THE HENRY FORD

COLLECTING INNOVATION TODAY

TRANSCRIPT OF A VIDEO ORAL HISTORY

INTERVIEW WITH

BOB METCALFE

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POLARIS VENTURES,

WALTHAM, MA

INTERVIEWER: BARRY HURD

PRODUCER: JUDITH E. ENDELMAN

QUESTION:

01:01:11;08 What goes on here?

BOB METCALFE:

01:01:14;05 Polaris is a venture capital firm. We raise money from pension funds and wealthy individuals and corporations into a big pool. And then we invest it in promising young high-technology companies. And we're diversified, so we do drug discovery medical devices, enterprise software, computer networking, energy. We run about $3.2 billion here.

QUESTION:

01:01:39;14 Is there anything that's out on the market now we know about that came from a venture capital here, is it too early, or…?

BOB METCALFE:

01:01:46;10 We did a company called Akamai that delivers all the video on the Internet, more or less, not all of it, but most of it. There is a long list. I can't think of anything.

QUESTION:

01:01:58;18 That's just one thing for $3 billion? That's...

BOB METCALFE:

01:02:01;18 No, the company; no, the list is longer.

01:02:03;26 I'd show you, you know, we've done some drugs and some, so the company was founded in '96. So, it takes about ten years. So, we're at the point where a lot of our companies should be more famous. We didn't do Google, and we didn't do Cisco and we didn't do IBM. And we didn't do Ford. We were late for that one.

QUESTION:

01:02:25;18 I think they're gonna redo that one...

BOB METCALFE:

01:02:29;12 A restart.

QUESTION:

01:02:29;20 A restart, right, they're gonna reboot Ford

BOB METCALFE:

01:02:32;07 Let's not talk about Detroit today, okay?

QUESTION:

01:02:33;25 Yeah, no more, well, I'm not against that.

BOB METCALFE:

01:02:36;06 I'm not even an expert on it.

QUESTION:

01:02:38;10 Let's go back, when I was doing some reading on you, you jumped into the education thing in college and right through to get a Ph.D. Were you driven and knew what you wanted to do right away? I mean, what was motivating you to start out with like...

BOB METCALFE:

01:02:49;03 Well, I loved going to school. So, I went to school for 23 years in a row. I did two years of kindergarten. I did five years of college, then I did my Master's and Ph.D. And so, for 23 years to this very day, every September, I want to stack my books in the corner of some new room as part of being a student returning to school. I love school.

QUESTION:

01:03:11;00 It was just the exploration of knowledge, or what was driving you?

BOB METCALFE:

01:03:14;15 Well, like, learning things and building things and my

parents had two goals. They never went to college. My father passed on last year. And he had two goals, which he achieved. One was to retire early. He retired at the age of 50, a union man, retired on pension. And second to send me to college, which kind of annoyed my sister, who didn't go to college until she was 60. But I did go to college. So, there was that education thing in his plan, in my parents' plan. And I guess I sort of also went to school to be a good son.

QUESTION:

01:03:55;20 Uh-huh. Other than your parents, were there other things or other people that inspired you? Did you have like an historical figure or contemporary that...

BOB METCALFE:

01:04:03;19 Many mentors and many heroes, but I would hesitate to name one. By the time I got to Silicon Valley, then, of course, there were all the obvious ones. Bob Noyce of Intel, and Hewlett and Packard, Steve Jobs, those became my heroes.

QUESTION:

01:04:20;11 Tell me, how did you go from the education out to Silicon Valley? What drove you out there?

BOB METCALFE:

01:04:29;25 Well, I was finishing my Ph.D. and it was time to get a job, at last. And I was offered a job at the Xerox Palo Alto Research Center. And I'd been a big fan of the Beach Boys, who spoke about California. And I had a job offer to go do research in California. So, I went. And then so that took me from school into research. And then I did roughly research for eight years and then I got into entrepreneurship and direct innovation.

QUESTION:

01:05:01;00 If I were to ask you what your favorite music is, would it still be the Beach Boys, or have those tastes changed?

BOB METCALFE:

01:05:06;05 The Motown girl groups. It was very appropriate for Detroit, isn't it? Yeah, all the girl groups. Yep. Recently saw The Platters. That isn't a girl group, but The Platters are still around. I know all their words.

QUESTION:

01:05:19;18 Can you sing *Smoke Gets in Your Eyes* for us? No, that's... would have to do that.

BOB METCALFE:

01:05:25;13 They asked me how I knew...

QUESTION:

01:05:25;24 He's doing it!

BOB METCALFE:

01:05:26;20 Our true love was true. I just heard it recently sung by The Platters. And the funny thing is that this was at an MIT event. Three days later, I'm at the MIT Museum and a young man walks up to me with a platter with hors d'oeuvres on it. And I take one, and I look up, it was one of The Platters serving. So, apparently The Platters aren't doin' so well, or they're not rock stars anymore.

QUESTION:

01:05:52;18 Let me ask you this, going back to the education, I mean, that was a lot of math and science. Do you have a natural knack for thinking in terms of math and science? Do you remember back to that age, was it natural to you, or what?

BOB METCALFE:

01:06:02;24 Well, I did well in school, constantly, but I think that's because I loved it. And you can do something well if you love it. I think my father was an engineer, he was a technician. And eventually, they called him an engineer, but he was a union member. That's very important. So he was, I think, they made him an engineer after 30 years in the union or something. But he was a technician and the basement was full of gadgets. He was a gyroscopic test engineer for aerospace. So, there were lots of little toys down there. I think that's how I got into it, science and math.

QUESTION:

01:06:36;07 Yeah, I mean obviously, later in life, we knew you, we know you were very innovative. But at that time, with your father in the basement, did you feel any sense of, "You know, I can do something that's a little bit different here?"

BOB METCALFE:

01:06:47;04 Well, my father started a company, which is odd for a

union man. He did it on the side. He would not leave his job, 'cause job security was number one. But he started a telephone/ television repair company. That's when television was new. And he brought some, only the broken TVs home. And I played with them. And one day, he came home and found me unconscious on the basement floor because I had reached into the television like this and there's a high tension, high voltage line in the back of those big ol' CRTs. And apparently, I had grabbed it and fell unconscious and he then removed all the televisions from our home. Didn't want me to kill myself. So, maybe that was curiosity. I mean, why did I reach into the back for the television without looking what might be there? I don't know.

QUESTION:

01:07:37;06 Do you remember reaching back there and it knocking you out, or?

BOB METCALFE:

01:07:42;18 There are gaps.

01:07:43;13 Yeah, I remember fiddling around. I remember him

waking me up on the floor of the... one of the things he taught the kids is, "What do you do if you come across someone who's being electrocuted?" And the answer is, you get to the opposite end of the room and you run at them full speed ahead and you knock them free. What you don't do is grab hold of them. This is the sort of stuff my dad taught me. So, I'm ready, if you want to get electrocuted, let me know.

QUESTION:

01:08:09;17 Okay, so, you were invited out to California to do research. And that was with who now?

BOB METCALFE:

01:08:13;14 The Xerox Palo Alto Research Center, which was relatively new in 1972, when I got there.

QUESTION:

01:08:18;23 And well, the whole industry was kind of starting at that time out there, wasn't it? I mean, what was that like?

BOB METCALFE:

01:08:23;29 It was pretty exciting. It was just beginning to be called Silicon Valley. And it was known for semiconductors and

software. The Internet hadn't happened yet, the personal computer hadn't happened yet. So, we pretty much invented the personal computer at Xerox Research, although that's, people will argue forever about that. So, we built computers that look very similar to the ones that are used today.

01:08:53;08 And then, Silicon Valley picked up the personal computer and ran with it, unlike the East Coast, which didn't. And I had come from the East Coast. And then we ran with the Internet in a way that no one else ran with it. So, you're right. I arrived in Silicon Valley at exactly the right moment in June of 1972.

QUESTION:

01:09:13;17 Well, that Palo Alto Research Center is legendary for being a hotbed of innovation. And when you read about it, tell me a little bit about what it was like. There were a lot of people running around with ideas, or take us back there.

BOB METCALFE:

01:09:24;10 Well, some really smart people George Pake, Bob Taylor,

Jerry Elkind, then they started recruiting people from the ARPA, the Advanced Research Projects Agency community of researchers at MIT and Utah and Stanford and so on to join this computer science laboratory. So, we quickly believed that we were the best computer science laboratory in the world, naturally. And we were well supported by Xerox, which was at the height of its powers using the copier monopoly revenues.

01:10:02;28 So, it could afford to have such a research center. So, we were well, very well supported and out popped some pretty great work, I think. And that was when I, that was one of the, my second major stroke of luck. My first major stroke of luck was being born to Robert and Ruth Metcalfe, who were great parents. My second stroke of luck was landing at the Xerox Palo Alto Research Center as the networking guy.

01:10:31;21 And my colleagues turned to me and said, "We're going to fill the building up with personal computers, one on every

desk, but we need a way to connect them together. Why don't you work on that?" And that was my good luck, 'cause out of that, I invented Ethernet. And they, the breakthrough there was not so much the invention, it was the being there to get that job, you know, lucking out. Because that was the first time in the history of the world that there would be one computer on every desk. That had never happened before. So, no one had ever had to solve that problem before. So, that was my second stroke of luck.

QUESTION:

01:11:09;18 Well, tell how did that happen? I mean, they, how did you just invent something for the first time around? Was it intuitive? You just sat down and...

BOB METCALFE:

01:11:19;01 No, this is where sort of the narrative about inventors having this 'a-ha', this kind of falls apart. Because in my case, I had been educated for 23 years, and the last part of which I had gone into computer networking. So, by the time I was lucky enough to get that job, I had the

shoulders of giants all around me. And it was sort of an obvious thing to do, there was no flash of genius.

01:11:54;10 In fact, it was just sort of the next obvious thing to do. It was not, and I generally use this to convince people that inventing stuff is something that anyone can do. It's not something that special people who drop out of the sky magically can invent things on purpose. It depends on what's around you and what, in other words, it's not a divine gift. It's a skill and something you can practice doing.

01:12:23;06 So, when it came time to do this invention, I had been studying networking for, let's see, four years. And the most advanced networking in the world, the ARPA computer network, which became the Internet. And I was steeped in the technologies related to that. And then, so then, given the problem, how do we, how would you go about networking a computer, not one per city, which is what the ARPANET did, one per desk, how would you do

that? And then I combined ideas from the ARPANET and then another network which I had encountered called the Aloha Network at the University of Hawaii. And those two sets of ideas convolved to become the design of Ethernet.

QUESTION:

01:13:11;11 But still, you had to sit down and in some orderly fashion or intuitive fashion say, "This is how I'm gonna do it." As a matter of fact, this is what Jay Leno does to people. He pulls these pictures out. I think you've seen this. We have this diagram that somebody said maybe that's what you sketched on a napkin or whatever?

BOB METCALFE:

01:13:31;17 Well, now, this was in the memo. This is a diagram of the memo that I wrote on May 22nd, 1973.

QUESTION:

01:13:40;14 This is when you started working on the problem?

BOB METCALFE:

01:13:43;17 Well, I'm gonna be brutally honest here. One of my skills is marketing. So, somewhere in the '80s, it became useful to me to have a birthday for Ethernet, to hook, you know,

an event. It needed to have a birth, when was Ethernet born was the question. So, I'm in charge of that. So, I sat down to say, "Well, God, when was it born?" And so, Ethernet was not invented on a single day. But if it were, it was May 22nd, 1973.

01:14:16;11 So, I declared this to be Ethernet's birthday. So, that's a bit of an approximation of what really happened. So, no, it wasn't invented on a single day, and it wasn't really invented in this memo. Got named in this memo. And its general principles were all laid out on May 22nd, 1973. But of course, there had been a few memos before. And there had been the ALOHANET before and the ARPANET before. Then there was 35 years of hard work following the memo. So, it's hard to, but if Ethernet were invented on a particular day, this would be it. And that was the memo, this is the memo that I wrote on that day in which, you'll see the word “ether”.

01:14:54;20 Notice it's hand-written. So oh, this isn't the actual memo.

This is somebody retyped the memo, actually. 'Cause the original memo was written on a Selectric typewriter using the Orator ball. I, that's how I wrote, that's how we wrote then. We didn't have personal computers. We didn't have Microsoft Word. We hadn't invented that at Xerox PARC yet. So on an Orator ball, I typed this memo. And then, by hand, drew this diagram and wrote the word, "ether." So, that's where the word Ethernet, the word ether first appeared. And this is an extremely insightful diagram, written as it was in 1973 'cause all this has happened.

BOB METCALFE:

01:15:45;10 What it says is, is that there's gonna...

QUESTION:

01:15:58;10 Okay, so you said this is a marketing memo, but there's also a historical accuracy...

BOB METCALFE:

01:16:02;07 No, this isn't the marketing memo, this is...

QUESTION:

01:16:03;11 Tell us what that is.

BOB METCALFE:

01:16:03;29 So, the marketing came later, in the '80s. This was the, what we're looking at here is a diagram, a hand-drawn diagram that I drew in a memo that I wrote on May 22nd, 1973, describing what became known as Ethernet. And you'll notice here, the word "ether" with an exclamation point. I used a lot of exclamation points. Ether, and what I was saying there is that we want to connect, we want to create an ether, meaning a passive medium through which all these devices can communicate.

01:16:39;10 And so, this term here, a cable tree ether, that meant that this particular passive medium for communication would be built out of a cable that could branch. It could [be] like a tree. It couldn't be a loop, but it could branch as much as it wanted to. And then, you'll notice I drew a machine called an "Alto" connected to the ether. And then another Alto. And then there's a Nova, that's a data general mini-computer, a little one. This particular one had a VTS, a video terminal system connected to it.

01:17:10;00 And it was on the ether. XGP was a Xerox Graphics Printer and it was on the ether, so that these Altos could print on it. And some more Altos. There's a little box here. I haven't looked at this in a while. This little box says, "Dynabook." Dynabook was an idea about a personal computer that Alan Kay was in, was planning to build. And somehow, I put it on the ether, too.

01:17:35;25 Although, I think in the early days of Ethernet Alan Kay wanted his Dynabook to stand alone. So, this may have been the beginning of an argument between Alan Kay and me where I said, "No, Alan, you really want your Dynabook to be a, not a standalone PC, but actually a communicating device. And there I put it on the ether. And then there's a PDP-11, which is an old mini-computer.

01:17:57;02 So, here's a little ether. This other part is amazing to me, 'cause here's the cable ether coming in. And then here is a thing called a telephone co-ax booster, which you might,

in modern day parlance would be called a router, like, what Cisco makes. And it connects two locations together using the telephone network to connect two Ethernets through the telephone network, carrying packets back and forth through the telephone network, which I call the telephone ether between these two locations.

01:18:29;19 And then what's even amazing is over here it says, "radio ether." So, this is WiFi. This is the wireless Ethernet with little antennas on these devices. Who knows what these were. Remember, there weren't any personal computers in 1973. So, I, what was I thinking? I don't, I don't know. Something mobile one, and then, here's my signature.

01:18:48;09 And then, here's the Xerox, Xerox is spelled with two Rs. This big R and then there's a little R and a circle right above. That's what they taught us at Xerox. "You spell Xerox with two Rs." So, this was the diagram in the memo on May 22nd, 1973. This is not the memo itself. And but then, later in the '80s, and this gets back to the marketing.

QUESTION:

01:19:18;07 All right, now you said, "What was I thinking?" What were you thinking? And what was the “a-ha” moment? You said there was an “a-ha” moment, and you certainly remember actually doing this. Tell us about that.

BOB METCALFE:

01:19:27;16 Well, first, let me go into the 1980s and come back. Because I want to talk about this marketing moment. And I think marketing's a very important part of innovation, which is why I insist on doing it this way. But in 1980, by then I had started a company called 3Com, and whose, one of whose principal purposes was to promote the adoption and sell Ethernet. And I had many jobs at the company, but one of them was VP marketing from time to time.

01:19:55;29 And for some reason, I was doing some marketing and I figured Ethernet needed a birthday. We needed to have a birthday for Ethernet so we could celebrate it and organize promotional energy around Ethernet. So, I sat down to

figure out when exactly was Ethernet invented. But, if you're familiar with the innovation process, or in particular the history of Ethernet, you realize it wasn't really invented on any one particular day by any one particular person. It's kind of a cloud of events.

01:20:31;20 But if there were one day, it would be this day, May 22nd, 1973, which is the day on which this, I wrote this memo, sitting down at my Selectric typewriter to, with, putting, I actually put on an Orator ball. It was something about the Orator font which appealed to me, it was very clean. I didn't have a correcting Selectric. That was later. I didn't have one of those until 1979. This was, this is back in '73, before the correcting Selectric. Do you remember the correcting Selectric?

QUESTION:

01:20:57;14 I had one.

BOB METCALFE:

01:20:59;11 You had one. Well, they were wonderful inventions. Anyway, so here I am typing this memo. Here's how

Ethernet's gonna work, blah, blah, blah, blah. And then I drew this diagram, which we're now looking at here. And I'm looking at it now 30-some years later, or is it 40 already? No, not quite 40, 30, 35, 36 yeah, it's 35 years later, almost exactly. And so, I see WiFi here, it's called radio Ethernet. And I see routers here, they're called co-ax boosters, but they're using the telephone network to connect two locations.

01:21:36;24 And I see the ether itself on here and a bunch of the existing computers. And our new personal computer, the Alto, which is important. And it but, by this time, of course, Ethernet had been in the works for a while and it all goes back to, and you have to promise me you're not gonna tell Harvard about this, okay? So I was a Ph.D. student at Harvard. And I hated Harvard, hated it, every minute of it. And I was doing my PhD work at MIT. And then going up for classes and visiting my professors up at Harvard, but I was doing my research, you know, studying the ARPA computer network.

01:22:19;19 And eventually, it came time for me to finish my PhD at Harvard. So, I went up the river, I submitted my dissertation and went up, went job hunting, got a bunch of job offers, my wife got a new job, eventually, we decided on moving to California. And graduation day is coming up and I'm getting, my parents are planning to come to Harvard Yard for my PhD and I have to go to my thesis defense, that last little thing you have to do before you get your PhD and I failed my thesis defense.

01:22:50;25 I went up the river, I hadn't paid enough attention to who the professors were. I hadn't worked there, I was hostile to Harvard, so no big surprise, although it was a big surprise. They said my thesis was not theoretical enough and I needed to work more on it. It was just an engineering thing. And that was sort of the main problem between Harvard and me, is I'm an engineer and Harvard is not really into engineering, even to this day.

01:23:19;06 So, the, so, engineer versus Harvard. I called up Xerox who had made me this offer and said, "I've just failed my thesis defense." And they said, "Oh, come on out anyway and take, start your job and you can finish your thesis while you're here," which I did, a year later. So, here I am at Xerox now, beginning to be the networking guy there. And, but I had to finish this dissertation for my Ph.D. and I needed to be more theoretical. So, I'm looking around for something theoretical to do.

01:23:54;05 And I happened to be on a business trip to Washington D.C. I was generally promoting the Internet in those days, promoting it to mostly the Department of Defense. "You see, it works, you should use it in building a nationwide network." I was working as an affiliate of ARPA doing an ARPA Net facilitator they called me. And I happened to spend the night on the couch of one Stephen Crocker, who was an ARPA program manager.

01:24:19;10 And I was from California, which meant I was jet lagged,

which meant I was having trouble getting to sleep on time. And on his couch, next to his couch was some shelves. And I was sleeping on the couch. There were some shelves with some books. And I grabbed one of them. And it was an AFIPS conference proceedings. AFIPS is the American Federation of Information Processing Societies, which had an annual conference called the NCC, which I used to attend. And here, they had proceedings of all the papers in that particular 1970 conference.

01:24:49;03 I took that book trying to go to sleep, and that's a good way to go to sleep, is reading conference proceedings. And I opened it up and there was a paper on the Aloha network at the University of Hawaii by Professor Norm Abramson. And it described this radio network, the University of Hawaii, in which packets would be sent by radio in toward the central computer on a radio channel. And all of the terminals would use the same radio channel. And if the packets happened to collide in space and interfere with each other, the terminal would notice this by

not getting an acknowledgement back.

01:25:27;04 And then it, what it would do is it would resend the packet until it got through. It would just keep doing this over and over again. And the neat idea was that if the terminal decided to retransmit the packet, it would choose a random number and wait that long and then send it. And why would they do that? Is to prevent two terminals from transmitting over and over again and interfering with each other over and over again. But by choosing a random number, then those retransmissions would be very likely staggered and would get through.

01:26:01;12 And I, that was an appealing kind of idea, choosing a random number, randomized retransmission. And then Abramson had a model in there, a mathematical Markov stochastic process model of how such a system would perform. And this, the mathematics in that model I had just finished studying at MIT, in a probable/probability course, and in stochastic processes course. So, I

understood the model. And I didn't like it very much because it assumed two things.

01:26:36;28 It assumed that there were an infinite number of people using the channel. And I happened to know there were fewer than five people using the Aloha network at that time, so infinite was not a really good assumption. And the other assumption he made was that people would keep typing at this terminal even though they were getting no answers back. And that's not realistic. Realistically, you would type and you'd wait for an answer. And if you got an answer, you'd type some more.

01:27:03;19 So, I decided to revamp this model, just redo it and make it more accurate. And I did, and I wrote a little paper about it. It was called something like An *Aloha System with Finite Population Model of an Aloha System with Blocking*. And it was pretty theoretical. Theoretical! I needed a chapter for my dissertation at Harvard that was theoretical. So, I took this and made it into a chapter and

got my Ph.D. But then, Xerox turned to me and said, "We're about to put a personal computer on every desk. And you're the networking guy, figure out how to do it."

01:27:46;14 And I had just finished submitting this chapter studying the Aloha network, and that's how Ethernet got, Ethernet has randomized retransmissions, just like the Aloha network. But it, but we needed to send data at hundreds of kilobits per second, 'cause we had a high-speed laser printer. We were building the first laser printer, a group, not me, principally, but I was part of it. And it was fast.

01:28:13;24 So, we needed high speeds, so we had to be fast, faster than radio could be. The Aloha network ran at 4,800 bits per second. And the radio was as big as a refrigerator. Well, this network that we're gonna put in these desktop PCs had to be this big. But it had to run at hundreds of kilobits per second, so radio wasn't gonna work. So, we had to choose a medium, not radio, although radio's not a bad thing. So, what we chose, ultimately, co-axial cable,

'cause you can send stuff very quickly.

01:28:47;17 And that's where the word ether comes from, because we knew that you could build an Ethernet with radio, but you could also build it with twisted pair wiring or you could build it with co-axial cable, or you could build it with optical fibers. So, we weren't gonna refer to this cable as the co-ax, 'cause it didn't have to be co-ax. So, we started referring to it as the ether. This passive medium for the propagation of electromagnetic waves. So, that's how it got the name Ethernet, from this.

01:29:15;07 And so, anyway, this all got written down on May 22nd, 1973, how this was going to work, how these computers would all be connected to this passive ether, a piece of co-ax, running down the middle of the hall was the original conception of it. And then each PC in each desk would run a cable up and tap into this co-ax in from which it could send and receive packets through the ether and it would be part of Ethernet. So, that's how, that was the one, the

biggest “a-ha” experience in the early invention of Ethernet.

QUESTION:

00:00:57;12 Tell me that “a-ha” moment again. You were, you were trying to get to sleep at what, "’A-ha’, well, read this"? Or redefine that for me a little bit. I'm...

BOB METCALFE:

00:01:04;19 Well, the goal was to get to sleep. And reading conference proceedings is a good way to do that. And I read this paper and understood the model. That was a key point. I had just spent a couple of years studying how to model things, with both Markov models and stochastic process models. And...

BOB METCALFE:

00:01:54;16 So, when I was reading for purposes of going to sleep, reading these conference proceedings, the model which Professor Abramson had used to analyze the Aloha Network was familiar to me. 'Cause I had studied Markov processes, Poisson processes, all of which he used.

00:02:09;09 Which are pretty simple, straightforward math, which I got. And got so well that I disagreed with it. With, so there was that, "This model isn't a very good model." And then I saw the beauty of the idea, this idea of using randomized retransmissions to share a communication channel.

00:02:30;01 Rather than schedule all the transmissions, "your turn; your turn; your turn; your turn," everyone would just send onto the shared channel when they had something to send. And if there happened to be a collision, then to, you would just send it again, only you would randomize to avoid re-colliding over and over again. Cute little idea. An exploitation of randomness. Which I had just finished studying.

00:02:52;18 So that became the germ of the Ethernet idea. Now, there, I've been promoting Ethernet now for 35 years. So, over those years, I've encountered thousands of people who dislike me, or the idea, or something about it. And

one of the unkind things that people say is that basically, Ethernet is the Aloha Network and I just stole it.

00:03:16;26 And there is a germ of truth to that; but just a germ, I like to point out that the Aloha Network was a radio network, but the first Ethernet was a co-ax network. And the original Aloha Network ran at 4800, or maybe 9600 bits per second. The first Ethernet ran at 2.94 million bits per second. The Aloha Network had two radio channels; inbound and outbound. The co-ax Ethernet had just one channel; the co-ax. And 50 other little differences.

00:03:50;12 But the germ of randomized retransmissions definitely went from Aloha Network to Ether Network, as I have repeatedly acknowledged for 35 years. But still, there are those nasty people out there who think I stole the idea. But you're supposed to stand on the shoulders of giants, aren't you? Just as long as you acknowledge the giants, then I think everything's okay and I've been acknowledging Norm Abramson now for 35 years.

QUESTION:

00:04:16;25 Okay, so you got the sketch; you got the idea. Now your back, what? You build a brig board in the lab? How does that, how did you get to the point where it first got set up? And...

BOB METCALFE:

00:04:23;16 So after this memo, the first thing I did was, I didn't know how to send data very long distances. I had built a delay line memory, as a senior project at MIT. Which, in which I launched a pulse down a coil of cable and then recovered it at the other end. So that's a little bit like transmission line, but I really didn't know the physics or electronics of cable transmissions.

00:04:53;25 So I bought a kilometer of co-ax cable. And I took it down in the basement of Building 34, at Xerox. And I hooked a signal generator to one end. And I hooked an oscilloscope to the other, and I tried to see what would happen if you sent a square, nice square pulse down, a bit down the cable, what would it look like at the other end? I had no

idea. I hadn't studied that.

00:05:19;15 And it turns out it did come out the other end. And it was kinda' rounded. The cable does impair the signal, especially a kilometer of it. And I was fiddling with it. And I had to do some soldering and some connector stuff, all of which I had done before, but it's not something I did very well.

00:05:41;14 And it, and a guy also working in the basement, a man named David Boggs, noticed me fiddling with the co-ax cable ineptly. And David, having been a ham radio operator, knew all about co-axial cable and how to put connectors on it. So he came over to help. And David Boggs got the connectors on, and we observed the pulses going through this cable.

00:06:05;08 And, in that moment, Boggs and I became a team. And we built the first Ethernet together. And we, and so, what the lab was doing at that time was building a personal

com, what we called a personal computer. So Lambson, Thacker, Kay, McWright, had this idea for a personal computer, which became the Alto. And that's the moment in which I was asked, as the networking guy, to tie them together.

00:06:41;18 Find a way to network them together. And I had just finished getting this theoretical chapter into my Harvard dissertation. So I had randomized retransmissions on my brain. And I'd just finished the ARPANET Project, that is connecting computers into the early Internet.

00:06:58;15 So I had the hardware and the software experience related to how you network computers. So, I wrote this memo sketching how I would build a simple high, very high speed, it'd have to be, it had to cover a whole building. It had to have hundreds of computers on it. And it had to transmit data at hundreds of thousands of bits per second.

00:07:20;12 And the Internet was relatively new. And it would connect

to the Internet, that would be one of the, and we called it the ARPANET then. It would ultimately connect to the ARPANET. And therefore, it had to carry packets. Packets being a unit of data transmission. So it had to be a packet-switch network, which Ethernet is.

00:07:38;15 So Boggs and I begin designing a card that you would plug into this new personal computer. But, of course, you'd have to plug another one into another personal computer. And then you'd have to hook them both to a piece of co-ax. And then they could send packets to each other. And then the software running in those machines would take those packets and do useful things.

00:07:58;25 Like connect you to the Internet; send email; do printing. So Boggs and I built that. Now we called the first two computers that we put on the first Ethernet, we called them Michelson and Morley. That's history. Because Michelson and Morley were physicists, who, in around 1900, were pursuing a theory related to what was called

"aluminiferous ether."

00:08:24;21 Physicists, till about that time, couldn't figure out or thought they had figured out how light got here from the sun. They knew that sound had a medium, like the air, and it was propagated through a medium. So they wondered, "How did light get from the sun to the earth? There must be a medium that carried it; a wave." As a wave.

00:08:48;08 And they predicted that there was a thing called "the ether." Which was an omnipresent, passive medium for the propagation of electromagnetic waves. And Michelson and Morley wanted to devise an experiment to detect the ether, which, heretofore, had not been detected.

00:09:05;29 So they devised an experiment in which they sent light between two points. And then they waited for the earth to go around the sun. And they figured, at one point in this orbit around the sun, the earth would be going downwind,

and then it would be coming upwind, on the other side. So if they measured the propagation of light between these two points, they ought to be able to detect a difference as the seasons progressed "ether wind."

00:09:37;15 Anyway, they did the experiment and there was no ether wind. The speed of light was constant. There is no ether. And so, the aluminiferous ether was debunked. And the word "ether" was then up for grabs. And I snapped it up for "Ethernet." So we called our first two computers Michelson and Morley, connected by the ether. See?

QUESTION:

00:10:01;18 Did it work the first time you hooked it up?

BOB METCALFE:

00:10:03;03 No, of course not.

QUESTION:

00:10:04;09 Tell me about that. And did it, how many times did you have to like physically structure it before it worked?

BOB METCALFE:

00:10:09;29 Well, one problem we had to solve is getting the bits to go

down the cable. And we knew it had to be a mile actually, we weren't metric then. So we said a mile, not a kilometer. And a thousand computers separated at a mile, at hundreds of kilobits per second.

00:10:28;01 And we began designing this card that would take bits out of the computer and put 'em on the cable. And this card actually had to have a cable that came out of it and went up into the ceiling to where the big piece of co-ax was, the ether. And then there had to be a transceiver, a transceiver that connected.

00:10:48;19 So this is where this diagram comes from. So here's the computer, sitting in the office. And this is the co-ax, this yellow cable, is running down the center of the corridor. And there, so there had to be a cable from the PC through the wall, up to the ceiling.

00:11:03;09 And there would be this transceiver, which would tap into the co-ax to put, inject electrons and extract electrons

from the ether. So David and I had done some early experiments with how to transmit data down a cable. But it became of, it's a very specialized thing, how you do this for a thousand computers.

00:11:22;01 Because they eventually, they screw up the cable with all that tapping. So we got the help of a man named Tat Lam to design the transceiver. He had been working in the lab on a display, and he knew a lot about analog electronics. So we asked Tat Lam to help us design this transceiver that had to tap into the cable without disturbing the cable.

00:11:45;19 In other words, a very, just connect up to it, but don't screw it up. Just tap in enough to inject electrons and pull 'em out. So that we could send and receive packets along the big yellow cable. And then those bits would be sent back down into this card that we were building, and associated software, so that this personal computer could send and receive data with all the other personal computers on the network.

00:12:07;08 So that's what David and I built. David Boggs, he and I built this controller. And we got Tat Lam to help us with this. And then we built a two-node network with Michelson and Morley on it. And began exchanging packets between those two.

00:12:21;06 Now, we had to debug one card. And we got it working. But as soon as we connected two of them together, it stopped working. So we had to get the two working. And then it turns out, in networking, there's another big step. Is when you have three. 'Cause then it gets more complicated.

00:12:36;17 But after three, it gets easier. So the fourth and the fifth and the sixth aren't as hard as the first one, two, and three. And then, we encountered some hostility in the lab. There was a cultural belief that personal computers should be "stand-alone." And this belief persisted for some years, even outside of Xerox.

00:13:00;26 Steve Jobs, the original PCs were stand-alone machines. He was proud of how stand-alone they were. We thought that every PC should be on the Ethernet. But fellow scientists at the Xerox research center, who shall remain nameless, felt that this project that David Boggs and I were doing was not that important.

00:13:21;28 So the Ethernet was going to be an option. That is, when you got one of these Alto computers on your desk, you would decide whether you wanted to have Ethernet or not. And there was even some funny money. You'd have in your budget, you'd have to, I forgot what the amount of money was, but $500 or $1,000, you would pay of funny budget money in order to get one of these cards that David and I were building, to be plugged into your PC so your PC could be on the Internet and, thereby, directly connected to the laser printer, for example.

00:13:52;00 The laser printer turned out to be the draw. Everybody

wanted to be connected to the laser printer. So, therefore, everybody had to have an Ethernet card. That's how it worked out eventually.

QUESTION:

00:14:02;04 Was there any sense at the time that this was all, "We now have this huge idea that everybody connects up with everybody else"? I mean, at that time, I mean, everybody was going for this printer. But was there any sense that, "We've created something even larger than that"?

BOB METCALFE:

00:14:14;16 Well, there was an “a-ha” moment there too. Ethernet in its earliest moments, was an option. And our opponents, who shall remain nameless, wanted it to be an option, 'cause they didn't like us. Or they didn't think it was a good idea. Or somethin'.

00:14:30;05 But anyway, it was an option. And there was this day in which Boggs and I remember vividly, where we had a bunch of cubicles. And there was something like ten Altos sprinkled among the cubicles. And there was one Ethernet

connecting them all together.

00:14:47;19 And it was a feature of our early Ethernet, that, at the end of the co-ax, were these little "terminators," so-called. And in order for the co-ax to really be an effective medium for communication, you needed the connectors on the end. You needed the terminators.

00:15:02;17 And there was a funny thing about terminators. They were very useful, and beautiful little things. And people kept taking them off, borrowing them or, you know, using these little, I don't know why; they're not that expensive. But anyway, we had a problem with every once in a while, somebody would take off.

00:15:18;13 On this particular day, a lovely afternoon in Palo Alto, somebody took the terminator off the end of the co-ax. And immediately, ten people stood up and looked in and here were the cubicles. And we all stood up and we're looking at each other. "What happened?"

00:15:38;12 The Ethernet stopped working. And that's when we knew, Ethernet was no longer an option. So, thereafter we decided that every Alto would have an Ethernet in it. So that was an “a-ha”, Ethernet is not an option. And that was probably 1974.

QUESTION:

00:16:00;11 Why do you think that the competition, who shall remain nameless, didn't see the potential of the interconnectivity of computers?

BOB METCALFE:

00:16:06;25 Well, there's, it's complicated. Some of it is just personal animosity. Because when you have a bunch of high ego individuals, like moi, it's easy to get into, you know, just petty personal disagreements. And I have more than my share of those.

00:16:24;13 And so, some part of it was that. Part of it was that Boggs and I had had some early trouble debugging the Ethernet. And the other people thought less of us for that. "They're

these, they're not really that good at what they're doing, 'cause they can't get it to work." Of course, the real problem was that the computer we were using wasn't finished yet.

00:16:44;19 So there was a debate as to whether the bugs were in our hardware or in the personal computer. So there was a little goin' on there. But we all, we eventually got it to work. And the PC eventually got to work. So all that went away, although there was some lingering resentment.

00:16:59;22 There were also some other ideas about how to connect computers together. And there was another project, called X-Net, which one of our colleagues thought would be a better way to connect the machines. And there's a bit of a story about this too.

00:17:13;06 Because this person who was promoting X-Net, who shall remain nameless, he is a god and I wouldn't want to, at this late date, piss him off, he thought X-Net was a better

way to do it. But he was a god in the lab, and I was just a new kid who just arrived.

00:17:29;00 So I was feeling forlorn and set upon and conspired against. So I went to the head of the lab, Bob Taylor. And I said, "Look. This other person is doing X-Net and it's sucking up all the resources, like the technicians' and everybody's attention. And this Ethernet thing is a much better idea than X-Net."

00:17:48;07 'Cause X-Net was a kluge. "Bob, what am I gonna do?" And this is where Bob and I disagreed. I think he then squelched X-Net. That's what I think. And he denies it. But, in any case, X-Net went away shortly thereafter, and Ethernet became the preferred method of locally networking with these Altos.

QUESTION:

00:18:40;22 So tell me a little bit about, it changed the culture in the lab. Now, you suddenly these computers are all, for the first time, were all hooked together after this printer, et

cetera.

BOB METCALFE:

00:18:49;01 Well, a bunch of things are happening at the same time. The PC was being built. The network was being built. The Internet was being developed. That's what my project was. And they were all tied together. So the laser printer, which is a page-per-second, 500-dot-per-inch printer so that's a very fast, very high resolution became a popular way of printing out your memos, and your document, and your papers that you wrote for conferences.

00:19:14;18 So everyone had to have access to this laser printer. And the only way you could get access was over the Ethernet. I wrote the operating system for this printer. I put the packet protocols in it. I plugged in the Ethernet card. And the way you talked to this printer was you know, my friend, Ron Rider built it, and Gary Starkweather built the printer.

00:19:32;12 But I hooked it to the network. So the only way you could

get to this printer was through the Ethernet. That made Ethernet not an option. So everybody had to have an Ethernet card. But then, when you had the Ethernet card, we wrote a program that allowed you to type at your personal computer and get onto the Internet.

00:19:48;27 So you could send email on the Internet, you could do that before, when you, with a dumb terminal. But now you could do it from your PC also. And then, another thing. Since Ethernet was not an option, that meant every Alto had one, which meant you could rely on it having a network.

00:20:05;24 So, for example, diagnostics were written to test the PC when you weren't using it. Do you know a screensaver, have you ever heard of a screensaver on your PC? Well, the first one was at Xerox PARC, where the PC, you'd say, "I'm done with it now." And a little dot would appear on your screen to save the monitor from burning up.

00:20:29;12 And what was moving that little box around was a memory diagnostic that was testing the memory of the PC. And it would send its results over the Ethernet to a central collection point. So we could tell the maintenance people could tell which memories were beginning to fail. And then, you see, that was possible because every machine was on the network you could, network diagnostics could rely on being able to talk with the maintenance machine down the hall.

00:20:53;17 But then, new applications started getting developed. Email that ran, not on the mini computer that you connected to through the Ethernet, but ran on, it was, its name was Laurel, I think but it ran on the PC itself. The way email does today.

00:21:11;26 So anyway, five years later this is another great story that comes to mind. Five years later, we looked at, we're now hundreds, thousands, thousands of Ethernets well, maybe hundreds. And the one, the big one at Xerox, Palo Alto

was about, I don't know, 50 percent utilized.

00:21:32;25 Which is pretty heavily utilized. And there was some excess capacity. So when you needed it, your applications ran fine. And people came and said, "Boy, that was really insightful of you to be able to know that we were gonna need two you know, a boot, a good fraction of 2.94 megabits per second. Five years ago, you knew that.

00:21:56;16 "And here we are, five years later, and these networks are 50 percent utilized. What a great insight, to guess that our requirement for networking was 2.94 megabits per second, or some substantial fraction of that." People thought this. It was really funny.

00:22:14;04 How did we arrive at 2.94 megabits per second? Dave Boggs and I are working on the card. We're working on the card that you're gonna plug into the Alto. And the card was exactly this big. You weren't allowed to make it a little bigger. And we started designing it and putting the

memories and the FIFOs and the shift registers, and the CRC. And then, and we "Oho. We've run out of room."

00:22:40;28 And we don't have room for the clock chip that's gonna clock these packets onto the cable so they can be recovered at the other end. You know, "Tick, tick, bit, bit, bit, bit, bit, bit," little. "What are we gonna do? Wait a minute. The mini computer has a clock that it uses, and that clock is present on one of the pins here, on the back plane.

00:23:01;23 "So we can get that clock onto our card. And we can use that clock to clock our packets. And thereby save space." So because we didn't have enough room on the card, we decided to use the system clock of the PC, which just ticked every 170 nanoseconds. And since it took two ticks to make a bit, it turned out that's 340 nanoseconds per bit, which turns out to be 2.94 megabits per second.

00:23:32;12 So that's how we decided that it should run at 2.94. But

then, we lucked out, obviously. Five years later, it was about as fast as you needed. No, there's a fallacy too. It turned out that every time somebody tried to put an application on this network that demanded more than 2.94 megabits per second, guess what happened? It didn't work.

00:23:55;28 So they didn't use that application. Or they redesigned it. So what had happened is, over five years, only the applications that could run at 2.94 megabits per second persisted. Ones that demanded too much died. So people were wrong to think that we had anticipated the requirement for bandwidth. We chose the speed because of a completely exogenous reason, having to do with available clock.

00:24:25;21 And the applications that ended up using about half the network was sort of a self-fulfilling prophecy. Applications that didn't work at 2.94 were never used. And they went away. So anyway, the big lesson there was, and I've stuck

to this ever since, is when building a network, you build it as fast as you possibly can.

00:24:44;25 Within, in other words, you spend more and more money until it gets crazy. And then you build it as fast as is practical. You don't sit down and try to develop the requirement. You build it as fast as possible because that will enable new applications that you never thought of. That is, the universe of possible applications would grow as you made the network faster and faster. So it was your duty, as a network designer, to run as fast as you possibly could, even if you couldn't think of an application for all that bandwidth.

00:25:16;04 So Ethernet started at 2.94 megabits per second. Then, a few years later, inside of Xerox, we tried to run it at 20 megabits per second. But then, when Intel came along with their chip, we realized we had to slow it down to ten megabits per second. Having nothing to do with requirements; having only to do with, "How fast can we

run with this chip, down this cable?" And it turned out to be ten megabits per second.

00:25:41;02 Then a few years passed, and we went to 100 megabits per second. Then a few more years passed, and we went to a gigabit per second. And a few years passed, and we went to ten gigabits per second, which is where we are now. And now, we are gettin' ready to go to 100 gigabits per second, following this general rule: even if you can't anticipate the requirement, make the network as fast as possible. Because it'll open up all sorts of possibilities that you can't anticipate.

QUESTION:

00:26:07;20 So nowadays, when we go out to buy or when anybody goes out and buys a computer, that Ethernet card, I mean, that's essentially the thing that you guys invented in the lab there still, isn't it?

BOB METCALFE:

00:26:17;28 Well, most PCs have a little plug you plug a cable into it. Which is the Ethernet cable, RJ45. But now, more and

more, they have WiFi, which is a wireless, and now, WiFi is Ethernet coming full circle. See, Ethernet started with the Aloha Network, which was a packet radio network at the University of Hawaii.

00:26:38;03 And then we went onto co-ax. And then, from co-ax to optical fibers, to twisted pairs. And now, 35 years later, it's radio again. Except now the radios are this big instead of as big as a refrigerator. And that's why we've been able to go back to radios. So WiFi was originally called wireless Ethernet. And then some marketing people decided to call it WiFi. And I'm glad they did.

QUESTION:

00:27:01;19 That's interesting. But I mean, the basic concept, it's still, is there, right?

BOB METCALFE:

00:27:05;22 Yeah, the cons...

QUESTION:

00:27:06;07 The, that sort of hit you in the head when you were on the couch and...

BOB METCALFE:

00:27:10;10 The concept that being connected is a good thing. In about 1994, I estimate, is when people started buying personal computers in order to be connected to the Internet. Prior to that, they had other cockamamie ideas, like balancing their checkbook or doing spreadsheets. But around '94 or so connectivity became the dominant reason.

QUESTION:

00:27:34;06 Well, one of the big things about this Ethernet was that you could suddenly hook a lot of people together. Before, nodes were all over it, there weren't that many, right? Entry ways onto the…

BOB METCALFE:

00:27:42;05 Well, in fairness, before Ethernet, there were no personal computers. So Ethernet and personal computers sort of evolved together. And you sort of see why they have to. Ethernet doesn't do anything if there were no PCs to connect together. And PCs are not as useful stand-alone as they are when there're networks. There're just many

more things you can do with a network device than you, than a stand-alone device.

QUESTION:

00:28:04;19 Okay. Now, earlier, you were talking about innovation was sort of a thing you really believed in. You had some great quote, which I can't remember, when we first sat down. But did you know at the time you guys were puttin' all this together and developing these standards, that, did this feel like it was innovative?

00:28:17;25 Or it was just a day at the office? I mean, you said you were just right, in the right place at the right time. But did you know you were doing something that was really going to become such a big part of the world?

BOB METCALFE:

00:28:27;10 Well, we were working at a research center. And we were privileged to be well supported and encouraged to develop new and exciting things. And the overarching theme was ironically, the paperless office of the future. Of course, the first thing we did was invent the laser printer, which

produced more paper than had ever been produced before. So that backfired.

00:28:51;07 But moving things around the office, like memos, requires you to have a network. So, if you're going to be a paperless office, you need a way to send a memo without printing it out. So you just send it down this cable and it would pop out the other end. That was the overarching vision.

00:29:05;22 It was our modus operandi at in the computer science laboratory, to build our own tools. So we built PCs 'cause we needed PCs ourselves. We built the mini computer before that because we needed a mini computer. So we were in the mode of building our own tools. And we needed a tool for connecting our PCs to the maintenance center, to the Internet, to the laser printer. So we built it.

00:29:29;25 And the notion that this would well, this year, 2008, 350 million new Ethernet switchboards will be shipped; 350

million new ones. In 1973, no one that I know conceived that that would ever happen. That's, this, it's been an unfolding surprise for 35 years. At one time, I wrote, I thought carefully and wrote a paper predicting that Ethernet would die in the year 2003. Well, I was wrong. It's not dying. It's proliferating.

QUESTION:

00:30:06;24 Do you think it will die some day? Or that we, I mean...

BOB METCALFE:

00:30:09;27 Well, now you're getting into philosophy. A funny thing has...

QUESTION:

03:00:05;25 Okay, you said in 2003, you predicted Ethernet would fall. You were wrong. So tell us why you predicted that. Why you were wrong, and what you think'll happen in the future.

BOB METCALFE:

03:00:16;15 Well, Ethernet is now 35 years old. And I am fond of saying that in 19-, it was invented in, as you know, in 1973. But by 1981, there were people buying Ethernet

whom I did not know personally. And by 1985, there were people inventing Ethernet whom I did not know personally. So Ethernet has come, it's proliferated and it's gone through many generations and has many forms. And so there's a bunch of Ethernet inventors out there who are pretty much annoyed that I get credit for it. But that's okay, I try to, I just then tried to share credit with them, although not by name.

03:01:05;14 So Ethernet has evolved. And there is this funny phenomenon that has occurred; it gets to your question about when will Ethernet be dead. And the funny thing is that when a new technology comes along that looks good, they call it Ethernet. So in a way, Ethernet has a longer life, the Ethernet that's now being shipped is not the Ethernet that Dave Boggs and I built in 1973. It has changed considerably. But it continues to be called Ethernet and I'm delighted.

03:01:37;11 And that has something to do with the transcendent

qualities of Ethernet that go above the technology. So there's something about Ethernet which is not the thing that Boggs and I built in '73. And what is that? And I think it has to do with the notion of connecting things, at high speed, using packets, using standards, carefully developed industry standards. Having fierce competition among the providers of the networking.

03:02:12;07 And then evolving the technology with experience in the marketplace, but somehow always being backward compatible to the installed base. It is that constellation of ideas which I think is, has become Ethernet. And so new technologies that exhibit those qualities get called Ethernet. So 100 gig Ethernet operates when it comes, will operate completely, they'll call it 100 gig Ethernet. And it won't be very much like the thing that we invented 35 years ago.

QUESTION:

03:02:46;00 But you'll have started the ship on its voyage.

BOB METCALFE:

03:02:49;13 Yeah, and that goes to the “shoulders of giants” thing again. Which is, you know, there is, there are these point events of invention, but they're all part of a very complicated process of technological innovation which we need to take care of. That process of technological innovation can be designed and structured and made to be more prolific, or not, depending on the ecology that you develop, the innovation ecology.

QUESTION:

03:03:16;21 You said back at PARC you were encouraged to be innovative. How did they do that? How did management encourage you to be innovative?

BOB METCALFE:

03:03:24;26 Well, we were called members of the research staff, and we were encouraged to think through what would be required of the paperless office of the future, and develop technologies that would move in that direction. And the, so it was our job to invent. It was in our job description to invent or to do research.

03:03:48;00 Or computer science is a little ambivalent. It's sometimes it's a science and sometimes it's engineering. I think it's mostly engineering. So do you, was Ethernet discovered? No, Ethernet was invented. That's a different, so that makes it more engineering than science. But any case, you need science and engineering in this innovation ecology that I benefited from.

03:04:09;28 So I happen to fall into a very rich innovation soup there in Palo Alto. I had Silicon Valley right outside the door. So when I needed to go start a company and take my invention to market, there was a whole infrastructure there. Venture capitalists, real estate printed circuit card suppliers, people all waiting for this idea to pop out of the research center. And the research center itself is a rich ecology of innovation. And it was our going back to your question, it was, it was our job to innovate there.

QUESTION:

03:04:44;24 Now, you stayed there for Xerox, it was, then you started

your own company, primarily to promote Ethernet?

BOB METCALFE:

03:04:50;13 Well, after eight years at Xerox, four in research, in the computer science laboratory, and four years in the system development labor division, which was a product development division, I decided I wanted to start a company. Like everyone else was doing. I mean, if Bob Noyce and Steve Jobs and all those guys could do it, why not me?

03:05:13;08 So in fact my resignation at Xerox says, "I am leaving" I left cheerfully. "I'm leaving Xerox to pursue entrepreneurial ambitions." I had no idea what that meant, but I was gonna go pursue them. And the, I came back here to Boston and hung out at MIT for a while, and then came up with the idea that, with a guy named Gordon Bell, who was the vice president of engineering of DEC at the time. He tried to induce me to design a local area network for DEC, then the second largest computer company in the world, that was a lot like Ethernet, which

he admired.

03:05:47;14 But I had patents on Ethernet that were owned by Xerox, so I couldn't really just do that. So Gordon and I had the idea and we forget exactly who had the idea, but it was in a meeting in February, 1979. We decided that we should go back to Xerox and say, "Why don't DEC and Xerox work together to make a standard based on Ethernet?" Make an Ethernet standard.

03:06:11;06 And then we got Intel involved. And that's when I knew it was time to start a company. So if DEC, Intel, and Xerox were gonna cooperate to make an Ethernet standard for the industry, then I could start a company that would serve that market. And the company was called 3Com, Computer, Communication, Compatibility. The "compatibility" word meant we were gonna do a standard. "Communication" was a reference to the protocols in the hardware.

03:06:37;29 So 3Com was founded to actually, we promoted three standards: UNIX, which is today known as Linux, the TCP/IP protocols, which today is known as the Internet, and Ethernet. So we were three for three. And no wonder 3Com became eventually a $5 billion a year company.

QUESTION:

03:06:56;15 And tell us some of the highlights while you're at 3Com. What happened there?

BOB METCALFE:

03:07:02;23 Well, here's a research scientist who's suddenly president of his own company. And that's, it turns out running a company is different from being a research scientist. So two things had to happen. 1) is I had to learn a lot, and 2) is I needed other people who knew what they were doing to join.

03:07:17;12 And being in Silicon Valley, I could find those people. So a lot of them came from Hewlett Packard Company which is sort of a graduate school. Recruit people from them, who have learned how to build products and market them from

HP or Intel or now you can do it at Microsoft, Google. Think of them as, think of large companies as graduate schools for startups. Part of the innovation ecology. So I learned a lot and well, the principle thing I learned was selling. And then there was getting people on the team who knew what they were doing. And then we built this company.

QUESTION:

03:07:55;28 Now is, was this, would you classify it as a pretty innovative company, based on your sort of take on innovation? Was it more of a sales and marketing, or?

BOB METCALFE:

03:08:05;18 Well, we built products that implemented these three standards. The UNIX standards, the TCP/IP Internet protocol standard, and the Ethernet, we built products. They worked. People bought them. So there was some technology there.

03:08:19;19 But you need, one of the standard failures of a startup, and I've noticed this a lot at MIT, is the technical founders

have a low regard for people who know how to sell. So like you get this attitude problem where there's the suits versus the nerds. And if they disrespect each other, then the company is dead. Because every team needs to have, well, suits and nerds and others on it.

03:08:46;10 So a good company looks like the *Star Wars* bar. You know, has its different life forms. And you can't imagine two more different life forms than nerds and suits, or engineers and salesmen. So I learned, my principle learning, had to do with selling. How do you sell and market products? 'Cause I had one that I needed to sell and market and it was quite a struggle there for the first few years to figure out how to do that.

03:09:13;12 It was hard to sell Ethernet for PCs when there weren't any PCs. That's kind of a problem. So we had to mark time for a while until the PC got introduced, and IBM introduced the PC in August of 1981. A year later, we were make, we were shipping Ethernet cards for the IBM PC. And by

1984, we were public. And started shipping millions of them per month over time.

QUESTION:

03:09:46;01 Let's just talk a little about innovation. You said innovation can sort of be structured I think. Did you say structured, or...

BOB METCALFE:

03:09:52;14 Infras...

QUESTION:

03:09:52;04 ...am I in the...

BOB METCALFE:

03:09:53;07 Infrastructure or planning.

QUESTION:

03:09:54;29 A plan. I mean, how would you, how do you go? I mean, you observed a lot of companies. What are, just give us some riffs on innovation the way you see it.

BOB METCALFE:

03:10:03;15 Well, innovation, I like the word "ecology", I didn't come up with the word, but I like the notion of an innovation ecology. Different people, different stages, different

activities. So you need some knowledge. So I'd call that science. You need some science somewhere. Somebody discovering new knowledge.

03:10:21;14 And then you need engineers who can take that knowledge and build it into things that might be useful. And then you need sales and marketing people who can get it out into the world. And then you need customers. And the customers some and you can see there immediately there's a problem because the knowledge has to relate to something that the customers need or want, and very often the people who are doing the science have never heard of the customers, and the customers have never heard of, so how that connection gets made is complicated.

03:10:55;06 So when 3Com, so we had this Ethernet technology, but we had a huge advantage over everyone else in the world. We had lived at Xerox PARC for eight years. We knew what the future was going to be like. There was going,

even though the outside world didn't know it, we knew there was gonna be a computer on every desk. We knew that, 'cause we had them. And we knew there would be a laser printer in every office. How did we know that? Well, we had one. And we knew it would be connected to the Internet. How did we know that? We were…

03:11:24;19 So we had a vision of what the future was gonna be, so we started going right toward that vision even though it didn't exist in the real world. So that creates problems, 'cause the customers don't know they need what you're developing 'cause they don't have PCs yet. So we had to mark time for a while until the PC came. Thank goodness IBM, well, Apple had been shipping PCs, but their PCs were too weak to require Ethernet.

03:11:53;04 So Steve Jobs, who was extremely helpful to me, by the way, in founding 3Com, and he is a god and difficult god, but a god. He wanted me to build Ethernet for his pitiful PCs, which were not even close to what we had at Xerox.

And I told him I really prefer to do my own company. So Steve helped me do my own company. He didn't hate me for wanting to do my own company, and that was extremely helpful.

03:12:24;10 And then he hired one of the guys who had worked for me at Xerox to build Ethernet for his what later became known as the Macintosh. So they developed a low-end Ethernet for the Macintosh which was called Apple Talk, and it was like the standard Ethernet that I was promoting, but it was slower and cheaper. Which is what he needed for his pitiful PCs, as opposed to the coming PCs that I was getting ready for.

03:12:48;27 So Apple Talk and Steve Jobs went off in this direction, and they built a laser printer at Apple, the, you know, LaserWriter, which they shipped in 1984. Where did they get that idea? Oh, Xerox PARC perhaps. Meanwhile, we were building the equipment for the coming PCs that were 16-bit PCs, not 8 bit. More capable PCs. And they arrived

in thanks to IBM, in August of '81. And we had products for those PCs.

QUESTION:

03:13:18;28 How did all these other companies get all of PARC's ideas and get it onto the market? I mean, does the mouse and the graphical user interface… I mean, these are the stories.

BOB METCALFE:

03:13:29;15 Well, Xerox, where I worked, I was lucky enough to work, had the problem that we created this science environment to develop new technologies, and it was very successful. What wasn't successful at Xerox was bringing those products to market.

03:13:45;26 So what you saw was the people eventually boiled off. So here you had Xerox PARC, and the people like me boiled off, left, and went other places. And then took these ideas, some of them licensed from Xerox and some of them not, and built Apple and Microsoft and 3Com and Cisco and all of which were based on ideas that originally,

you know, had at one time or another come through Xerox PARC.

03:14:14;25 For example, the mouse was not invented at Xerox PARC. It was invented by Doug Engelbart at SRI, and then it came to Xerox PARC where it got really perfected into the user interface of PCs. Engelbart didn't have a PC, so his mouse was not really as useful as it turned out to be for the PC.

03:14:35;03 So the mouse wasn't invented at Xerox PARC, but it was transformed into what we now use today as the mouse. And the, so Adobe spun out of Xerox PARC, Warnock and Geschke. And 3Com had routers before Cisco existed, and those routers came from the first routers that we built at Xerox. But then Cisco invented better routers, and then of course now Cisco is the Internet company. If I were a better person, there would be no Cisco 'cause we would have done it at 3Com. But gotta know your limitations.

QUESTION:

03:15:18;25 Is there anything nowadays like Xerox was? That pure research component going on?

BOB METCALFE:

03:15:25;12 Well, there's still Xerox PARC. It's still there.

QUESTION:

03:15:28;11 But is it still as...

BOB METCALFE:

03:15:29;25 And even though..

QUESTION:

03:15:29;22 ...prolific?

BOB METCALFE:

03:15:30;15 I think that we were the best, and that Xerox hasn't been the same since we left, there are people at Xerox who disagree with that. And they think they're hot stuff, and I'm not gonna disagree with them. Only time will tell.

QUESTION:

03:15:41;20 It almost goes to a bigger question, though, which is kind of irrelevant today. But America and our innovative edge; do you think we still have that? America's still a great

place for innovators, or?

BOB METCALFE:

03:15:50;12 I do, but things are changing. I mean, there are now other innovators in the world, so it's more of a, it's not just the U.S. Now it's the U.S. and the rest of the world is innovating more. And innovation is not a zero-sum game. So we shouldn't be sad that China is innovating, we shouldn't be sad that Japan is innovating. We should be happy that they're innovating. But it's no longer just our game anymore, if it ever was.

03:16:16;24 Another question I've looked at is what's the best way to do science? Which I think feeds into innovation. I worked at a research center supported by a monopoly. So there, you remember Bell Labs was supported by AT&T, which was the telephone monopoly. And then Watson Labs at IBM was supported by IBM, which was the computer monopoly.

03:16:38;27 Xerox PARC was supported by Xerox, which was the copier

monopoly. Microsoft Labs, which is the current hip and happening place, is supported by Microsoft which has the personal computer software monopoly. So what do we observe? We observe that the only companies that can afford to do research are monopolies.

03:16:57;09 Is that a good way to do research? No. There's two things wrong with that. One is those monopolies overtax their customers. They charge too much, and that's bad. Second, even when they're successful, as Xerox was, as Bell Labs was, as Watson was, those ideas have trouble getting to making because the owners of those ideas are the status quo. They are the monopoly. Their incentives for bringing the new knowledge to market are lower than, say a new entity. So I don't think, although you'll often hear it said, "Industry should do research." I don't think that's the way to go.

03:17:34;26 Another alternative is that science should be developed at government laboratories, like the Department of Energy

laboratories are the most famous ones, but there are others. But in my experience, that isn't a good use of money. For a particular reason is that if you take a government lab where people go to work for their whole career and then they retire, as opposed to a research university where people go and they study for five or ten years and then they graduate and they leave, "a-ha". So if it's innovation that you're after, the best vehicles for innovation are people. These labs don't graduate people, but universities do.

03:18:15;20 So I conclude, by that argument, that the best place to do research is at research universities. And the United States is blessed with the best. I mean, we've got ten good ones in the Boston area alone, not counting Stanford, not counting Carnegie Mellon, UCLA, USC. We have many, Michigan. The list goes on.

03:18:33;11 We have these fine research universities. That's where we should be sending money to do research. And that the

science, the new knowledge developed by that research then feeds the innovation machine from underneath.

QUESTION:

03:18:45;16 So I know you, you sort of have, I don't know if it's a dislike, but you're antagonistic towards monopolies, obviously. AT&T, Microsoft. Tell us a little bit about that. Is it just the research component, or are there other reasons?

BOB METCALFE:

03:18:59;16 Well, there's, you know, there are markets that are un-served. They have zero suppliers. And that's a bad situation. Then there are markets that have one supplier; that's called a monopoly. And that's better than having none, but not much better 'cause they're slow to innovate and they charge too much. Then you have two markets served with two, three, four, five, six, seven, eight, nine, ten different suppliers that gets better, 'cause they become competitive and innovative against each other.

BOB METCALFE:

03:19:37;26 In 1972, at the Hilton Hotel in Washington, D.C. I kicked a

table.

BOB METCALFE:

03:19:49;13 So in October of 1972, the ARPANET, the Internet, debuted in Washington at the Hilton Hotel. And it was my honor to edit the book, which was entitled *Scenarios for Using the ARPA Computer Network*, which is sort of like the Internet for dummies, 1972.

03:20:09;14 And having edited that book, when the ten AT&T executives showed up in their pinstripe suits for a tour of the Internet on the ballroom floor of the Hilton, I was given them. Picture a graduate student with a huge red beard escorting these ten pinstriped AT&T executives around the floor, showing them, "Here, I'm now going to UCLA. Ah, here I am now going to Stanford. Let's run up to MIT and try that software."

03:20:38;25 And I'm doing this demo. And the ARPANET packets, which is on a pedestal in the middle of the ballroom and as I've learned, the most hostile place for doing a

demonstration is a hotel ballroom. You never wanna do that if you can avoid it. But we, there we were, and guess what? The computer crashed, in the middle of the demo.

03:20:59;09 Here's a grad student, showing off his life's work. He couldn't be more excited. This is gonna change the world. Isn't this cool? And, uh-oh, it crashed. And I turn around to the ten guys who are watchin' me, and they are laughing. They are happy. And that in that moment, my lifelong hate of monopolies was formed.

03:21:23;08 'Cause these people, who were peddling a technology which we now call circuit switching for telephones, had felt threatened by this new technology that the DOD was promoting called packet switching. And, you know, they are at a monopoly and their careers were set. And they were steaming toward retirement. And packet switching didn't work, it had crashed. It was unreliable. They were happy. They could go back to their humdrum existences just grinding out circuit switching.

03:21:59;16 So guess it's getting personal now. In that moment, I decided that, now there's a new company called AT&T, which I hate only 'cause it's called AT&T and because it reminds me of that experience in 1972. Maybe I should let go of this. You know, just let it wash over me and become calm.

03:22:18;26 But no, monopolies are not a good thing. Fact, in my ideology, I tend to disagree with, I agree with the *Wall Street Journal* about almost everything, except they don't feel as strongly about monopolies as I do. That's where I depart with the Wall Street Journal. Monopolies need to be broken. It is the duty of government, government is a monopoly. It is the duty of government to crush monopolies and break, "crush" is the wrong word. But to prevent them from slowing down innovation.

QUESTION:

03:22:49;27 Well, one way to fight monopolies is competition, but there's also another movement, this open source

movement. They have the same philosophy. They don't, they don't like monopolies. But you're not really, you don't really think that's a good answer either, do you?

BOB METCALFE:

03:23:00;17 Well, I have a, I was a pundit for ten years and I wrote a weekly column. And among the many topics I took up, many topics, 500 topics, was the open source movement, which I carefully analyzed. So first I attacked Microsoft, which is a monopoly, for Windows, which is junk.

03:23:25;18 And then I turned to open source and looked at Linux, which is certainly not a monopoly, but it is junk. And you can see, I attack both of them as being old operating, UNIX is an old operating system. It was developed in 1967 or '68 when I was a senior in college. And the Windows operating system is sort of based on that. So they're both old, crummy software.

03:23:54;01 But the question is, if you want new software, where are you gonna get it from? Are you gonna get it from the

modern software corporation, the epitome of which is Microsoft? Or are you gonna get it from the open source movement, a bunch of vaguely hippie volunteer ideological people? What's, where are we gonna get our software from?

03:24:20;07 And I, so I was neutral. I say, I'd really, am dyin' for you guys to give me my new operating system, and I don't know where it's gonna come from. But frankly, I'm betting that the modern software corporation will outperform the ragtag group of volunteers. So therefore, I had everybody hating me. All the Microsoft people hated me for attacking Microsoft, and all the open source people attacked me, I made a horrible mistake. I actually went after Linus Torvalds in one of my columns. I will never do that again. I have learned, I've met Linus, by the way. He's a perfectly lovable man.

03:24:57;10 But I was calling attention to the fact that he worked for a company that was not open source. And I wanted to

know, if open source was such a cool way of doing things, "How come your company, Linus, doesn't do open source?" But, in that appeared to his sycophantic followers as an attack on Linus, and they buried me in hate mail for a month. So I will never do that again, you know?

03:25:21;18 Anyway, I'm skeptical of open source. Now, what's happened is that open source and the Microsoft model have converged. So there, Microsoft is more and more open source-y, and open source is more and more Microsoft-y. And they're sort of converging. So in the end, it won't be clear who was right or wrong about that.

QUESTION:

03:25:40;28 Let's talk about the future. I mean, the big thing now they talk about cloud computing, and your operating system'll just be on the Web somewhere. And what do you think's happening with that?

BOB METCALFE:

03:25:50;26 Well, that's a classic pendulum. In the history of computing, the pendulum swings between centralized and

distributed, and every once in a while some, when we're over here, we get the idea, "This looks better." So we swing over here and then we swing back.

03:26:04;23 So remember, there were mainframes, and then there were stand-alone PCs. And then there was client server computing with big servers, and then there was peer-to-peer computing without servers. And now we're going back to cloud computing, which has big servers again. So this pendulum just keeps swinging back and forth.

03:26:24;02 And we're obviously gonna, cell phones are now becoming formidable computing engines. So we're getting way distributed out here, doing all this computing out here in cell phones. And then cloud computing says, "Oh no, we need to do all of our computing over here in a centralized pool." And clearly, everything in between is all of them are needed and they'll be used in some mix, and that mix will change over time. But that's just a pendulum swinging back and forth.

QUESTION:

03:26:51;26 Do you think it's marketing, or is it science?

BOB METCALFE:

03:26:55;09 No, neither. It's a pragmatic adjustment to the existing profile of available technologies. You know, so storage gets cheaper, communications gets cheaper, the process, and they all proceed at different rates. So over time, sometimes this solution looks better and then some technologies will change, and then this configuration looks bigger. So it's more of a, it's more of an adjustment of products to the available technologies. And that's why this pendulum swings back and forth.

QUESTION:

04:00:44;16 Tell me a little bit about Metcalfe's Law, where it came from, what it means and how it's worked over the years.

BOB METCALFE:

04:00:52;02 In the early days of 3Com, and that would be around 1980, we were selling Ethernet cards to plug into PCs. And my sales force was about eight guys, all of whom had sold mini computers that cost $30,000. But these little

cards cost $1,000.

04:01:13;07 But in order to get their commissions, they wanted to sell $30,000 systems. They wanted to sell 30 cards at a crack. But our customers didn't wanna buy 30 cards at a crack, 'cause they didn't know what these cards were good for. And many of 'em just barely had PCs.

04:01:28;23 So I had this brilliant idea that we would sell starter kits consisting of three cards and the software to allow you to share a disk and a printer among three PCs. And it would cost $3,000, not $30,000. And that made them nervous, 'cause their commission on $3,000 was small. And they couldn't send their kids to college on that.

04:01:49;18 But the neat thing was, the customers wanted to spend $3,000, not $30,000. So we started selling them and a lot of them. And then about a year later, we went back to them all and they weren't very useful. So we were having trouble getting them to buy more. So I went into a

marketing trance and said, "How can we explain this phenomenon?" 'Cause I know the Ethernet's useful 'cause I lived at Xerox PARC and I saw how useful it is. What's going on here? Why are these people not enjoying their Ethernets the way I think they should?

04:02:27;17 I know what it is. Their networks aren't big enough. There must be some, oh, I know what it is. Each time they buy a card, it costs 'em $1,000, so there's, the cost of the network is a straight line that goes up. N nodes, N thousand dollars is a straight line going up. But the value of the network has to do with how many other computers you can connect to.

04:02:52;26 So when you just have one computer on the network, that's a value zero. You can't connect to anything. When you have two, that's more valuable. So the curve must relate to the number of other connections you can make, which is like, N time[s] each of the N computers can connect to N other computers. So that's roughly N

squared.

04:03:13;13 So you draw another line, like this, which starts out flat and then it curves up, quadratic. And there's this point at which they cross. This curve catches up to the linear and crosses. And at that point, I, by hand, using my Orator ball, circled it and said, "Critical mass point." So if your network was lower than the critical mass point, the cost was higher than the value. But once you passed critical mass, then the value exceeded the cost and you began to enjoy the benefits of the network.

04:03:47;03 'Cause the problem with all these little starter kits we had sold is they all worked as advertised. They just weren't above critical mass. And so you didn't enjoy them as much as you should. So I made a slide that expressed this idea. And it's available. And it was, it's called The Systemic Value of Networking or something like that. And I gave it to my sales force. And we went out to our customers. And we explained to them that the reason that

their networks weren't so valuable is that they weren't big enough, so they should buy more from us.

04:04:18;23 And they did. And the networks proved useful. And 3Com became a multi-billion dollar company. So we didn't lie to 'em. We knew that they would be useful. We just had this slide that explained why they weren't useful. The networks weren't big enough to be useful. You need to buy, say, 30 nodes and maybe you would; and they bought the 30 and the 30 did prove useful, so they bought a hundred and a thousand and then a million. And the rest is a happy story.

04:04:46;16 In 1995, many years later, 15 years later, I was interviewed by George Gilder, the famous journalist, writing a book called *Telecosm*, the first chapters of which appeared in *Forbes* magazine. And George was looking through my paraphernalia. And he came across this, well, he asked me just, you know, see my stuff. And he saw this slide.

04:05:13;05 And now George Gilder is famous for another law. He helped popularize a law called Moore's Law when he wrote a book called *Microcosm*. So George analogized this and said, "Okay, I wrote a book called *Microcosm* promoting Moore's Law. I'm gonna write a book called *Telecosm*, and we'll use whose law? Metcalfe's Law." So he called it Metcalfe's Law. And the law is that the value of a network grows as the square of the number of users.

04:05:47;00 There are many ways of saying that. V approximately N squared. That's Metcalfe's Law. Now, unlike Moore's Law, Moore's Law has been numerically true since 1965. You can plot a graph of Moore's Law and it is amazing how accurate it's been over such a long period of time. Metcalfe's Law is not the same kind of law. Metcalfe's Law has never been numerically evaluated, to my knowledge. There is no plot showing how it's true.

04:06:19;00 And this has led to a lot of debate. So since 1995 various

people have been including me, have been touting Metcalfe's Law, and then there's this huge number of people who suspect there's something wrong about it and who have been criticizing it and improving it and adjusting the parameters and the exponents and futzing with it. And it's one of my hobbies now is defending Metcalfe's Law, which is kind of a vision thing.

04:06:44;06 All Metcalfe's Law says is it's good to network things, which it undeniably is true. So what you think of Metcalfe's Law as an effort to quantify the network effect. That is when you build a network, there is a certain value of the network that accrues from other people being members of it. And the more of them there are, the better it is. And that this is roughly N squared.

04:07:05;21 And, of course, there's people who say it's two to the N. And there's other people who say it's N cubed. And the, you know, all sorts of parameters. And it's irritating to all of them that Metcalfe's Law is, you google Metcalfe's Law,

it's amazing how many people talk about Metcalfe's Law. And, of course, they expect me to defend it to the nth decimal point, and I disappoint them. I tell 'em just what I just told you now, which is, it's just a vision thing. And I did sell a lot of Ethernet cards with it.

QUESTION:

04:07:34;24 Let me ask you this. You've obviously done a lot of these things, Metcalfe's Law and the Ethernet and the punditry, etcetera. What are some of the things you're most proud of when you think back over your life?

BOB METCALFE:

04:07:46;16 Well, I think my biggest accomplishment at 3Com was selling. So I suddenly and inadvertently became VP of Sales and Marketing at 3Com when we had zero revenue. And two years later we had a million dollars a month in revenue. So that would be the single thing I'm most proud of, is getting us from zero to a million a month.

04:08:08;02 And we went public shortly after that. But then, of course, selling got too complicated. In other words, going from

zero to a million a month was something I could do, 'cause it was mostly personal selling, where I had the advantage of being the inventor so I had credibility and I could get an audience with people and had an opportunity to sell to them.

04:08:27;23 And then having taken Xerox selling skills training at Xerox, I managed to close some business and get to about a million a month. And I learned about quotas and I learned about sales compensation. And then it got complicated. So around a million a month we wisely went out and recruited somebody who knew about the technology of selling and replaced me in that job. So that would be the one, certainly in my career at 3Com, that was my big accomplishment getting us through that zero to a million a month.

QUESTION:

04:08:58;22 But do you sorta see your life as compartmentalized in these different phases? The student, the engineer, scientist, inventor, pundit, venture capitalist? Or how do

you view that?

BOB METCALFE:

04:09:09;06 Well, the way I've conceptualized it is a series of careers in technological innovation. So there was the student period where you're accumulating knowledge and skills. And then there's the scientist period where you're discovering new knowledge. And then there's the engineering period during which you're taking new knowledge and making products.

04:09:27;00 And then there's the journalist period in which you write about technologies to help build them, help people to buy them intelligently and make good use of them. And then there's the venture capital phase where you're financing innovative companies. I view all of those as different careers in technological innovation.

QUESTION:

04:09:44;07 And if we had a bunch of young kids here, you know, junior high or high school, and I mean, you've probably been asked this before, what would you recommend that

they do to, to get their careers started, their life started in this field?

BOB METCALFE:

04:09:57;28 Well, I once asked my father what I should do. And he said, and this is a man who never went to college and, you know, his horizons were by comparison, were so, you know, we came from Brooklyn, New York. Brooklyn is a place famous, in those days, where you could live your whole life and never move three blocks from where you lived.

04:10:22;15 So it was a very closed world. But when I asked what I should do, he says, "Well, it doesn't really matter what you do as long as you're good at it." So that would be the first advice I'd give is, "Be sure you're good at something." And it doesn't really matter what it is as long as you're good at it.

04:10:39;12 And then the second thing, piece of advice right behind that is, "You're never gonna get any good at anything

unless you enjoy it." So find something you enjoy and get good at it. And you can't be good at something that you don't enjoy, because you just can't sustain the effort. You have to really like doing it. Innovation and invention is something that you do on purpose. It's not a lightning bolt from heaven. You set out to do it. You practice it.

04:11:06;26 You can develop innovation skills. Maybe you don't wanna be an inventor. So not everyone should be an entrepreneur. Not everyone should be an inventor. And so if you wanna be an inventor, then it isn't, once again, it's not a bolt of lightning. And there's usually a lot of preparation involved. You have to know what customers need or want. You have to know the underlying mechanisms for building whatever it is you're gonna build.

04:11:36;08 So you have to know stuff. You just can't invent. You just can't have brainstorms. Occasionally, in my field, venture capital now, I'm forever finding people who have had these great ideas. They forget the fact that 20 other people

already invented that 30 years ago. So haven't you done any research? Have you checked that there might be other people who did this before you?

04:12:00;08 That's an important part of inventing is to be up-to-date as to what other people have done before, to look where the opportunities are for innovation so you don't just invent stuff that's already invented a long time ago. There is an expression that, "There's nothing new under the sun." I forget who said that. Whoever said it, it wasn't the first time it was said. That's true by degrees. I mean, there are, ideas recur.

QUESTION:

04:12:27;13 All right, tell us, I'm sure you've had to answer this many times, the time you had to eat your words in front an esteemed body of colleagues, where you throw everything in a blender and...

BOB METCALFE:

04:12:36;02 Yup.

QUESTION:

04:12:36;24 ...for you to go on?

BOB METCALFE:

04:12:37;01 Well, for ten years I was a journalist. I wrote a column a week, 605 words, read by a million people a few days later. Talk about a heady experience. Imagine sitting at your personal computer typing in words that in a few days will actually be read, not just mailed to, read by a million people. Is that terrifying or what?

04:12:59;01 So I really loved doing that. 'Cause every word was worth it, I liked to delete "the." One of my favorite things was deleting "the" 'cause I had to cut it to fit. I had to edit to fit. If I didn't edit to fit, then the copy editors would edit to fit. And you don't want them doing that, 'cause they make mistakes.

04:13:18;10 So I did my own fitting. How did I get on that? Oh. So that meant I had to have something interesting to say every week. And what I often did was make predictions.

And my column was about the Internet. And I began to notice some perilous trends in the Internet in the mid '90s.

04:13:42;04 So in 1995, so I'd been at it a few years, I realized that my job as a columnist was to have an audience. And I was building an audience. And it had hit a million people, which was really cool. But the way you kept the audience was to be interesting. In fact, it was more important to be interesting than to be right. And that's, by the way, that's a hazard of journalism.

04:14:11;00 Often journalists will take a bad turn there and they will try to be interesting and they will lie to their readers. And that's not a good thing. I was trying not to lie to my readers, but I was trying to be interesting. So I made a prediction. I made a prediction that the Internet would collapse in the year 1996. I did this at a conference.

04:14:29;28 It was an Internet conference in Santa Clara, California. I had to think up something to say. I had a column. I had

just, I was writing at the time. So I wrote the column predicting this collapse of the Internet during 1996. And then I said it out loud to this conference of a thousand Internet enthusiasts, who of course were delighted to hear that the Internet was gonna collapse. And one of the guys in the audience yelled something nasty at me, I forget exactly what it was. It meant my speech was working.

04:15:02;29 In any case, I then promised that audience that if the Internet didn't collapse in 1996, I would eat my column, predicting such a collapse. And they loved that. They just ate it up. And then I proceeded to write a bunch of other columns about this. And I refined the prediction. And ultimately the prediction was that during 1996, there would be a gigalapse. That is, there would be an episode on the Internet in which a billion user hours would be lost, a billion, a gigalapse, a billion lapse.

04:15:37;02 And on August 4th, there was a 118 megalapse. That is, there was an outage of the Internet that cost 118 million

user hours were lost. But you'll notice, that's not a gigalapse. It's close, within a factor of eight, but not quite a gigalapse. So my prediction did not come true. So I went back to this conference in Santa Clara, the following April, I think it was [the] same audience to whom I had made this promise. And it was a marketing moment. I had to decide how to handle this.

04:16:15;29 And I wanted to play it for all it was worth and get a, this was gonna be a P.R. stunt. So I went to this conference and I prepared. So, first of all, the night before, I took the column and I cut it up and I tried to eat it. And I discovered in that moment, you can not eat paper. And, by the way, I checked the inks that *InfoWorld*, I was the publisher of *InfoWorld* and a columnist there, used soybean-based I think, so it would not kill me to eat the inks. They weren't heavy metals, for example.

04:16:49;28 But I learned that night in the hotel, the night before, that you can't eat paper. You choke on it. It's hard. There's

not enough saliva in the world to eat paper. So I had to innovate. So I came up with using a blender and make a soup out of it. And then if you tore it up into small enough pieces and you put it in water, you could drink it.

04:17:11;06 So, and then I had a cake made that looked like the column, you know, a big, nice big cake. And it looked just like the column, had the, you know, you can pay a guy to put icing on. It looks like a, you know, I had that. And then I find myself in front of this audience of a thousand people, all of whom wanted blood 'cause I had promised.

04:17:31;14 So I began by saying, "You know, I made this promise a year ago that I would eat my column. But, you know, I think my prediction was essentially correct. You know, 118 megalapse is pretty close to a gigalapse. So I don't really think I need to eat my column." So the audience started booing and hissing and getting angry.

04:17:51;01 And so then I said, "Okay," I ordered in the cake. And the

cake came in and I started handing out the cake to everyone. And I took a piece of the cake and I started eating it as if this would suffice. And the audience grew more and more unruly and was murmuring and booing and hissing. And then so I reached under the podium and I took out the blender. And I put it on the stage. This had all been prearranged, of course. And I put water in the blender and I took the column and I showed the column to everybody in the audience.

04:18:24;05 And the cameras were zooming in on this. This was the biggest P.R. stunt you ever saw. And then I tore up the column, put it in the blender, blended it up. Then I had to check, I said to the audience, "What do you do with soup? What is the verb?" Eat. You eat soup. With a spoon. Good because I had promised to eat my column. And I wanted to be careful that what I did was in fulfillment of that promise.

04:18:51;14 So I ate the column. And I held the bowl empty over my

head, which is the old method at beer drinking parties. You always hold the empty cup over your head to prove you've drunk the beer. I got the cover of *Barron's*. I got coverage in the *Wall Street Journal*, *Forbes* magazine. It was the biggest P.R. stunt I've ever been involved in.

04:19:16;04 The only unfortunately part of which, is that today, more people know of my name in connection with that failed prediction than associate it with the invention of Ethernet, which is an unfortunate by-product of this stunt. That's the story.

QUESTION:

04:19:37;10 It's a great story. But there was one prediction you were right on, the dot-com bubble, right? You got...

BOB METCALFE:

04:19:43;06 Excuse me, I made 500 predictions. And my batting average was .987. But...

QUESTION:

04:19:47;16 Oh.

BOB METCALFE:

04:19:48;01 ...but yes, I was, I predicted that the Internet bubble would burst. And that was a very unpopular prediction also. And I was almost exactly right on that one. And so I have a book called *Internet Collapses*, which is about all that. And that book is available on Amazon.com.

QUESTION:

04:20:04;06 That book's available right here. And we would like you to sign a copy.

BOB METCALFE:

04:20:08;20 *Internet Collapses* and other Info *World* punditry.

QUESTION:

04:20:12;20 I did not mean to imply your other predictions weren't correct.

BOB METCALFE:

04:20:17;06 And the cool thing about this is that you can buy this book to, you know, in the old days books would go outta print. This book should be outta print by now. But it's not outta print. You can get it overnight from Amazon.com. Now, you may have to pay $.97 for it used, but it is a major

accomplishment of the Internet that thanks to Amazon's long tail, you can buy books that, I don't know how old this is, I've lost track.

BOB METCALFE:

04:20:44;09 2000? So here's an eight-year-old book that wasn't that popular to begin with. And it's still available at Amazon.com. *Internet Collapses*, buy one today.

QUESTION:

04:20:56;11 Were you really 98 percent...

BOB METCALFE:

04:20:58;17 No.

QUESTION:

04:20:58;22 ...accurate?

QUESTION:

04:20:59;08 No, I didn't think so.

BOB METCALFE:

04:20:59;27 I was, that was hyperbole.

QUESTION:

04:21:00;29 Right. I know. That was a marketing moment.

BOB METCALFE:

04:21:02;24 That was a marketing moment. No, I think my column was generally honest. But I made a lot of predictions. And that made it interesting.

QUESTION:

04:21:11;27 Oh, yeah. Well, you say you gotta be entertaining and engaging.

BOB METCALFE:

04:21:14;27 Of course, there are, I have many enemies who, I remember once my daughter applied to prep school. And I wrote in her, the parents had to fill out a form. And I said, "I hope some day my daughter is the kind of person who makes enemies." She got in to the prep school, so it worked.

04:21:35;28 But that's sort of something I'm proud of, that I am the kind of person who makes enemies. And I guess it's because I think collegiality is overplayed. Collegiality is a pathology of the status quo. That is the enemy of innovation. So the status quo, one of its tools is what they

call collegiality. You're polite. The old boy network.

04:22:02;03 So to be an innovator, you have to be willing to make enemies. You have to be willing to fight the status quo. And the status quo is resourceful and nasty and mean and conniving. And so you gotta be unafraid to have enemies. And I have enemies. And I rejoice in what losers they are.

QUESTION:

04:22:24;27 Now who do you have as an enemy that's a true rival, that you both have been pretty successful but still don't agree on things? Is there such a rivalry like that?

BOB METCALFE:

04:22:34;15 Well, there was my old nemesis at Xerox PARC who's been very successful. And so have I. And our petty, pettiness, personal chemistry problem didn't really stop either one of us from moving forward. The inventor of the IBM Token Ring, Olof Soderblom, whom I've never met, he was my enemy for a long time 'cause the IBM Token Ring was the alternative to Ethernet.

04:23:02;25 And eventually, Ethernet killed the IBM Token Ring. So some day I hope to console Mr. Soderblom if I ever meet him. I did actually license his patents and pay him royalties, 'cause my own company sold IBM Token Ring. My board of directors insisted that we offer the IBM Token Ring, because IBM had made it a standard. So our company, whose business was interconnection, needed to offer the IBM Token Ring. But I hated the IBM Token Ring; but they made me do it.

QUESTION:

04:23:34;18 What about, we've given everybody a chance to correct the record. Sometimes people say there's a thing that's been written about me that's just not true. Is there anything that you'd like to correct the record, some misconception or something you think maybe has not been characterized properly about you or what you did?

BOB METCALFE:

04:23:54;10 No. I've been treated really well by the record, I think. Very well. So I'm afraid, I'd be afraid to answer that question.

QUESTION:

04:24:02;21 Well, that's fine.

BOB METCALFE:

04:24:03;15 The record's pretty fair. Actually, there's this very interesting part of the record. So I mentioned earlier that Dave Boggs and I built the first Ethernet. And, but Boggs and I are quite different people. So I'm sort of an outgoing bullshit artist. And he is sort of a quiet, introverted, very technical person.

04:24:27;15 And we together built the first Ethernet. But various people studying the history of the Ethernet have met me and they meet Boggs, and then they form this impression about what must have happened. What must have happened is that Dave Boggs really invented the Ethernet, and then I being the more outgoing, articulate bullshitting guy sorta stole it from him.

04:24:50;28 And this is a story which has come up repeatedly over the years, because our personalities invite that interpretation

of events. Thank god David Boggs was there. And so everyone runs to Boggs and they try to get out of him this story. So for example, the famous Ethernet paper is, "Metcalfe and Boggs," which you'll notice is not alphabetical. So that must be proof that I sort of shoved Boggs aside and because of my outgoing nature, contrasted with him that's how it must have happened.

04:25:27;22 And so then they run over to Boggs to get his side of the story. And Boggs says, "No, Bob wrote that paper. And then at the last minute he invited me to put my name on it because we had worked together on the building of it. So I'm grateful that he included me on that paper." So that's, see but that's in the record.

04:25:45;28 All that's in the record. So I really have no complaint. But it's just funny. That's a recurring narrative about how this innovation occurred. I could not have done Ethernet without David Boggs, that's for sure. That's why I frequently mention his name.

QUESTION:

04:26:01;21 What about this? This is kind of a tricky one, but we ask people this. You know, a hundred years from now when people are looking back or reading about you or watching this interview, what would you like to be remembered for of all your accomplishments and what you've done? I mean, how would you like people to think of you?

BOB METCALFE:

04:26:19;18 The secret of happiness is a word. And my boat is named this word. And so that's how I would like to be thought of. Would you like to know what the word is? Enthusiasm. So somewhere along the line I learned that the secret to happiness is enthusiasm. To be enthusiastic about something is a source of happiness.

04:26:43;20 So this goes back to wanting to do something and then being good at it, because it's so much fun, it's easy to be good at it 'cause you invest lots of energy and time 'cause it's so much fun. So I think enthusiasm, I would like to be remembered as someone who's enthusiastic. And not just

about Ethernet, just about, almost about everything, including this interview. I couldn't be more enthusiastic about talking to you.

QUESTION:

05:00:46;29 You left Silicon Valley at some point, why? And you came back here? Is that what happened? And why'd you do that?

BOB METCALFE:

05:00:52;12 Ten reasons. We lived in Silicon Valley for 22 years. And then I wanted to work more and more with MIT, of which I'm an alum and now a trustee. And MIT's here in Boston, so we moved, we actually moved to Maine first and then Boston. Another event was we spent a year in England at the University of Cambridge. I was a visiting fellow there for a year. And we enjoyed it a lot. And what we enjoyed is looking around at a city which was all new. Everywhere you looked, you saw stuff you hadn't seen before.

05:01:23;26 But we had lived in the environs of Palo Alto, Woodside, San Francisco for 22 years. Everywhere you looked was

familiar. You'd seen it before. We decided for a change, we needed a change of scenery, so we just up and left. It had nothing to do with Silicon Valley being a terrible place. It's not. And plus my job, the headquarters of the company I was working for, International Data Group, for which I was a pundit, was headquartered here in Boston. So, I moved to headquarters.

QUESTION:

05:01:54;15 Okay, tell us a little bit more about the influence your parents had on you.

BOB METCALFE:

05:01:58;27 Well, my parents, Ruth Christine Muir Metcalfe and my father, Robert Aisles Metcalfe are, their parents, my four grandparents moved to New York City, about 100 years ago, then they met, married and had children and so I was born in Brooklyn, New York. My grandmother was an organized crime fighter on the docks of New York. My grandfather was a chauffer.

05:02:26;28 My other grandfather died at the age of 41, he was a ship's

captain and he died in a freak accident involving water boiling over on a stove and extinguishing the flames so that the gasses killed him while he was napping at the kitchen table. And then there was my other grandmother who was the organized crime fighter. So, ask me about the Mafia on the dock sometime, I'm full of stories about that. But then, my parents married as the war was ending, World War II. And my father had lost an eye as a child, so he didn't go fight in the war like his brothers.

05:03:05;07 But he worked at an aerospace company where he met my mom, who was, I call her [a] Rosie the Riveter-type person. But she points out to me she never did any riveting. But she was a war factory worker. And they met out of high school. And then they had two goals in life, or at least that's how I felt. One was to send me to college and the other one was to retire early, both of which they accomplished. And my father was an engineer, sort of a, he was actually, his title was "technician" since he didn't have a college degree.

05:03:39;14 So, he was interested in gyroscopes and I remember, we lived in Bay Shore, Long Island in a development. Imagine block after block of brick ranch houses all of which look the same. And all the trees were tiny with little stakes holding them up. This is where I started. And then, we kept watching these rockets take off and then crash on the launching pad. These were my father's rockets. And I, not that he was totally responsible for them.

05:04:07;24 And then one day, the rockets started taking off and we bought a new house in a neighborhood next door called Brightwaters, where every house was different. I mean, like, we lived in a house like this and the one over there was like, it was really cool to move upward to this new Brightwaters incorporated village, inside of Bay Shore. So, I went K-12 in the Bay Shore school system. And then went to MIT. What question was I answering?

05:04:36;00 Ah, anyway, the culmination of the American dream

occurred in 2005, when George Bush invited me and my parents to the White House to give me the National Medal of Technology. And I still have, I'm about to cry now. I've got this picture of my parents standing in the White House with the medal that I got, the American dream. You have another question?

QUESTION:

05:05:03;04 Yeah, but I want to make sure we honored that one properly. The energy net, you're putting something together, tying together energy companies, or?

BOB METCALFE:

05:05:14;15 No, not really, the...

QUESTION:

05:05:14;27 Do you want to take a moment to compose yourself?

BOB METCALFE:

05:05:17;09 Oh no, let's plunge on. So, I'm an MIT alumnus. And I was attending an MIT conference in 2005, same year, and MIT's new president then, Susan Hockfield, announced that MIT was gonna solve the energy problem, or make a dent in it. And so I decided to join. And so I came back to

my partners here at Polaris and said, "You know, we do life science investing, we're diversified. We do life science investing, energy and, I'm sorry, networking, enterprise software. Why don't we do energy?"

05:05:54;07 My partners said, "Sure, let's go find some energy deals and go do them." So, I began working in energy to solve the energy problem, to provide the world with cheap and clean energy. But I wasn't the first Internet tycoon to decide to do this, Vinod Khosla, John Doerr, famous VCs, and many others, have all made a similar decision to shift from Internet, basically to get into energy. And then the question arose, "What standing did we have?" What standing did I have to invest in energy? So, I found a standing.

05:06:29;15 I decided to undertake a history project. And that it went like this: study the history of the Internet, which was a project over, I estimate, 62 years, to provide the world with cheap and clean information. And then from studying

that history, derive lessons for how we're gonna supply the world with cheap and clean energy. In other words, we built the infrastructure for information, now we're gonna build a new infrastructure for energy.

05:07:01;18 And sort of an underlying assumption of this is that it would be easier to teach energy to Silicon Valley-type entrepreneurs than it would be to teach entrepreneurship to the energy establishment, which is insulting to them. So, they're among my enemies. You know, the energy industry says, "What are you Internet people doing here making investments in energy? We know what to do." And to which my answer is, "Hey, guys, you've had it for the last 50 years and you haven't solved the problem, so get out of the way, here comes entrepreneurs from Silicon Valley. And we're gonna solve the energy problem."

05:07:34;04 So, then I decided, having been a pundit for ten years, I would continue that. And so I derived a talk based on this historical study. And I call that *Enernet*, and I've been

giving this talk every few weeks around the United States attempting to mine Internet history for lessons on how we're gonna actually end up with cheap and clean energy. And among the findings are that, you know, there was an Internet bubble, well, there's a global warming bubble.

05:08:05;28 This is a very annoying conclusion. You know, how do I know that there is a global warming bubble? How do I know that? Al Gore and I inflated the Internet bubble and it went boom on March 10th, 2000. Guess who's inflating the global warming bubble? Al Gore is back. He's doing it again. And it's gonna burst in the same way. We're all gonna get excited, we are all excited about green this and green that. And the global warming bubble is going to burst.

05:08:35;19 Now, does that mean the Earth's not getting warm? No, the Earth, the Internet was growing during the Internet bubble. But there's just a distraction there. What we need to focus on is cheap and clean energy. And this linkage

between, for example, climate change and energy is a transient linkage. If we solved climate change, we would still have an energy problem. And if we solved energy, we would still have a climate change problem.

05:09:02;14 So, they're not the same. They're not exactly the same problem. And so, I'm careful to focus on what I call EnerTech investing, energy technology investing, whose goal is to provide the world with cheap and clean energy for a variety of reasons, one of which is climate change. And so, I'm out giving this talk. And if you want my PowerPoints, I'm happy to provide them. And I change the PowerPoints each time I give the talk.

05:09:26;01 And ironically, this is the first PowerPoint presentation I've ever done. And it's ironic, because I was on the board of the company that developed PowerPoint and sold it to Microsoft in 1987 for $14 million. And it took me 20-some years to get around to figuring out how to use it. And now, I are dangerous. I am updating my PowerPoints

every time I give the talk.

QUESTION:

05:09:46;16 I think we would love to see that, and have a copy of that.

QUESTION:

05:09:53;01 Final question here, but we talked a little bit about what you did here at Polaris Venture Capitalists...

QUESTION:

05:10:06;10 But tell us a little bit, again, what you do here.

BOB METCALFE:

05:10:09;20 So, Polaris is a classic venture capital firm in that we invest other people's money in high-technology startups. Unlike many of the classics, we are highly diversified, though. We don't focus on a particular technology. So, we do anything which is a high-technology, high-impact potential company, drug discovery, medical devices, enterprise software, computer networking and now, energy, EnerTech, energy. So, there is about a dozen of us who make, there's 60 people here total, but a dozen of us are the investing partners.

05:10:49;06 And we have about 100 and, I'm guessing, about 150 companies in our portfolio right now that we are on the boards of them all, helping them grow. We provide them money and advice and hope that they become the next Google. They don't all become the next Google. In fact, none of them have become the next Google. But, you know, we may get lucky in the future. That's what we do here.

QUESTION:

05:11:10;13 Okay, what about, is there another chapter of this, in a couple more years, you retire, is there a fifth chapter for the career of...

BOB METCALFE:

05:11:16;22 I've attempted retirement three times and I've failed. So, I don't think there's going to be a retirement. But that is a fair question. What is my next career? 'Cause I've been at venture capital eight years, and my attention span is generally around ten years, plus or minus. So, we have our fifth, we're now investing out of our fifth fund, and pretty soon, we'll embark on our sixth fund, and that will

be a decision point.

05:11:44;15 So, that is, as you go to do a new venture capital fund, you're basically making a ten-year commitment to that fund. So, the question, since I'm 62 years old, I have to ask the question, "Do I want to be doing this until I'm 72?" That's the form of the question. I haven't answered that yet. But what else could I be?

QUESTION:

05:12:04;01 Enthusiastic about something.

BOB METCALFE:

05:12:06;07 Well, that's for sure. But what would it be? I don't know.

QUESTION:

05:12:11;26 Well, I hope you'll tell us...

QUESTION:

05:12:14;25 ...someday.

BOB METCALFE:

05:12:15;04 I just don't know. I just don't know.

QUESTION:

05:12:16;22 You don't know what it, what you want to be when you

grow up, right?

BOB METCALFE:

05:12:19;09 No. So, I have eight companies in my portfolio now, one we're allowed, generally our quota's one investment per year. Now my inclination is to do an investment every Friday, 'cause I used to write a weekly column. But my partners have convinced me that, "No, you do, you get to do one a year." So, I bet you that's a surprising number to you. That's a small number. So, after eight years, I have eight companies in my portfolio. And now I'm working on getting each of them to be the next Google or the next 3Com or the next Cisco. And it's very interesting work.

QUESTION:

05:12:54;09 Okay, Bob, I thank you. I think we've got it.