computers.

I have a very historical argument for that. One of the things that's sad about the technology business is we don't generally have a notion of history. Yesterday's technology is old, and it's obsolete, and it's quaint, but people generally don't learn anything from it.

I think it's a huge mistake. People accuse me of being a real old timer in computing. Well twelve years may make you something of an old timer, but a lot of my attitudes are way older than that because I very consciously studied the history. In the mid 1960's IBM came out with a radical computer architecture called the 360. They invented the notion of architecture computers.

Prior to the 360 every computer was different. Scientific computers were different than business computers, different in every way, different processors, different instruction set, different software, and high end was different than low end. Basically, every model was developed from scratch, more or less. Well IBM had this radical notion. They said, "We'll create one programming interface." And they claimed the term architecture to describe the high level aspect of a design that could be done in multiple implementations. So you could make a scientific machine or a business machine, you could make a little one, or a mid range, or a high end machine that were all compatible, that all run the same software.

It was an incredibly radical proposition. It went totally against the grain. It was a huge risk for the company. Yet that move is what made IBM IBM. Today of course, you have a scaleable architecture. There are processors with scaleable architecture as part of their name. So everyone is into the notion that you would have one architecture for software compatibility in multiple different implementations. But it was that innovation that IBM had that made them fantastically successful, successful because their customers' problems didn't come in any given size.

In retrospect it's all obvious. You'll say, "Well of course, people wanted to upgrade from one machine to the next without throwing their software away, and the group that did science and the group that did business would want to share software." In retrospect it was so obvious, but at the time it was radical. Well, in the late 1980's, maybe 1987, '88, I decided we should do this for operating systems. Prior to that every operating system was effectively written from scratch for its own purpose. People would have lots of rhetoric as to why it had to be optimized just like they did in the case of the hardware. I said, "No, what you should do is have one architecture," which we call the Windows 32 architecture. We didn't have 32 bit computers then but you could see they were coming. So I said, "Let's design one architecture, one set of software interfaces with multiple implementations."

Every argument that the people made against doing this for hardware, people made for the software. They said, "No, no, no, we have to optimize at a different level. You don't understand Nathan, you want different things in that big computer." I said, "Maybe there are a few things that are different, but the core should be the same. It worked so well in this other case, why can't you do that for software?" The other thing people said, "No, no, you don't understand Nathan. We'll make one operating system, one implementation and we'll just run that same thing on every machine.

Well, the problem with that is that when you've got the high-end machine, you have lots of features and functionality that affect the implementation, not so much the interface, but the implementation is radically different. With the high-end machine you'll have mega bytes worth of operating system, whereas you need kilobytes worth of operating system for the tiny machine. So I said, "Look, we should develop multiple implementations of Windows." It was hugely controversial but we decided to do it. And that decision, and the decision to do Windows NT, I think have driven Microsoft to great success.

NT was widely criticized inside and outside the company at the time. I think we made two billion dollars a year revenue on it in the last year, but I think the gross rate is nearly 100%. I think the power of having this set of interfaces - Windows 98 now are mid range, and windows NT is the high end platform - I think that basic idea is going be responsible for a tremendous amount of growth in our whole industry, both at Microsoft and outside for the next decade or two. It's a very powerful concept.

DA: You said you were getting more and more interested in history, why?

NM: I've gotten very into history because so many ideas in high tech have occurred already. That's the first thing. So, if you just look at the technology history itself, there are so many ideas that have come up over and over again, and if you have that perspective, you make a different decision if you didn't know the history.

DA: I always envied my father's generation about Americans for having won the Second World War and changed the world permanently and I thought I could never be part of anything that would be that profoundly effective. What is it that you've done that you're most proud of and where do you think this revolution is going? What's your vision in the future?

NM: I'll answer that and I'll go back to research. I think at every age, at least in the ones that are high profile enough, we think of them as an age. There's some driving technology that helps define it and help set the stage for what comes next. The first information age came with Guttenberg's invention of the movable type, and it caused a tremendous change in the world. It's utterly amazing because it made information something that was a commodity. It took 8,000 or so books in Europe to millions of books within a 20-year period. It made people literate. It exposed them to new ideas. That was a fantastic age.

The industrial revolution was a tremendous one. We like to think that the 1990s are such a great era for technological innovation. Every year always thinks it's the cat's pajamas. The latter part of the 19th century, you have the telegraph being involved in the early part of the 1800s. You have the telephone. You have photography. You have railways. You have steel, an industrial revolution. The 19th century change literally changed the face of America. We went from 60% of the work force being on the farm in the turn of the century, to 6% by the 1960's. Our cities themselves were invented. So much of what we take for granted was invented in that century.

So, the 19th century was a period of enormous technological innovation, which was further developed to the 20th century to make the modern world that we know. At that point in time I think the two most interesting things would be one of the inventors that was responsible for that. Someone like Fox Talbot, who was the father of modern photography, or Edison, who invented half a dozen wonderful things, or Bessemer with his steel process, or some of the people that helped make that really happen on a big scale. The industrialists of that time, and the enormous expansion in creating an industrial society, were incredible.

Right now I think we're in a time very similar to the latter part of the 19th century. It has very striking parallels. We're in the midst of the second information revolution where computers become this tool, which tremendously change the way we think and use information. They make the world fundamentally a smaller place. Computing technology may well deconstruct our cities to the same degree that the industrialization of the 19th constructed them. Information workers can be anywhere. It changes our whole notion of the world because we get Email from people all over the globe. There are large parts of Microsoft that I only have contact with via Email. I don't really know where they're located. I think they're located in some building a mile or so from where I sit, but soon they could be on the other side of the world.

Our taxes could be done by a bunch of Indian accountants in Bombay, or our ad agency could be in Paris, and who's to know because the communications world has shrunk so much. So again, the two most interesting things to do at this point in history are either to be a technological or scientific pioneer, helping building the understanding that both drives this revolution and that of the next century, or being right in the thick of it in helping make this happen.

The computing industry is something that is important, and I don't mean to be slapping my own back here too much, but I think it is a very important industry for the world because it will change the shape of our society. I think largely for the better, for the same reason I believe in democracy. We have a fundamental faith that if everyone gets to vote that they'll make a better decision. In franchising the world's people with technology, getting them all personal computers and then connecting them to the Internet and all of the tremendous services, software that can harness the raw power in the hardware, and by doing something useful for individuals that is a very democratic thing. It's a very empowering process that I think is going change the world.

Now, you could already see that at some point genetic engineering and biotechnology is going have a gigantic impact. It could change us dramatically. It could change our bodies. My nine-year-old twins read very well, and they read the paper. A couple of years ago they were reading the paper and they saw something with the human genome project. They had heard what DNA was, but they came and asked me, "What's this dad?" So I explained that human genome project was about sequencing the DNA, and discovering what it's made of, and how that relates to various traits in our bodies, or how problems in it cause various diseases. So I said, "By the time you're my age boys, there may not be any cancer or heart disease or many of these things that are leading killers of people today." One of them said "Hmm, by the time we're your age Dad, it might be too late for you." They are exactly right. I am on the cusp and there are new medical discoveries every day, but the ones which are important to my life may or may not happen before it's too late. I think my kids may have an incredible opportunity, that their world will be influenced incredibly by biotechnology more so then by computing, and certainly my grand kids. Their lives will certainly be driven more by biotech than computing, but only if computing does its job now. You sequence that genome and you get a billion little AGCG things, you're not going write it down on paper. The only possible way to deal with the information that comes from biology, or other aspects of understanding our world, is through computing.

I think it's the only way to really knit the disparate peoples of the world into one culture, in the sense that we communicate by sending Email packets more often then we send nuclear weapons, or any of the other things that divided us. It's really about removing the barriers of geography.

Throughout history, the tyranny of geography has governed the actions of mankind. People would live and die within a very small area, languages developed across the next chain of mountains because you didn't talk to those people often enough, so the French went one way and Italian went another from the original Latin. Even in this age geography is still an enormous barrier, but for my kids' generation, and their grand kids, they will have a fundamentally different way of working in the world because of what happens in this industry. That's why I feel very lucky that I can play a role in it.

DA: So you have the opportunity to shape the research?

NM: Well, I try. Once we've gotten NT started and we had this notion of scaleable Windows architecture, we were on the verge of taking these little computers and making them big. The first thing I knew that would be true is that literally, they would be big, because the rate of the speed increase of microprocessors was much faster than mainframe computers or super computers. So it was inevitable that little computers be big. The largest fastest computers on earth will be based on microprocessors just like a PC was, or there'd be more copies of them.

The second thing that I knew was going to be true, is we would soon finish the laundry list of features and technology that have been done on big computers. People asked, "When are you going to have virtual memory, and when are you going to have multitasking, and what do you have multiprocessors for?" Well once we started the NT project, I knew that it was in sight, that we'd finish that sort of stuff. So, how do you move forward then? Well I didn't feel we could rely on saying, "Look, we're going to wait for somebody else to invent it. We'll wait for the big computer guys to do it." There wasn't going be any big computer industry that was different. There might be some big companies, companies like IBM and others will still be involved, but technologically there was no differentiator anymore. So we couldn't sit back and say, "Look we're going to wait for all that stuff to be invented somewhere else." We would have to take the bit in our teeth, and take up the challenge, and say, "Let's create a research lab. Let's put a significant amount of money and effort into inventing technology and to pushing forward the realm of what's possible." If we wanted to have a future, we had to start acting like it because if you wait until you actually need it you'll say, "Oops, I guess we should have started this research eight years ago."

Well, this is very controversial for two reasons. The first thing is people say, "Look, you're never going to hire great researchers. Your research will be polluted by the corporate mind set, "whatever the hell that is. "Great researchers won't want to come to work for Microsoft because they'll want to come to an entity that's been around for 100 years - Stanford, Harvard - those places have been around for at least a hundred years. Their labs, IBM research, they've been around for a hundred years." Academics are very conservative and new upstarts have a hard time. So that was the first barrier - you'll never get good people. The second barrier was even if you get good people, you'll never actually amount to anything for your shareholders, your customers, because you'll never take that technology and move it into a product. Yet we've proven it. Look at Xerox PARC; they invented personal computing, nothing happened. Look at Bell Labs, they invented the transistor, they invented all these other things, never done anything. Look at IBM research that is criticized for not making a bunch of things. Well I thought both those were wrong, and we could succeed. There were plenty people inside Microsoft that didn't think so but Bill thought we should go for it, and so we did. Now, eight years later, I think it's fair to say we've succeeded on both of them.

For some interesting reasons, when I first went to recruit people it was very hard to recruit them because we didn't have a long history. We weren't around for a hundred years, and at the time we were known as the company that wrote DOS, which was not a high tech operating system, but they said it was. The challenge then was to get an operating system at all, not to make the world's most high tech one. So computer science professors would have an attitude about this.

Computing is fundamentally an empirical discipline. It's something where people want to see their work have impact. I know a lot of mathematicians that will prove theorems, and they can care less for whatever amounts to anything, and they probably have some computer science like that. But a lot of people want to see their work have impact, and it's because of this I had a chance to recruit good people. I would say, "Look, if I want to recruit you, you are going be a successful person. You already are or I wouldn't be talking to you. So you can stay exactly where you are, unless you want to impact lots of people, because if you come up with something great at Microsoft, we can take that technology and move it into products, and market it, and finance it, and get the bugs out of it, and make your great innovation reach the lives of hundreds of millions of people, faster, better, more certain than any other place you go. So if you care about that, it's no contest. You should come here." Well, a few risk-seeking individuals decided that they would come, and of course they helped me recruit some others.

Today when we recruit someone for Microsoft research, we have lots of things to say. We can say, look at all the great people we have here. In many areas, we have some of the best groups in the world working at Microsoft Research. Computer graphics is a stealer line of both young, up and coming people, and many of the masters of the field. That is true in area after area. We can point at lots of other things, but our most powerful one is still this notion that if you come here, you can really affect peoples' lives. That matters a lot to folks.

That brings me to the second risk. Suppose we do great research, are we going to see any of it in products? I argued yes on a couple of basis. The first is, these stories about Xerox PARC and other things are just silly. They don't give Xerox or Bell Labs or IBM the credit they deserve in a variety of ways. The first is that people do dumb things. There are mergers, disastrous mergers, but because a company does a disastrous merger, does that mean every company doesn't do it? People have disastrous ad campaigns, does that mean everyone stops? No, but for an odd reason, if you have one example of a failure in research, everyone says, "Oh, you shouldn't do it." Well, mistakes were made at some research organizations. That doesn't mean you shouldn't do it. In fact if you look at the next level, you discover that a lot of companies do research that they have no business doing literally. They do research outside their area of business. If you look at Xerox PARC, Xerox invented the Laser printer there. In fact the guy who invented the Laser printer now works at Microsoft. So I've heard all the early stories about this. The Laser printer made billions of dollars for Xerox. It more than paid for Xerox PARC a zillion times over. So Xerox PARC was actually one of the best investments the Xerox Corporation ever made, and people who make fun of it are just being ridiculous. The Laser printer succeeded because it was similar enough to the core business of Xerox. They understood how to make it. It's been on the same assembly lines as those they made their copiers on. They understood how to sell it. The sales force could do something with it. It integrated in their package as a company. It was useful to them.

Xerox PARC also invented personal computing, and people make fun of them for not commercializing it. It's very hard to commercialize something that is widely outside your own scope. It also turns out that they did a merger. They acquired a company in the 1970s that I think they paid almost a billion dollars for, and wrote the whole thing off. It was a disaster. If you're going to beat up on Xerox, beat them up on that. It costs five times what PARC costs them, but nobody thinks of that. Instead they want to make fun. PARC was a great thing for Xerox. It's true that they invented a spectacular technology, but they didn't manage to commercialize it.

In fact if you look around, all software research was done by a company other than a software company, but if you look at their areas of strength, you discover that they were hugely important for them. So Bell Labs invented the transistor, but due to legal restrictions they only made a little bit of money from that. But Bell Labs also invented lots of things that made the phone network possible. It was a great investment for AT&T, and anyone who says not is taking a bizarre look at history. IBM research has done tremendous things for IBM. There are some things, particularly some software things, where IBM research didn't commercialize them as well. They invented something called SQL, which is a database line. It was a huge success, but one could argue that companies like Oracle and Sybase and others made much more money on SQL as IBM ever did. So you could say that's a failure, yet in fact, IBM research is a great success.

So the first lesson was do research in the area in which you have competence. It sounds enormously simple, but almost everyone doesn't do that. So if I decided to do cancer research at Microsoft, suppose that we were lucky enough that we found a cure for cancer. We would be all left thumbs at commercializing it. What's an FDA trial? What does double blind mean? We would know nothing about the pharmaceutical business, and we would probably screw up commercializing it just as much as Xerox did with something that was too different in their business. Now companies like Glaxol or Merck, pharmaceutical companies, they would understand what you could do with a cure for cancer. Yet if those guys, someone inside said, "Hey I wrote a word processor." Well good luck to them.

Yes, we would be a software company doing software research. Further we were a technologically driven software company where the whole chain of management from research data products is me and Bill Gates. It isn't some huge multilevel pyramid. You don't reach some inversion layer. So both of us, both Bill and I are involved in helping set the technical strategy for the company for products. We figured, hey, if we work in our own field, and we have the same guys that run our strategy also be involved with research in a hands-on basis, and finally if all the people we hired were people that came here because they wanted to see that happen, that in fact it would take care of itself, and it has.

We've had all kinds of successes at Microsoft Research in terms of awards. Our people have won a whole variety of distinguished awards from groups like the IEEE and ACM. We even have had two people win Academy Awards, which is a surprise, but it was for innovations in computer graphics that affect the way movies are made now days. We also have succeeded in another sense, that every major Microsoft product has significant functionality that came from research.

So Office 97, our office productivity package, it includes word processing and spread sheet data base that has a grammar checker developed by our national language group. It's the best grammar checker in the world. It's the first one that corrects your grammar while you type. And I would like to highlight this one because they call these programs word processors, but until Office '97, they weren't word processors, they were character processors. They helped you arrange characters on a page and get them lined up, but the program had no understanding that those strings of characters were words, that those words were organized into sentences and paragraphs, and that there was structure meaning. What we need the computer to be is not just your scribe in helping you remember where the characters go.

Computers should be your copy editors, your partner in writing that helps you understand the deep structure of language and it helps apply that to something. That's really what it should be about, and that's what it's going to be about because we have a very strong set of research efforts supporting our product. This is true for a whole bunch of other projects, and our operating systems in games, every part of the company has really benefited, so we have both examples of doing great work and hiring great people, and having an effect with products.

DA: That's very interesting to hear your strategy. I've studied research organizations for a long time. One of the problems usually is the hand off. When the researcher develops this idea, he thinks it's great, he publishes it, or hands it off, or writes a reports, and he goes to the next idea. And some people say, "No, you need to keep at the research, keep with the idea through product development, or use a certain kind of plan." What is your plan for making that transition between research and product development?

NM: I am proud to say we have no process for this. Most of the best things in life don't have a formal process. Most people meet their spouse in some ad hoc basis. There's not some formal process where you apply, and you do this, and you do that. Most breakthroughs, although they may occur by people that have degrees, aren't as a result of completing a certain number of degree requirements and then the breakthrough happens. And transferring technology from a research group over to products isn't something that happens in any single mode either, at least not here. Sometimes it happens because Bill Gates or I will be reviewing a product group. We will know it went on into research and say, "Hey, you should go talk to those people." Sometimes it happens the other way around. We tell the researchers, "You should go see if someone wants to use this." But it also happens because people are friends. They get together in the hallways, or someone says, "Hey, let's have lunch, and let's discuss it."

Sometimes you find a passionate advocate in research of their technology that goes around giving stump speeches trying to drum up support, and may find somebody who wants it. Sometimes you find someone in the product group that finds a problem, and will go around and find a researcher who's interested in it and convince them to help them with it.

So the connections are made every one of those ways, and half a dozen other ways, and it's because you have this broad interchange with people in research who genuinely want to see products, and people in the project that genuinely want the help. It's a healthy ongoing process. If we had to force people to do something, then I don't think it would be healthy. Sometimes researchers travel with their product and they will transfer to the product group for a while. Sometimes they hand stuff over. Sometimes people from a product group come and work over in research, and if you looked around our different projects, you'd find an example of each of these modes and about a half dozen others.

DA: And you decide when it's time to kill something?

NM: Well, that's a very difficult question. One of the ways that you manage research is just people management. If researchers are stuck in a rut, often you can tell, even if you know nothing about the field. It's the human element; that people aren't getting along, and there's frustration, and there are a variety of leadership issues that often manifest themselves at the same time. That's the kind of time when you as a manager should step in and should get things going in the right way. Some as that means killing a project or redirecting it.

At the same time you've got to be careful about killing things prematurely. Windows was a product for five years, and not a huge or successful one before it suddenly was a great success. We stuck with it because we believed in it, and there are times when you have to believe in something. Unfortunately, it may be many years before you know you're right. Take speech recognition as an example. We have a very active group in speech recognition. I think it will be an important to mainstream product within five years. If you had asked me five years ago about it I would have said the same thing. Maybe it will take twenty years, and I kind of don't care. I know that speech, both input and output, is so important to so many of our customers. It would be such a compelling feature for computers that it's worth the wait, and as long as our researchers seem to be doing good work, they are reaching milestones they set for themselves, and they're doing well in their field, I'm going to keep funding them.

Maybe in retrospect, we'll discover 25 years from now that there's some fear, but the only way it goes is by exploring, so you've got to do some things like that.

Another thing that influences the way we do research at Microsoft is that we're very open about our research. A lot of companies try to make research an armed camp thing, protect it. Getting in to see the research group is very, very difficult because they don't want to lose an idea, and people have to go through a formal permission process to publish a paper or even go to a conference. We have none of that. We just trust our people. We tell them that if you think there's a patent for this other thing, you should file for that before you go talk to banks. It turns out if you can't trust your people, no amount of process will save you. If you do trust your people, they will feel more responsible than you'd ever make them be. Most important of all, you need to exchange with the rest of the outside world. How do I know that some very obscure part of research is going well? How does anybody at Microsoft know that my dinosaur research is worth a damn? There's no other dinosaur expert. But if you work in the open research community, if you publish in peer review journals, if you go to conferences others are only too happy to point out your shortcomings. So it's a very healthy part of managing a research group. You have to have contact with the outside research community. Only a small fraction of the world's IQ is going be inside your organization, under your roof. If you cut yourselves off from them, you're not only cutting themselves from their wisdom, but they're helping managing what you're doing. So one of the many things that go into whether you continue a project is how it is doing relative to the rest of the field. If we're keeping up with the rest of the field, and the whole field is stuck, then you're going to have to decide whether you get rid of the field, or just slug in there. If you're doing substantially worse than everyone, then that's a flag. It doesn't mean you stop, because sometimes going in a completely different direction is what gets you to the goal.

DA: Can you talk about your work with Phil Currie?

NM: I've been in interested in dinosaurs ever since I was a kid, I've been interested in a lot of things actually since then, and many of them completely go away. Yet at various points, there'll be some opportunity and I'll get more involved in one or another. My interest in cooking led a few years ago, to me going to a professional Chef school in France, and working as an apprentice in a restaurant in Seattle. I just went one night a week to get my apprenticeship.

In the case of dinosaurs, I learned it being meeting and being Email contact with a number of paleontologists, including Phil Currie. He and I were discussing things in Email, initially about using computers to model aspects of the Therapod dinosaurs like T-rex. Dinosaurs are fascinating creatures in many ways, but one of the things that is particularly interesting about them is their scale, and their construction. Dinosaurs are anatomically very different than any other animal that exists today. They exist on a widely different scale than any other animal. They're huge. So if you're trying to figure out what a fossil fish was like, you look at an existing fish and generally you'll find them about the same size as a few giants, but most fish are fish size and they look like a fish. I think it's true with fossil mammals. Trilobites don't have any living descendants directly, but probably they were a lot like crabs. But I came to dinosaurs, as big as a house or bigger and the dinosaurs would weight 100 tons, as much as a blue whale. Of course the biggest animal that ever lived is still the blue whale, not the dinosaurs, not so. Argentinasaurus, a Sauropod from South America is certainly blue whale size. There may be dinosaurs were bigger than that that we haven't discovered yet.

So you've got these creatures that are unlike any existing animal and they exist at a different scale. How can you make well-reasoned arguments about how their bodies worked? You can try to use intuition, but you wind up waving your hands in some kind of argument because you don't know for sure. You can't quantitatively do it unless you use a computer. So I got interested in this notion of using computers as a way to quantitatively check theories and check our understanding of the biomechanics of dinosaurs. Here is a way in which we could accurately model and test hypotheses about these things. The scale didn't matter because we can construct them in cyberspace with an arbitrary degree of fidelity as well as cars, or the bridges, or anything else that we design using computer engineering tools. So Phil got very excited about this, and he said that would be great. So we got to talking about a couple of different problems and the first one we settled on doing was this notion of the tails of the Sauropod dinosaurs. I had read all kinds of books on dinosaurs, and I remember reading one written by a guy by Mcneil Alexander, who was a bio-mechanicist in England. He had mentioned, just as a little throw away line in the book of his on dinosaurs, that he wondered whether they could make a noise with their tail. Now, he knew as I had learned at some point, that the noise that a bullwhip makes, like the noise that comes from a sonic boom. In fact the tip of a whip exceeds the speed of sound. It goes almost mach 2. It's counter-intuitive. We think of supersonic in terms of the Concord, or a fighter plane, or a missile, but in fact an ordinary whip produce the sonic booms. Well what about the tails of these Sauropod dinosaurs?

So the Sauropod dinosaurs were the largest and included Argentinasorus, which was the heaviest of all dinosaurs. The group my workers were most interested in is a group called the Diapsids, and includes Apotasaurus, Brontosaurus which is an older alias for Apatosaurus, Diplodocus, Berasaurus (ph.) which is the one in the American Museum of Natural History, rearing up on its' hind legs in the rotunda.

Those dinosaurs were enormously heavy, enormously long, at least 100 feet long many of them. They had very long thin necks and very long thin tails. The tail would start off a meter in diameter and end up about this big around, and be 45 or so feet long. It was huge, so this huge long tail. What was it for? People had speculated a variety of things, that it was defense, that it would be used like a whip to hit something, or it was used for swimming. For a long time they felt they were aquatic. More recently they've discovered they lived in semi-arid areas. So it's like the aquatic thing was just quite wrong. And the shape of the tail is so outlandish. It tapers down so. The last three-quarters of the tail I think weigh about five percent of the mass of the tail. All dinosaurs have a well-developed tail, but why after the normal size tail, why did it keep going? Most other Sauropod dinosaurs had 40 to 50 colloidal vertebra, that's a vertebra in the tail. These would have like 80, and the vertebra at the end were very unusual. They're thin little bones with a cone at each end. So you'd have a cone joint, which would be enormously flexible. Why would you have a joint like this? Well Mcneil Alexander, the British biomechanics guy speculated that maybe they used their tails like a whip.

So I sent an email to Phil saying this is one of the things we could check. And we decided we'd start with that. So he managed measurements of the tails of the dinosaurs from the literature, some things going back almost 100 years when they first discovered these dinosaurs, as well as more modern measurements. And I set out to model them in a computer. At first I thought I'd have to write my own program. Then I discovered that there was a package for Windows that was made for engineers and was used in product design and it would accurately simulate physics and friction and air resistance and all this stuff. So I could use a program that was calibrated by engineers on a daily basis. So the next thing I do is get a whip. I searched on the Internet under "bull whip," and you get a very interesting, very diverse set of pages, you know. Someone watching this 100 years from now, the Internet may be different by then, but let me tell you, you get a very kinky set of pages on a bull whip. Not about dinosaurs at all.

So these various pages actually told me a lot about whips. One of the things I found was where I you could get a whip. I figured I needed to get one and learn how to use it. It turns out the greatest living whip maker lives here in Seattle. David Morgan made the whips for the Indiana Jones movies and a variety of other things, and he hand-makes the whips. Almost nobody else does that any more, but these kinky web sites said that you have to tell him some other reason for why you want to buy it, because he won't sell it to you if he thinks you will use it basically for sex.

So I went into his shop. I had my cover story all made up. I get to talk to him about whips, and at a certain point he looks at me and says, "What will the whip be for?" I couldn't help myself, I said, "dinosaurs." Well immediately he looks at me with this combination of disgust and pity. Disgust, he thinks this has got to be some made of story, and pity because it's the stupidest story anyone has ever come up with. Yeah right, you're going to use it for dinosaurs. So I'm in the middle of my discussion about the Sauropod dinosaurs and so forth, and this guy comes out of the back of the shop, and says. "Hi Nathan." It turns out his son works for Microsoft. So he assured him that in fact if Nathan wanted a whip for science, it really was for science. Then his son gave me lessons in learning how to use it.

The first thing I did was make a computer model of the whip, and made sure that the computer model would reproduce the behavior of the whip. In fact I could measure the tip going faster than the speed of the sound, which it turns out you could. Of course you'd expect that because it was an accurate simulation of the physics, but still it was nice to get confirmation that in fact the same principles that went into this, would make it happen there.

In fact the same principles have been studied a lot in the human biomechanics literature. Because the momentum transfer phenomenon of transferring momentum from a large, slow moving thing, to something that's smaller and quick moving is what a karate chop is about. It's what a golf swing is about, a javelin throw. So human biomechanics experts have studied this and modeled it extensively. But when people say to put your body into it, and the timing in a golf stroke is largely about how you can take a slow moving, heavy object - your torso - and transfer momentum for that down through your arm, down to the head of the golf club, which is very light and which therefore moves very quickly. Because conservation of momentum means that as you move down some chain like this, if you keep decreasing mass, velocity has to go up.

In the case of a whip, you also have a radial. You're swinging it in a circle usually, so you have conservation of angular momentum in addition to the mass going down a whip, because the mass tapers from something very big down to something very thin. You also have the radius going from something very big when you swing the whole whip, as it unfurls at the end, you get the radius goes. So you have m x v x r = a constant. M is going to zero, r is going to zero, v has to go way up. So it's a natural physical reaction. It's like a kind of leverage. Instead of levering a fulcrum, you're levering against a dynamic conservation law. But that's what allows you to concentrate energy from the base part of the whip into the tip.

Well I measured the whip, and I measured the tails, and I reconstructed what the tails would be like in life, making reasonable assumptions about how you put flesh on the bones. And the first striking thing is that the ratio of the cross-section lariat at the base of the whip to the tip - you can think of this as sort of the speed up ratio, crudely - for the whip it was about 566 to 1. The cross section lariat was 1/500th less than that of the tip. For these dinosaur tails, it was 1300 to 1.

The whip followed an exponential drop off, which is what you'd want to concentrate energy the most. It's basically for the same reason that a loud speaker has an exponential horn, or a trumpet has an exponential horn that opens up. So did the dinosaur tail, and if you plot them on the same graph, in fact they look very, very similar. Only the dinosaur tail looks like it should be a better whip than the whip. So that already told me it was probably going to work. But then I made the full dynamical model with this engineering package, and sure enough it went faster than the speed of sound.

Now we tried lots of different parameters to make sure that this wasn't a fragile phenomenon. We tried varying the joint angles because if the tail was too stiff it wouldn't work. We've got some ways of determining the joint angles both from the angles of the bones. There are cases where the tails were fossilized in situ and you could find them articulated. You can see that they make a loop, and that will give you some idea of what the range of motion was in life, probably. We varied the mass over a factor of four because we wanted to see if maybe we put too little flesh, maybe too much flesh, maybe the flesh was denser. Well we varied it by a factor of four, and it turns out every combination would still break the sound barrier.

Then we did a bunch of calculations because you say, well how could a dinosaur tail go faster than the speed of sound? The first question everybody asked was what about the damage, how could it be flesh and blood, because we're conditioned to think of super sonic in terms of an F-16 or a Concorde. In fact bullwhips are made out of cowhide and they go super sonic just fine thank you. And the very tip of the whip is the only part that goes super sonic. The velocity drops off exponentially from there. That's the flip side of having the mass be exponential. So all of the super sonic part is a tiny part of the whip. In the case of the dinosaur it was the very tip of the tail, which even in most living animals is not terribly sensitive, it's often got dead skin stretched over bone out of the end.

It's quite possible that it had a tassel-like thing of dead skin that would grow and be worn off by the cracking of the end. We calculated with the velocity and it turns out that in order to make the super sonic thing at the tip, the base of the tail only had to go about two meters a second. By tracking where these dinosaurs walked through the mud, and knowing how tall the legs are, and the space between the steps, you can determine how fast they walked. They walked one meter a second. Now in order to walk one meter a second your legs have to swing at two meters per second. Think about it as your legs have to catch up to you, and go faster to get there to plant, and that's how walking works. So you only had to move the base of the tail as fast as you could move a leg. And one meter per second was not their maximum walking speed. That's how fast they walked in soft mud, which is the only one we have any record of. They were probably capable of much more.

Well then you ask, was there enough kinetic energy? Sure enough there was enough energy. You say, okay what about in a forest, maybe all these other things work but maybe their muscles wouldn't put out enough in a forest to do it. One of the ways you can estimate that is that these track ways don't have any tail marks. The tails are 45 feet long but the tail is coming out only about 15 feet off the ground, was way longer than it should have been, yet they held it off the ground. So you can say, what's the torque necessary to hold the tail off the ground? Let's compare that to the torque necessary to move the tail to crack it. And it turns out the torque necessary to crack is only a small fraction of what it would take to lift it off the ground.

But the best part is one of the mysteries of Sauropod tails, is that mid-way down the tail, there's a place where the bones fuse together. Half the specimens would have one or more vertebra fused and stuck together. Then we knew what this was about. First I thought, well maybe they stepped on each other's tails. It turns out that that part is too far off the ground, plus we don't think they ever had their tails on the ground in the first place. And maybe they used their tail like a tripod to lean back on. Well the problem with that is that there's this thing called neuro-spines. It's the things up on the top and chevrons down below. Those aren't damaged. So something else caused it. It would have to be a side-to-side motion that caused it. Well a few years ago a human osteopathic surgeon decided to investigate this, he was into bone abnormalities. He got in Bruce Rothschild. He and a co-worker x-rayed and sawed some of these bones apart and looked at them, and decided that in fact it was physiological condition that would happen in humans called diffuse-idiopathic scaphoid hyperostosis, which means the bone's fussed together. And it would happen to relieve stress.

It happens in humans, particularly in the back where people will be under high stress. It turns out that sometimes you encourage it, in that if someone has a slipped disc, people put screws in to lock two vertebrae together. It basically has the same effect as that. So something was causing stress. Then I discovered an interesting thing people hadn't noticed before, the vertebra of these dinosaurs, most dinosaurs tails, is long when they start off at the tail, and they get shorter steadily, monotonically as you get down to the tip. Not these Diapsid Sauropods. There, the vertebra start off a certain size, and they get bigger, and then they get small. The maximum size is a factor of two larger then the ones earlier in the tail sequence. So it's a very dramatic lengthening. Something was lengthening these vertebra. Well it happens that where the vertebra reaches its peak is the same place that the bones fuse together. So now you have a suggestion that evolution is trying to strengthen that part of the tail. It's trying to strengthen it by making the bones longer, a factor of two longer, to provide a lot more stiffness and reinforcement. Then in some of the individuals they were moving their tails so much that the tails fused. And the best part is that's exactly the same place on a whip where whips wear out first.

Whips they usually wear out at the end, most of the rest of the whip doesn't wear. Where it wears is right when you go from the transition of the stiff handle to the flexible part. That is under a lot of stress because it's flexible. The analogous area is the tail. So here was evidence that they were using their tails, but it also gives us some idea of what they were about. The tail as weapon hypothesis was one of the most popular ones.

The problem with that is that the tails is very thin out at the end, faint bones no bigger than your thumb. The last two meters of the tail weigh about three kilograms, six pounds. It's like a garden hose. So why would you have a garden hose size, shape, and weight object to hit another dinosaur? If you had any animal that would be a worthy opponent, it's either another of their own species, or some big nasty predator, neither one is going to be impressed with this garden hose thing. The bones are too delicate. They would break.

In fact you could look at other tails of dinosaurs that are built to be tail clubs, and they're built nothing like this. This bone fusion is interesting because it occurs in about half of the specimens. When something occurs half in biology, you suspect gender. And if you have a physical difference due to gender it's called sexual dimorphism, you suspect that it may be due to male sexual display. Female differences are usually practical things. Male differences are usually impractical things done for display. That's why peacocks have all those feathers not the peahen. That's why male deer, elk, moose, have those big antlers, and the females either have reduced antlers or none at all. It's a guy thing basically. Well what that suggests is that they used these super sonic cracking as a way of either males fighting with each other for females, or males calling females over long distances, which is what elk do. There are many species that do each of these things. They have dominance contests. They have calling and attraction. They have herding into harems, again elk and others use calls as a means of doing that. So I think that they cracked their tales to get a date.

DA: A natural link back to the Internet.

NM: It's been a very fun project because it's a way to reconstruct a behavior. We don't know for sure this happened. Behaviors don't fossilize, but we know that it was very feasible for these things to have been whips. It was very practical, and there's a whole bunch of evidence that would suggest it does. Hopefully in the future some other fossil evidence will show definitively that it did.

There are a bunch of ideas that people are working on right now inspired by this. I think there are two sort of long-range important things. The first is that computers really are a great tool for reconstructing the physical aspects of some of the most magnificent creatures that ever lived, that we really have very little, if any chance of reconstructing any other way. By doing a computer model we can quantitative tests of ideas that would simply be impossible any other way. So we can learn a tremendous amount about these giants that once roamed the earth.

The second thing is, wasn't Chuck Yeager that broke the sound barrier, but that Sauropods did it earlier, and it took over 100 million years before another species on earth learned the trick, and figured out how to go faster than the speed of sound.

DA: One last question that I have for you. We haven't talked too much about your vision of the future and we could spend another three or four hours on that.

NM: That's my job after all.

DA: I wonder if they're a couple of things that you feel like you really see coming that you'd like to comment on maybe different from sort of what you see others saying, and if there are a couple of things that you may have some concern about coming out of this technology. Just to sort of wrap things up here.

NM: Well I think that computer information communications technology is all becoming a blur in one topic. Paradoxically it is over hyped in the short run, and under hyped in the long run. In the short run, we read everyday about some new breakthrough, and some new Internet company's going to take over the world, and all of a sudden the company's worth a billion dollars, and you know, oh my god the world will change by next Thursday, and they'll be convergence of TV and computers and the sewing machines and god knows what.

A lot of it is very over-wrought. Yet in the long run I think it's under hyped, because I think people miss the tremendous power of putting people in touch with another in new ways. If you want a one-person talk to another person, the telephone is a great way. It changed person-to-person communications. It abstracted geography from it largely. It only works at the one to one level. Conference calls for work for like ten people, past that it gets very unwieldy, and people don't even like doing conference calls.

Television worked in another mode. It worked from one to a million. So if you sit down in front of the TV camera now, circa 1998, it's hard to address less than a million people because broadcast channels are precious. We share only a small number across the whole population. Although not a million people may not choose to watch it, you have to offer it to a million, and you have to make the opportunity meet cost assessment, is this worth a million? But television has changed the world, because one to a million is very important. And by abstracting geography out of the one to a million thing, it's had enormous effects on culture and politics and every aspect of today's life.

But one to one and one to a million are the extreme ranges of human communication. Most of the communication we do is the realm in the middle. It's ad hoc conversations between a couple of people. It's meetings at work. It's a schoolteacher to thirty kids. It's a whole realm of communication that we have had no leverage on. Even Guttenberg didn't help us very much in that realm. You know there are newsletters and some other things, but it's a realm of specialization of small size, many to many things that television is lousy at.

So we do it the old fashioned way. We get together physically, which is fine, but if you think about the leverage the world has got from automating and extending and taking a geography out of the equation for one to one, and out of the equation from one to a million. Now imagine what this new world is going to do, because it's going to handle all those things in the middle. The Internet lets you send email to one person or a million people. It lets you have conversations threads between a whole ad hoc group of people. Chat rooms do the same thing in a live basis. Web sites let you publish something that no one may look at, or millions may look at in a very scalable direct way. That's primitive. Today most of those things I just described you have to do in text, or you can use primitive sorts of images. But in the not too distant future, it'll be high quality video, which it will be moderated by computer agents. And to sort of extrapolate those trends, I think, my god, if we can really take all those forms of communication from one to one to one to a million, and automate them, extend them, enhance them and take geography out from them, we'll utterly change the way our species deals with itself.

In the long run it's not the technology that's important. It's what is putting people in touch with other people in new ways, and I think it's almost impossible to under hype this in the very long run. By long run I mean 10, 20, 30, 50 years. And in the long run, I don't mean long run like next year. Our industry has got a very short attention span, so five years seems like infinity. Technology changes over a five-year period, society doesn't. The societal impact of the technology that's coming out now will be rolling out over the next five, ten, twenty, fifty, one hundred years from now. The 21st century will be about absorbing those impacts in the same way that the 20th century was about absorbing the impacts of industrialization that was really kicked off in the 19th.

DA: That's something that you may worry about.

NM: Well there are a lot of concerns that one can have I think. There are some huge societal concerns. Our country was based on a set of bets on human nature encompassed in the Bill of Rights and the Declaration of Independence. Those were radical bets at that time. The notion is that you should have freedom of speech, that you shouldn't be enforced to incriminate one's self. It was better to have a legal system that let some guilty people go free to avoid prosecuting the innocent. In the latter part of the 18th century, the late 1700s when our country made those bets, they were radical bets, which I think have been hugely successful. I think every American would say they're hugely successful. But cyberspace is taking all of those same issues and they're bringing it back up to us, and they're bringing it back up in a new twist. It's just different enough that people don't recognize it as the same bet.

So very well meaning people say, "Well my god, we've got to censor the Internet. We've got to protect our children. We just can't let anyone do this." Yet if you think about it, it's the same bet on human nature. So I'm very afraid that in this country, or in other countries around the world, very well meaning people will shy away from renewing those bets. In many cases the stakes are very high because the Internet represents the precursors for society that is far more open. We think we live in an open society, and we do by analog standards. In practices freedom of speech, not every individual is exposed to everything every other individual wants to say, but in the Internet you certainly can. In principle there are rights that we have as individuals. In practice, at a certain point they can knock down your door and haul you off to court, and a variety of other things can happen. In cyberspace that may not be so. There are encryption techniques that are so powerful that so far as we know, millions of years of computers wouldn't be enough to break them. So in fact you can have more privacy in the digital world than you ever had, practically speaking. Privacy is an important privilege in American society, but online you end up getting more of it. So I think the biggest concern is whether our society or the global society steps up to the plate again and makes those same bets on human nature. Or whether in a well meaning but misguided way, we shy away from that and create a less than open society in cyberspace, which ultimately would not just affect personal freedoms or policies or politics, ultimately I think it will affect how well this whole mechanism works, and whether we can have the digital renaissance that this promises to have for our species.

DA: What a pleasure, just a genuine pleasure. Thank you.