

Interviewee: Vinton Cerf
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Abstract

Vinton Gray Cerf is an American internet pioneer, who is recognized as one of "the fathers of the Internet", sharing this title with TCP/IP co-inventor Bob Kahn. His contributions have been acknowledged and lauded, repeatedly, with honorary degrees and awards that include the National Medal of Technology, the Turing Award, the Presidential Medal of Freedom, the Marconi Prize and membership in the National Academy of Engineering. In this interview, Vinton discusses his thoughts about "Fathers of Internet", his childhood, his study experiences, his career development and his opinion about the future.

03:39

BZ: So, um, at the very beginning and [what] we'll have to do is, I'll say, and, where we are for this interview, and then I'll have to ask you to say your name, and the birthdate, and, you know, your parents' name, where you attended your high school and then to. I know all this; Stanford, and then, um, you know all this. And then, we start. All right? Today is October 7th, 2017. We are very fortunate, and, to interview Dr. Vinton Cerf at Google, Virginia; Reston, Virginia.

04:19

VC: So my name is Vinton Cerf. I'm Google's Vice President and Chief Internet Evangelist. And my mother and father are... I'm sorry, I'm a little confused about exactly how, I thought you were going to prompt me through each of those questions. (BZ: I will; I will after that one there, well, right, after that one, I will). So let's start over. So, um, my name is Vinton Cerf. I'm Vice President and Chief Internet Evangelist for Google.

BZ: And your parents?

VC: My mother's name is Muriel Cerf and my father's name is my name, Vinton Cerf. Uh, they were both college graduates from University of Miami in Ohio. Um, but I grew up in Los Angeles where they moved after World War II ended. So I was basically a young man in the San Fernando Valley, north of Los Angeles.

BZ: Where did you attend to your high school?

VC: There is a high school there, called Van Nuys High, and it's a very unique place, because there are people who were deeply associated with the internet who also went to Van Nuys High. One of them is Stephen Crocker who became my best friend. He's

now the chairman of ICANN. Uh, the other one was Jon Postel who became the editor of the RFC (Request for Comment) series and essentially the Internet Assigned Numbers Authority for many years until he passed away in 1998. There are others who also attended Van Nuys High, much to my surprise. I learned that the current Secretary of the Smithsonian Institution, David Skorton, is also a Van Nuys High School graduate; a little later than I did. So it's a fascinating place.

05:57

BZ: All right, tell us [about] your college, and you know, where you attended PhD?

VC: So, after I finished my high school years, I enrolled at Stanford as an undergraduate in mathematics. Then completed my undergraduate degree there. I went to work then for IBM in Los Angeles for two years. But I realized after those two years, and I needed to go back to school to learn a lot more about computer architecture, about operating system design, programming languages compilers and things like that. So I enrolled at UCLA in the graduate program in, ah, computer science.

BZ: And because of your friends Steve Crocker.

VC: Steve Crocker introduced me to his thesis advisor Gerald Estrin and so Gerald became my thesis advisor as well.

BZ: Okay, um, among the "Fathers of Internet", you are the most visible, I should say-- a lot of media attention, a lot people remember you so well. So, according to your interpretation, who [are] those fathers of the internet, you think?

VC: There are literally thousands of them if you want to be honest and clear about it. The internet wouldn't be the scale that it is now if it worked for the fact that so many people wanted it to happen. But there were people who were around in the very earliest stages, uh, prior to the internet design, there was another network called ARPANET that was sponsored by the American Defense Department, the Information Processing Techniques Office of the Defense Advanced Research Projects Agency.

And they got the idea that they should find a way to connect computers together that were being used by computer science departments that were doing research for ARPA in artificial intelligence in general, uh, computer science. So those schools like MIT and Stanford and Carnegie Mellon, uh, kept asking for world class computers every year. And even ARPA couldn't afford to buy a new computer for every school it was funding to do research. So they said, "We're going to build a network and you'll have to share your resources." Of course, everybody hated that idea, but they decided they built the network anyway. And they chose to use the technology which is now come to be known as packet-switching. That technology was very different from, uh, the kind of technology that was used to build the telephone network which uses circuit switching. So this is probably not the right time to go into a great deal of detail about

the difference between the two. But you could think of packet-switching as electronic postcards, because postcards have a lot of characteristics just like packet-switching, the two **address** from addressing some content. So, the ARPANET was built, uh, by a company called Bolt, Beranek and Newman (BBN). The first node of the ARPANET was installed at UCLA, September of 1969, in the laboratory of Leonard Kleinrock, who was nominated to run, uh, the Network Measurement Center, where I ended up working as one of the principal programmers. Steve Crocker was there and led the project to do protocol development for the ARPANET hosts. Ah, Jon Postel was there as well and he eventually became the editor of the RFC series-- Request for Comments-- that Steve Crocker had set up in April of 1969 to document the work that was going on.

09:24

So, you would have to argue that people like Kleinrock who did the mathematical modeling of packet-switching using **queueing theory**, uh, Larry Roberts who led the ARPANET project for ARPA, uh, from, like, he would come down there from Lincoln Laboratory; Robert Kahn, who is one of the chief architects of the ARPANET, working at the time at Bolt, Beranek and Newman; Frank Heart and others who were part of a team of about 30 people who built the ARPANET. All of those people are kind of part of the historical origins of the, uh, of the internet, beginning with the ARPANET. Uh, so, they all have been, one way or another, received some visibility and credit. I would also argue, however, that the real origins of the internet come after the demonstration that the ARPANET packet-switching technology works. Robert Kahn left Bolt, Beranek and Newman and went to ARPA in late 1972. I left UCLA also in late 1972 to join Stanford University's faculty, as a member of both the computer science and electrical engineering departments. And, in the spring of 1973, Bob Kahn came from ARPA to my lab at Stanford and said, "We have a problem." And my reaction was, "What do you mean 'we'?" Uh, he said, well, the ARPA, uh, the Advanced Research Projects Agency has concluded that we should use packet-switching as a means of, uh, command and control to apply computers, to be part of the command and control system. Well, if we're serious about this, Bob said, we have to figure out how to do this packet-switching thing in mobile operations; the computers are going to have to be in the tanks and mobile vehicles. one kind or another. They'll have to be in aircraft and they'll have to be in ships at sea, because the Defense Department uses all of those kinds of equipment, in additions to fixed locations, which is where all of the computers were of the ARPANET. So we have to figure out how do we build a system that handles all those different kinds of requirements. So, he had been working on a mobile packet radio system, and a packet satellite system after he got to ARPA, and the question then was how do we connect the packet radio, the packet satellite and the ARPANET together to make it look like one thing. And so that was the problem that we worked on and in the end of six months or so, by September 1973, we had invented an architecture and the technology that would allow this kind of, uh, arbitrarily large number of packet-switching nets to be interconnected with each other in such a way that the host on all those different

nets thought that this was one uniform system, even though it wasn't. It was made up of a network of networks, and so in some sense I feel likely the real internet design comes at that period but it would not have happened if it weren't for the success of the ARPANET project in the years before.

12:47

BZ: So you go back, a little bit there, with the ARPANET [that] was first built up, you know, based on four nodes and **as we know** with two nodes, so that will not be considered the real birth of internet until TCP/IP?

VC: Well, I think that I have a real problem with that definition, because internet, the conception of the internet, is a network of networks, different kinds of packets switch nets all interconnected with each other. Uh, and, a internet address space that allowed a computer on one net to refer to computers on other networks. The ARPANET was one network; the computers on the system knew only one net; there was no way to refer to another net. So, the internet was precisely intended to deal with multiple networks connected to each other. And that concept didn't arise until the work that Bob Kahn and I did at Stanford. So, I accept very much that the ARPANET is part of the origins of the internet, and its success contributed tremendously to it. We wouldn't have done the rest of the internet design without the success of ARPANET. But I really don't think it's fair to argue the ARPANET is the origins of the internet given the definition of internet today is the use of the TCP/IP protocols. But it certainly figures very strongly in its, uh, in its ancestry, if nothing else.

14:17

BZ: Thank you very much! You know, I began to see the point, and where, where you come from, you know, um, that's what [it] is. But generally, you know, people agree four persons, including you, like your reservation, Larry Roberts, Leonard Kleinrock, you and Bob Kohn **and work as the** four fathers of the internet. Do you agree, or how do you think about that?

VC: Well, certainly there's no doubt that the four people had a great deal to do. But Steve Crocker, for example, led the network working group that led to the original host-to-host protocols for the ARPANET. No one else had any idea how to do that. All the focus of attention was on getting the network running; that's what BB&N was responsible for, that's what Larry Roberts is pushing for, but then what to do about the computers that were attached to it, because the network without the computers and edged devices wouldn't have been very useful. So, Steve gets huge credit for organizing this network working group and then this is why he's still a graduate student pushing for the host-to-host protocol design and then file transfer protocols in telnet protocols for remote access to time-sharing systems, uh, uh, he's the one who started the RFC series and so, Steve really deserves much more credit than he has historically been given, I think.

BZ: Do you think, kind of, he could be considered one of the fathers?

VC: I certainly, well, I think that he has to be considered one of the, to the, to the extent that we consider Kleinrock and Robbers to be part of the internet history given that they're real focus was on ARPANET and then Croker deserves huge credit, um, for the same reason because he pushed the protocols above the basic network level, and we certainly make use of what we learned from the host-to-host protocols in the course of designing TCP/IP

16:06

BZ: I'm thinking about some day and you folks certainly will win the Nobel Prize, you know.

VC: You know, the Nobel Prize isn't given to any branch of mathematics, and computer science is considered a branch of math, so...

BZ: I would like to say, the big social impact...

VC: Well, perhaps, but then the only, the only two prizes it might even come close would be the Nobel Prize for Economics and the Nobel Prize for Peace, and given the current state of affairs on the internet where there's this constant war with malware, it's not clear how peaceful this environment is, so I'm doubtful that we would actually end up with such an honor.

BZ: We read a lot about, and, you know, your talk and everywhere, but very few of dimension about your childhood. So how your parents influence and your career path, or how your, like, you know, like you mention, there, high school friendship with Steve Crocker eventually lead up to come to the UCLA. I believe there's, a lot of, some stories. So can you tell us like how, what your childhood look like, and what kind of boy you look like. I know you have a little, like hearing issue (VC: Yeah, yes), but, um, how, how, how that, and, you know, I don't know, a very young man...

VC: Well, we don't need to go back through 75 years of history. I was born in six weeks premature, and so we think that, uh, because I was put in an oxygen, uh, tank, an oxygen tank, uh, as has that when I was born. Some people think that the hearing problem that I have, which is the progressive loss, might have been caused by that. It wasn't very apparent, however, until in my early teen years. So, if we go back to my childhood, as I say, I grew up in Los Angeles in San Fernando Valley. Um, my, my father and mother were both college graduates. My father, who did very well in college, he was Phi Beta Kappa and I always felt like I was sort of competing to, to do as well as he did in school. Um, I enjoyed school very much. For me, it was always an

adventure to learn something new. And, so, even going back to the 5th grade, for example, where I remember getting bored with the mathematics that we were being taught. I complained to my teacher, who, and I said there must be more to this than, you know, addition and subtraction to multiplication and division and fractions and so on. And, he said “yes” and he handed me an algebra book from the 7th grade which I, uh, took and worked all the problems during the summer vacation and loved it. By the time I was 10, in the 5th grade, I got access to a chemistry set from my best friend across the street. His name was also Steve, um. And I, you know, did all kinds of experiments with the chemistry set, at some point, I think, we actually made nitroglycerin which was a really stupid thing to do. Fortunately, didn't blow up. So, we didn't kill ourselves during the process. But I was fascinated by all that. I read *Scientific American*; didn't understand all of it but thought I was going to be a nuclear physicist or something, and particle physicist. I loved mathematics and chemistry and did very well in high school during that period. And I was encouraged by my parents to, normally, to do well academically but to read broadly and read lots of books at home. So, my childhood was really, it was a very comfortable and very stimulating childhood.

BZ: What did your parents do as...

VC: My father, my father was, um, uh, ran a personnel management in training operation for North American Aviation, specifically, he was at Rocketdyne, the company that made the Saturn V rockets that did the Apollo program. And I got to work there and, in fact, one of the big benefits I had of my father's work in North America is that I had summer work at Rocketdyne Atomic International Space and Information Systems Division automatics. It worked in almost all the divisions of North American. I got to work on the F1 engines for the Apollo program, uh, analyzing the tests that were done to see whether engines would hold up until they ran out of fuel after which nobody cared what happened as long as they worked until with the Germans called ‘potentially’, which is ‘end of burning’. So, um, so that was a very fortunate connection. My mother, uh, was a liberal arts-educated, so she had Latin and Greek. And she was French Canadian, uh. She loved classical music which imbued me with a great love for that. Uh, she encouraged me to play cello, which I did for a while until I got interested in computers. And then I kind of steered off in the other direction. But my parents were, um, very, um, encouraging of my academic work in school.

BZ: Do they also a little bit dictate to, there, say, hey, you should read this, you should do this, or...

VC: No, no, my parents were not at all dictatorial. They simply encouraged me to explore my ideas and interests. And, I had access to books at home and libraries. This is, of course, way before the internet was built. So.

BZ: How many siblings do you have?

VC: I had two brothers. They were younger than I. One, about 5 years younger; and the other, 8 years younger.

BZ: So you look like a leader among the boys.

VC: You know, if you're the oldest, you, you go through whatever learning the career of your parents have about dealing with children. So, yes, I took some amount of responsibility for my younger brothers.

BZ: I sort of begin to envision, and, you are at school, is quite like the boy, easily interact with other people, and got friends and then also built rela..... you know, friendship like, and you know, you and Steven Croker there, and that kind of friendship you start from the high school and always last, you know, so long, so long. So, are you a very pleasant boy when you were very younger?

20:09

VC: Well, I was a little weird because, um, I was nerdy at the time. Uh, so, I wore a sports coat and a tie and slacks to school, and carried a briefcase. I guarantee nobody else did that. But I didn't want to look like everybody else, you know. So that

BZ: You start that kind of tie high school? Okay.

VC: Yes, I wasn't wearing three piece suits but I was wearing, you know sports coat slacks and tie. Because I didn't, this is my way of being slightly rebellious. I didn't, I didn't want to look like everybody else with T shirts and jeans and things like that. And so, that sort of work. And I was also in the reserve officer training program ROTC, junior ROTC in high school. And so when I wasn't wearing my sports coat in slacks and so on, I was wearing a military uniform and I enjoyed that, because I learned a lot from that experience as well. I never actually served in the military because of my hearing. But, at least, I learned a little bit about what that was about from my ROTC training.

BZ: Outside. and you know, you look a little bit different from other, other things, but inside and how, how, how are you different also from other boys at that time?

VC: Well, it's always hard to tell because you can never figure out what's inside somebody's head.

BZ: How you mingle with, you know, a lot of people said, okay, you need mingle with other kids,

VC: Well, I had many friends in high school. I mean, I and I've kept them, I mean

some of the friends that I've known for the longest now well over 50 years are from high school, more so than even my college years. And, so, I still very close to some of those high school friends.

BZ: That's to reflect your personalities somewhere.

VC: Perhaps, um, I, you know, I didn't find any problem participating socially (BZ: Okay) with the, with the rest of the high school students.

BZ: So, I'm thinking like with dress like that, and, the people will say, "Oh my gosh, that's a weirdo" oh, you scared girls away, or...

VC: Oh no, I didn't scare the girls away. I had, I had my share of the girlfriends tie, I was actually surprised because my chemistry lab mate was a girl who was also the student body president. And, I was pretty surprised that she was willing to date a nerd. But it turned out she was kind of a nerd too. It worked out very well.

BZ: So, you wear a formal dress. I don't know the country back at that time; could that possibly be more formal than some teachers in the high school? Or everybody wear,,,

VC: Yes, not, I think that the teachers didn't, male teachers, anyway, didn't always wear ties. Uh, I think actually hard to think back about that. Some did. Um, I think this was part of my way of showing respect, I think, to dress well. (BZ: Respect for teachers? Or learning?) The teachers, the teachers. I, uh, I certainly feel that way here in Washington where I live now for 41 years and when I show up in a congressman's office, senators' office or the vice president's office, it would never occur to me not to show up properly dressed. I think that's a sign of respect.

BZ: Yes, is that, like, you know, you sort of like inspire your two brothers dress like you in some way?

VC: Not at all. They were very much more informal than I was. But they were both elected student body president in their, in their high school years. So, they clearly had a close touch with, with their, uh, cohort, uh. So, everybody does things a little differently.

25:56

BZ: You know, I'm teaching at university, too. I saw a lot of young people make friends. I know someone make a very good friends, and, their friendship last very long. They may not be very popular but they are sort of like everybody were saying.... What they say is, they always, and, make friends with the best people around them. Do you think kind of, you are sort of fitting to that categories?

VC: Well, let's see...

BZ: You don't want to easy to make friends with anybody

VC: But I'm, I'm pretty easy to get along with, on the whole. Um, the classes that I was in were usually the advanced placement classes. You know, you should think for a moment back because the, uh. Russians launched Sputnik on October 4, 1957. The response in the US, apart from shock, was to increase the level of advanced placement, uh, science, technology, engineering, mathematics in high schools, in particular. And so, when I entered high school, at the beginning at the beginning of 1958, um, I took all of the advanced math and chemistry and biology and so on. Classes, some like the, the cohort of students that I was with, were all the ones that were most academically capable. And so, and so we, we resonated well together, at least I thought so. I mean, I'm sure they thought it was a bit of a nerd and I turned out I was the class valedictorian in the end. And so, I had a very good grade point average. But, nonetheless, as I say, some of my best friends are the ones that I met in high school and we've stayed in touch all this time.

27:35

BZ: So, that's naturally, you would go to college, you want to go to Stanford and not about the East Coast, some MIT, like other people do, Harvard, Princeton or, so how, how you decide to go to somewhere close?

VC: Well, this is an interesting story. Because when I was 13, I would have been in 8th grade. And my father had a friend who worked at RSI International. At the time, it was called Stanford Research Institute. And, I was invited up to, uh, to, by my father's friend, to go visit the Stanford campus. So, we went on to the campus. I met some of the professors, I remembered 8th grade. So, I'm some ways away from graduating to go to college. Um. and I was convinced, once I got into the campus, that I really wanted to go there. It's a beautiful campus, people I met were smart, and they were, you know, uh, energetic and enthusiastic. However, it was expensive in relative terms, you know. Looking back on it, of course, the numbers are really almost comical, the, the, uh, annual tuition at Stanford in that time was 2,500 dollars. Today, it's more like 50,000 dollars. But, by good fortune, the North American Aviation had a scholarship program that you could compete for. So I competed for a four year scholarship in one, about 10,000-dollar scholarship to Stanford University. So, I was able to afford to go there.

29:00

BZ: Good. So, I want to go back a little bit there. Like the Stanford Research Institute, very well-known. So, you as a 8th grader, that's 4 years away from college. You got impressed by what?

VC: Well, several things. First of all, first, uh, the person that I met with, my father's

friend, was a chemist, and so I was enjoy just talking with him about chemistry and what he knew. I was still very excited about chemistry at the time. Um, and, on the Stanford campus, I was still, but mostly I met with people in the mathematics department, and, um, I had been so fascinated by mathematics., I had done well in high school. In fact, I ended up having to take calculus classes at UCL A while I was still in high school, because they didn't teach it in high school in those years. So, uh, I would commute to UCLA in the evenings to take calculus classes while I was still in high school. So, I think, I resonated with the, with the, uh, Stanford professors that I met, who were very enthusiastic about having another student in a mathematics program.

BZ: So, the major reason, after that, after you're, um, you know, undergraduate and you begin to work?

VC: At IBM?

BZ: At IBM, there. So, um, so how, how is that? How? What`s your work?

VC: Well, this was an interesting thing, because I went to, uh, Los Angeles to be interviewed, and IBM hired me, uh, in 1965 just after I graduated from Stanford. Originally, I was going to be working at Los Alamos. I was going to install 360/91, which was the top of the line brand new, new computer architecture that had been developed by Fred Brooks. I didn't know that at the time but Fred was the guy who led the 360 development, so 1965 was the year when these things were launched. So, I was all excited about that. And, in a few days before I was supposed to go to Los Alamos, they called and said, "We want you to stay in Los Angeles and run a time-sharing system at the Los Angeles Data Center on Wilshire Boulevard". But it was an IBM 7044 machine, which is sort of cousin to the 7094, but it's previous, uh, technology, wasn't, it wasn't the 360. And I remember feeling kind of disappointed. On the other hand, time-sharing was fairly new then; it had been invented around 1961 in MIT, John McCarthy being one of the key proponents, um, by 1965, now, IBM is running a commercial time-sharing system at the LA Data Center. So, I became a systems engineer for that. And it was a good thing for two reasons. First of all, I got to dig very deep into the operating system; it was all assembly language, big, fat listings and 132 column paper. I would take those listings home and read them to try to understand how this system worked. And I learn it well enough that I even found some bugs that I was able to fix. But the more important thing about having stayed in LA is I met my wife in November of 1965, which is just a few months after I had started work in IBM. And just to show you how things, how well things have gone, we celebrated our 50th anniversary last year. So, we were married in 1966.

32:20

BZ: What did she do at that moment?

VC: I'm sorry?

BZ: What did she do at that moment?

VC: While at the moment she's retired. But, but she had been an interior designer. So, uh, and her job was what's called rendering, which is to show someone what the, uh, restaurant or the office is going to look like in the interior. So, if you couldn't understand the blueprint and you couldn't quite figure out what the carpeting and the draperies would look like, Sigrid, my wife, would do a perspective rendering of what it's going to look like. So, she's an artist. And this was to help the client understand what it was that the interior designers were proposing. So, she did that for several years until our first child came along in 1973.

33:09

BZ: How, how did you meet?

VC: Well, it's interesting. She was, um, almost totally deaf when I met her, uh, in... She had lost her hearing in 1946 when she was 3 years old from spinal meningitis. So, uh, she was a lip reader. But she still wore one big body aid from a company called **San Atone** to give her some low frequency sounds, but she couldn't hear any high frequencies, and that's where all the intelligence is in speech because all of the consonance come out in high frequency. So, she had to lip read, but she had this, uh, hearing aid dealer that I also used. By this time I was wearing two hearing aids. I've been wearing them since I was 13.

BZ: So, you began to have hearing issues at, after 12?

VC: Twelve or 13 years old. I started wearing hearing aids, because it was clear that I was declining and I needed the assistive technology. So, it just happened by accident that we both have the same hearing aid dealer, and he simply asked me to come in on a Saturday and asked her to come in on the Saturday, and then introduced us and left. And, and then he closed the store. So, we're standing out on the sidewalk on Wilshire Boulevard. And, I'm thinking, gee, she's really cute, maybe we should go have lunch. So, we had lunch. And, that's when I discovered what she was an artist. And, so, the Los Angeles Art Center is just a block down the street, so after lunch she said, "Why don't we go and look at some of my favorite paintings?" Her favorite paintings. So, she took me to see some of her favorite paintings. And one of them was a Kandinsky. And I looked at it for a while, and I said you know this looks like a floating green hamburger. And, at this point, if this were a movie, this would be one of those things where the audience would get to choose, okay, this is the decision point, is this guy completely philistine is hopeless, and I should forget him, or is he reparable. Fortunately, she decided I was reparable. And so, we, uh, continued dating after that.

35:20

BZ: You must've dressed very nicely on that day; is that true? Also, very...

VC: To be really honest, I don't remember. It would have been a Saturday,

BZ: You do not ask her?

VC: You know, and let's see, I'm, well, hm, it wouldn't normally, normally I was working for IBM at the time; you wore suits, white shirts, tie to work. I would say IBM style. (BZ: Okay) So, all the time, I worked at IBM.

BZ: Did you ask her later on, see, you know, you met a young guy, anything on that particular day what attracts to you, you know, what did she say?

VC: Um, I think she was very enthusiastic about her work, and she was really pretty, and you know, that's an important part, a really nice person.

BZ: Okay, and what's her first impression about to you?

VC: Well, apparently, it must have been pretty good. Because she completely forgot that she was supposed to take her mother to the airport, and so her mother missed the plane, and so they were looking ahead in time this was not a good first step with my **potential** future mother-in-law, um, but whatever it was, she must have been interested enough that that she forgot what she was supposed to do.

BZ: Wow, I can't imagine, you know, how attractive it there is, so how you explained later on, and to her mom about that kind of...

VC: I actually don't know what she said, um, she may have just told her she met some guy and, and forgot, uh. But her mother never... was nice about it (BZ: Understanding) because she didn't get after me when we finally did meet, um, her mother didn't come and shake finger at me and say, you know, "you messed up my airport trip".

37:10

BZ: That's quite serious in those days and the airplane travel (VC: It's true) that. There are more important. So, um, I would like to say, um, you know you begin to make friends starting from high school, and develop the kind of friendship there. How is your friendship, you know, issues at Stanford and you know at IBM and all the way to UCLA. You make more friends, um, intellectually, or, or how, how things look like, your life?

VC: So, I think I didn't socialize too much with my IBM colleagues. Um, and at

UCLA, however, that was different as a graduate student and those of us who were working on the ARPANET project were really quite close. And there were others, um, who were part of the project at other universities. In fact, I think it was a very interesting, um, decision that was made at ARPA. Normally, every year, the principal investigators, people like Kleinrock, for example, would meet together with other principal investigators and ARPA would review their progress. But they decided that maybe the graduate students who were actually doing the work ought to meet each other without the principal investigators. And, so, they brought about two hundred of us to Allegheny, Pennsylvania for a weekend or three days or something like that. Then, we got a chance to tell each other what we were doing. And, that group of people bonded over that period of time. We have stayed in touch with each other, uh, in the 50 years since. Uh, some have passed away, of course, but we have known each other for a very long period of time. Steve Crocker was there, uh, with me, I think, Postel was there; Jeff Wilson was; there were lots of other people who, eventually, became part of the, uh, internet activity or things associated with it. So, uh, some of those people ended up at Xerox Park, which was another center of, uh, important innovation, uh, in the San Francisco bay area in the early 1970s. So, so, there was this, um, combination of social and technical connection that the ARPA community created. And those friends have stayed connected for many years since.

39:36

BZ: I'm trying to envision you, you know, pretty good at making friends within your similar research background. How about outside the genre and are you also a social butterfly at Stanford or UCLA?

VC: Well, it's, I guess we have to parse this in time periods, I suppose. Uh, I have very eclectic interests; I read widely. I like history, biography; I read science fiction a lot. And, so, um, I have known and made friends with a pretty broad range of people. At this stage in my life, uh, I've made friends with some fairly significant movers and shakers in our, in our community, outside of the technical community. Uh, so, I think that during the time at UCLA, I was just mostly focused on getting my dissertation done and working on the ARPANET. At Stanford, I was focused very heavily on the internet, and so didn't socialize all that much, but we had friends in the faculty. And some students of mine have become lifelong friends, some, especially the ones who worked very closely on the TCP protocol specifications, like Yogen Dalal and Carl Sunshine. Uh, some of my high school friends like Richard Karp, not the one of Berkeley, but the one at Stanford, um, have been friends ever since high school. I brought Richard into my laboratory to be, he broke the first TCP and BCPL. Uh, Judy Estrin, who is Gerald Estrin's daughter, my thesis advisor, was my graduate student at Stanford. We've stayed friends ever since, along with her two sisters, Margo and Deborah. And, of course, Jerry Estrin was a friend until he passed away as was his wife. So, so, you know, I have had these wonderful, um, connections with people who are outside of the, you know, my mainstream professional work. A few

other examples **peter** acquaintances, not I don't want to overstate some of this. But, um, Gene Roddenberry's son Rod Roddenberry and have become acquaintances. I worked with his mother Majel Roddenberry, uh, when she was doing, um, some television programs that Gene Roddenberry had invented and passed away. She resurrected those programs. So, I'm, I'm, I'm still a great fan of classics, music. And so, when I can, I go to concerts, and listen to classical music on the radio.

BZ: I don't know the country back then; I assume, and, you get along with your professors well, too, because of your personality, you know, how formal then will you be, do you have your hierarchical levels—oh, , you are grad students, you are undergrad students. How is your interaction with your professors?

VC: I think I've done along very very well with, with all of them. One, in particular, at Stanford, I remember very well, Harold Bacon, who has also passed away, but he taught the calculus classes at Stanford. And he was an old school gentleman, and didn't brook any nonsense in the class, if you came in bare feet, he threw you out of the class, if you brought a newspaper and you told you to leave and read the newspaper, and you're not in my class to read newspaper. On the other hand, he was a spectacularly good teacher. And I stayed in touch with him after I graduated. Overtime, of course, the graduate students get older, and eventually, you can't really make much of a distinction, so, some my graduate students have become prominent in their own fields and businesses. Uh, and I consider them co-equals. During the time that I was a graduate student, um, I felt, uh, uh, almost, well Jerry Estrin, in particular, was almost like a paternal substitute for me. Because while I was a graduate student, my father passed away, and, uh, Jerry really became a kind of surrogate father for me as I was going through my dissertation work, and we stayed very good friends, of course, all the rest of his life.

44:00

BZ: Okay, so, um, we just talk back like the most important achievement in your life and all other people are thinking TCP/IP, definitely, as your highlights of your career. Um, but when you look back there, I see a very rewarding career, a lot of achievements you already made even after that wonder, so what was the highlights of your career? You, you really think TCP will be...

VC: Well, certainly, uh, getting the TCP designed and, and then developed was a big deal, and, of course, it's turned into this gigantic global internet, Running the internet program for ARPA was a big change for me, one that was a huge opportunity because it gave me much more scope. I ran the packet radio and the packet satellite program, and the package security programs, in addition to the internet program, while I was ARPA for those six years. It's hard to beat that six years' experience, especially, because you're writing, the one writing the checks, right, so you could say to people, yes, you can do this and I'll pay for it. So that was an important part of my career. Then, I went into the private sector to work for MCI, and built something called MCI

mail, which is a commercial email service in 1983, which frankly, was probably 10 years too early. There existed email services at that time; there was a CompuServe, for example. Telenet, which was started by Larry Roberts, when he left ARPA at TeleMail, uh, TimeNet, which was run by Bob Harcharik, uh, had OnTime, which is, uh, another, uh, commercial electronic mail service. But each one of them was a separate independent, um, wall gardened. They couldn't interact with each other. So, I did MCI Mail for Bob Harcharik, who was taken from TimeNet to MCI, and he hired me to do MCI mail. We put that together in about 9 months at the beginning of 1983 to September 27, turned it on. What was interesting about that project is that we, we broke a bunch of rules about email, basically, allowing people to compose emails that would be sent either to other MCI Mail recipients or other email recipients of other, we anticipated, connecting to other email services, or to telex terminations, or to postal addresses. And, so, if somebody composed an email with a postal address destination, we would reprint it, put it in an envelope and mail it, in addition to the other electronic deliveries. That was very advanced for the time. Eventually, fax was also included. So, I was pretty proud of that effort; uh, it persisted from 1983 to 2003.

And, ironically, I left, um, MCI in 1986 after about 4 years of work on MCI Mail and rejoined Bob Kahn, who had left ARPA in 1985, and started a company called the Corporation for National Research Initiatives (CNRI). So, I was his first vice president, and probably, first employee. Uh, and we worked together for 8 years on applications of internet technology, so things like digital libraries and knowledge robots and mobile code and things like that. For, for that period of time and then MCI hired me back to put them in the internet business in 1994, and it was the same guy Bob Harcharik who hired me back. Uh, they had hired him back and to get us into this internet business. So, uh, my, um, associates and I built two internet systems for MCI; one was a commercial the internet service called MCI Net, and, and the other one was for the National Science Foundation. It was called the VBNS-Very Broad Band Network Service. It was for experimental research purposes. And the reason we had to do both of those is that NSF had shut down its NSFNET backbone, which I had started in 1985. So, they decided by the time 1995 rolled around that you could buy internet service, so, if you were university, you didn't need to be on the research network; you could just buy internet access. But some of the universities still wanted to do research in networking, so they sponsored this additional network. Eventually, that morphed into Internet2, which is a non-profit organization of a bunch of universities, which exists to this day (BZ: Yes) and operates at very broadband the internet service.

48:48

BZ: Let me go back a little bit there. MCI Mail is also called the MCI post office?

VC: Well, I don't think so. I mean, we called it MCI Mail; was the product name; it was an electronic post office.

BZ: Okay, yeah, all right. I read something there... were making... so, um, I feel like, you know, quite amazing about, you know, your later, after you, you invent these ones, are so amazing, like, you never stop there but you keep working on those things there, and so many examples like that, wonder, for example, ICANN, um, 1999 to 2007, that's a long time, and, you know, you, you join the board member, chairman there for so long, and then CEO of ICANN? 2000? And you...

VC: I wasn't, I wasn't the CEO at that time; I was just the Chairman. I'm, in, starting in 2000. So, the CEO, the first CEO was Mike Roberts, who had been, uh, I think CIO of Stanford University for some time; was also engaged in other academic institutions, non-profit institutions. And we hired him to be the first CEO of ICANN. And there was, a series of them, as you probably know, I, uh, I would say three or four. Some of them served during my period as Chairman of the board. Ironically, Steve Crocker is now Chairman of ICANN and has been for the last several years, and has served ICANN since about 2003, so, almost 14 years, much longer than I did, uh, in various roles in finally now as Chairman. His term will end as Chairman at the end of the 2017. So, uh, interestingly, he and I have crossed paths in many ways. I mean he went to ARPA before I did, he left then I went to ARPA; he lives in Bethesda; I live in McLean, Virginia, and we still see each other.

BZ: You live in McLean?

VC: I live in McLean.

BZ: Okay, all right, that's my best friends...

VC: So is Bob Kahn, by the way.

BZ: Bob Kahn there, okay.

VC: And Bob's company, CNRI is here in Reston, and my office is here in Reston Town Centre. This is one of those small world phenomenon where people who have known each other for nearly 50 years are still interacting and still close together.

BZ: By the way, we will interview Steve Crocker tomorrow.

VC: Wow, wonderful.

BZ: So, uh, we already set it up, you know, maybe at his house, I think, at his house or his office, I forgot.

VC: Well, it's probably his office.

51:27

BZ: His office, yeah, um. Coming back there, you also were involved in the Internet Society. (VC: That's right) So that's the... that's before or after? Internet Society is much older than ICANN.

VC: Yes, that's right. The Internet Society was started in 1992. In the, in 1988, uh, while I was still at CNRI, I was, uh, running the, uh, secretariat for the Internet Engineering Task Force and I'd hired Phil Gross to do that. He's been with the former chairman of IETF. Now he's the executive director of the secretariat. But around that time, I was told that the NSF contract that supported the secretariat would be ended somewhere around 1990 or 1992 or something like that. And, so, my immediate thought was, well, we have to create some means by which funding can be provided to support the secretariat to do the work of the IETF. IETF had been around since 1986, roughly, its first meetings were from that time, the internet was turned on in 1983. So, the IETF was part of the originally, as part of the Internet Activities Board which was started after I left ARPA by, um, my successor, um, Barry Wessler. I'm sorry, Barry? Wow, why am I drawing a blank? Barry? What's Barry's last name? Well, we'll have to come back to that. That's embarrassing. Winer! Barry Winer; here we go. There were several Barrys. Barry Wessler was was, uh, **Larry Roberts' sidekick** in ARPA in the early days of ARPANET. Barry Wessler, I'm sorry, Barry Winer came to ARPA as my successor and started what was called the internet; he called the Internet Activities Board. There were 10 task forces involved, one of which was the Internet Engineering Task Force. That, um, eventually, had its first, um, formal meeting of about 20 people in 1986, as I recall. So, anyway, the NSF said we're not funding the secretariat anymore, and so I told Bob Kahn that I thought we would need to create a non-profit organization that could solicit funding to support the secretariat work. And so the Internet Society, uh, was modeled after the Association for Computing Machinery, a professional organization, uh, it would solicit funds, it had a magazine that had published that **Tony** Rutkowski edited at the beginning. Um, we were housed inside of CNRI for a while. I announced the formation in June of 1991 at, uh, an INET meeting. This was a conference that had been started by Larry Landweber from Wisconsin and been going on for quite a number of years. It was an international conference about internet. And so, I asked Larry Landweber whether I could ingest his INET conference into the Internet Society concepts, so be our primary annual meeting. And he agreed to do that. So we announced it would start as of January of 1992. And the Internet Architecture Board, which, uh, also, uh, got started while I was still at ARPA only was called the Internet Configuration Control Board when I was running it. But Barry changed it to Internet Activities Board, and eventually, became the Internet Architecture Board. Anyway, they all raced to become members of the Internet Society and Jon Postel, one he wrote his check faster than everybody else, and so, he was the first official member of the Internet Society. So that got started in, in order to support the IETF secretariat. Of course, it's now grown dramatically since that time celebrating its 25th anniversary, uh, this year, and it is now supported by the operation of the dot org top level domain in the domain name system. They, they established the Public Interest Registry-PIR, which runs the dot

org top level domain and supplies about 50 million dollars a year in funding to the Internet Society. When I started it, I ran around with my tin cups begging for, for support. So it's grown substantially since then as has ICANN.

56:13

BZ: So, I began to see, you know, correct me if I'm wrong, doing tech work heavily, now, gradually move on to public service. um, when start, when did you start to do more, like a more public service, instead of just tech work?

VC: Well, it's always been a part of the picture. I was on the ACM Council, for example, in 1991 (BZ: Yes), uh, and my objective at that time was to establish a fellows program for ACM. IEEE had a fellows program that ACM didn't, and I thought, well, they should, professionals in computer science should have a similar kind of capability to advance professionally. I would say that the Internet Society was probably the first big, uh, effort from my point of view for public service. ICANN certainly represents public service from 2000 to 2007 or 1999 to 2007. Uh, I served **blader** as the president of the internet, of the Association for Computing Machinery for two years, and is past president. Now, for the last couple of years, I've been the co- chairman of the awards program for ACM. We, we hand out substantial amounts of money-- well over a million and a half dollars of awards-- every year. So, I continue to, to take those tasks on. I still have a technical interest, however. For example, in 1998, I joined the Jet Propulsion Laboratory as a visiting scientist, and I've been there ever since, working on Interplanetary Extension of the Internet, so that is another episode in the story of internet expansion, in this case, outside the planet, all way to Mars, and perhaps further, as new missions are launched to the outer planets.

58:09

BZ: I'm going to ask, you know, your Google experience. But before that, I just realized that media attention, public attention, sort of like, you know, became, like in the search light and suddenly find any your work, things like in the 1970s, there. So, why do you think that suddenly, or when do you think that public attentions come to your works, not just you and, you know, so many other people were talking about the ARPANET and you know, eventually, internet?

VC: First of all, I think the internet was not a very visible thing, except for those of us who were in the academic in research environment or in the military; that was described earlier, was initially, started by the Defense Department in order to do command and control. I think one small note that worthy of your attention is that, at the time we were doing this project in the 1970s and in the early 1980s, we recognized that this was going to have to carry more than just data, that it would have to do video and voice as well. And, so, we were working on real-time communications, including radar and things like that, or you know, the command and control as part of the internet project. The internet gets turned on officially in January

1983, it continues to grow overtime, primarily in the academic community and then, um, Tim Berners-Lee comes along at CERN in Geneva. Starting around 1989, he begins thinking about and working on what became the World Wide Web, um, and he announced the World Wide Web in December of 1991. He released the software, uh, that went with it in the same way that Bob Kahn and I released the design of the internet without any, any constraints of any kind, no intellectual property constraints. So, Tim follow suit did the same thing. Not too many people noticed, uh, that release in December '91. But two guys at the National Center for Supercomputing Applications, Marc Andreessen and Eric Bina, built Mosaic, which was a graphical user interface browser. Everybody noticed that. So, it was downloaded, you know, millions of times, it seems like very quickly after they, um, released it. Because people suddenly could see the internet as a, um, uh, uh, almost like a magazine, because the images it has, eventually, video and sound and everything else nicely formatted pages. Of course,...

BZ.: That was my first browser, and that kind of earth rolling...

VC: Yes, yes, exactly that little animated logo. So, what's interesting about it is the, the introduction of html allowed people to create content fairly easily, lowered the barrier to content production. So, millions of people decided that they wanted to share what they knew with other people through this medium. That got a huge amount of attention. And, so, the World Wide Web application sitting on top of the internet, made the internet much more useful. And, so, the two technologies were mutually reinforcing, in some sense. And we saw a similar phenomenon, by the way, um, some years later in 2007, when the iPhone was introduced that had internet capability in it, that suddenly made it possible for people who were, no matter where they were, to get access to the internet content. And, so, the mobile phone makes the internet more useful and the internet makes the mobile phone infinitely more useful, because all the content of the internet is available on that mobile phone. So, uh, those two technologies came together, and again, increasing each other's value, as usual.

1:02:01

BZ: But going back like, you know, those years there, do you already foresee the internet could be used by individual persons, like the daily use instead of, not just scientists?

VC: Well, you know, a trivial answer to that would be: No. But that would be wrong; turns out we actually had a pretty good idea of what was possible. And I can explain why. In the 1960s, Douglas Engelbart, who is at SRI International, had developed the, um, hm, on-line system, which was in some ways the WorldWide Web in a box. He invented the idea of hyperlinking between documents; uh, he invented the mouse in order to point the things on the screen with the bottom to click on, he had a five-fingered keyboard, um, and he did a demonstration in 1968. If you do a Google search on the net, you'll see the "Mother of All Demos". And the 50th anniversary of that

demo is coming up next year, and I'm sure there'll be some celebrations. But Engelbart had this deep belief that computers could be used for non-numerical knowledge work, and the collaborative efforts would be mutually reinforcing. J.C.R. Licklider, who was running the first, the first director the Information Processing Techniques Office, resonated very strongly with what Engelbart was saying, and supported his work at what was called the augmentation, human augmentation, augmentation, ain't that, and it was it was about augmenting human capabilities at SRI. So, uh, so, we had access to that system during the ARPANET period. Email gets invented in 1971, or at least network email by Ray Tomlinson. Ray is at Bolt, Beranek and Newman. And he realizes that you, you could send a file from one machine to another, and leave it in a place where a person could find it, and so the idea was to leave it in the directory where it was associated with that user. So he's trying to figure out "How do I tell the file transfer program which computer to send the file to and where to put it on that computer?" So, we needed the user name and the host name. And, so, he said, well, how do I separate those? And he looks at the keyboard and the only character that isn't in use at the time for something else was the @ sign. And user @ host seemed like a very natural way of saying send this file to that user on that computer. So he does network email; he announces this idea. Everybody goes crazy, even Larry Roberts ends up writing a program to manage the email, uh, you know, file by file, uh, and that gets augmented by other people. So, the, the, the point here is that by the time the internet project gets started in 1973, we've already had several years-- 4 years-- of experience using the ARPANET, and seeing how it's useful as a community. We even discovered social, uh, interactions, because some of the email distribution lists that we started just after email gets invented, network email gets invented, were, um, a distribution list that was called SciFi-Lovers. We were all a bunch of geeks; we all read SciFi- and arguing over who were the best authors. And then, another mailing list was called Yum-Yum, which was a restaurant review. The mailing list from Stanford University is looking at the restaurants in the Palo Alto area which, eventually, expanded, uh, to a larger geography. So, we're already seeing the social capabilities and potential of both the ARPANET and the internet. So, a point to be made is that we had clearly understood not only potential but also recognized that it had to be global in scope, because it was supposed to be for the US Defense Department which has to operate everywhere or anywhere where it might be called. And so our thinking was global to begin with, and it was multi-network to begin with. We understood that new technologies were going to come along, communication technologies we wanted to sweep them into the internet, so the IP layer protocol was designed to not know very much about what was going on underneath. And it was also designed to not know what was inside the packets. So, the internet protocol layer has no idea what the applications are. And that's why the internet has been capable of taking on so many new applications, because it wasn't designed for any particular purpose, except to move packets from one place to another; their interpretation takes place at the edges of the net.

1:06:51

BZ: So, I want to go back and, you know, clear one anecdote, you know, I read is, I know when you and Bob Kahn designed the TCP/IP and whose name should go first, let's go to a paper, right, so you toss the coin...

VC: We just flip the coin and I got lucky. But, but for all practical purposes, Bob and I had two hands on one pencil writing that, that document. In fact, it was done, uh, at the, uh, what was then called the Hyatt Cabaña Hotel on El Camino Real, across the street from **Dynes**. Uh, and then so there's a plaque in the hotel now next to the elevator. It says: In September of 1973, Vint Cert and Bob Kahn, wrote the first... No, we didn't flip a coin; we wrote the first design of paper, design that described how the internet worked.

BZ: So, when you flip the coin there, you got thrilled and because that's certainly go in your favor. So, you know, how about Bob Kahn's, you know, reaction to that?

VC: Well, we both agreed that it didn't matter whose name came first, and if you think about it, it's alphabetical order.

BZ: Yeah, yeah! But do you think that really doesn't matter?

VC: I don't think it matters...I don't think the, the fact that my name is first in that paper gave me any greater recognition. Bob is well-known and well-understood as the co-inventor of that TCP/IP protocol.

BZ: So, among the, um..

1:08:24

VC: I mean, let me, let me remind you, that the National Medal of Technology went to both of us, the Presidential Medal of Freedom went to both of us, the Prince of Asturias Award went to both of us, the Japan Prize went to both of us, and, so, I don't think that that anyone misunderstands Bob's role, key role in this project. In fact, he started the internet **in** project at ARPA and invited me to be part of it.

BZ: Okay, so, actually there's, uh, you, among the four of you, you know, very closely, um, worked together for so many years. Is there any like tension, frictions and, you know, occasionally, comes out of the, get into the way?

VC: Well, you know, it's pretty clear that I feel strongly that internet gets invented at Stanford and ARPANET gets evolved, starting at UCLA. I think, maybe, Leonard Kleinrock sees this is the more continuums and so does Steve Crocker, and, you know, to be fair if the ARPANET hadn't been successful, then we wouldn't have done the internet. And then, there is clear connection there. Um, I think that for some people, though, whose primary contributions were with the ARPANET, there is a problem because nobody knows much about the ARPANET, the general public knows

the internet but not ARPANET. And, so, people who would like to be better known as, as part of that history, feel a little bit left out because the unknown is part of the internet, they are known primarily as ARPANET. So, they, they, they want to be connected and would like to blend those things together. And that's not an unreasonable point of view. The guys at Xerox PARC would also like to argue that they have had role to play which they did, the PARC Universal Packet idea was being developed at the same time that I was doing TCP at Stanford. And I had people at, from PARC, who were participating in my seminar, some graduate students who were also working summer times for example or part time at Xerox PARC. And there was a lot of interaction there as well.

1:10:40

BZ: All right. Next I'd like to ask your experience with Google. You join them 2005 as VP, all these years, um, you know this may be, um, you know chronologically, um, so, uh, your roles at Google, so how, how you, how you start and, you know, to begin to work with them?

VC: So, I was brought in as part of the research department and originally reported to Alan Eustace who was a VP or a Senior VP for both research and engineering. Eventually, the company grew and I was, when I joined there were 5,000 people; now there are 70,000 people. So, during that period of time, Alan had found it necessary to structure the organization; split off research; had, um, wow, ...easy as, I'm blanking again on somebody's name. Alfred Spector. Phew! Yeah, so, Alfred was brought in from IBM to be the VP of research. And, so, I reported to Alfred during his tenure. Alfred, uh, left Google a few years ago and John Giannandrea became the head of research and now also artificial intelligence in search and everything else. So, I report to John Giannandrea now, um, so, during this time from 2005 to the present, uh, the substantial piece of, of my effort has been on policy, because the internet has been at the crux of a lot of policy debates network, network neutrality, uh, questions about fragmentation of the internet, censorship issues, uh, the freedom to invent things, permissionless innovation, and all of these things have had the international and global, um, debate around them, the internet governance forum started as a result of the World Summit on the Information Society. There were tensions because the US government had a very a contractual relationship with ICANN during the time that I was Chairman. All the way up until now, October 2016, last year. So, uh, I had a role to play on Google's behalf with regard to policy and articulating our view, which is that openness was very important part of the internet's capability and utility. So, I have that policy stuff. I have a role in standards making activity, because some of my engineers are very involved, very high levels now, in the IAB, in the IETF. So, that's been part of this whole 5 year experience, uh. Because I'm in the research department, I've been free to stick my nose into a lot of different things that are going on, just to try to be helpful. So, inside the company, um, I'm, been free to, uh, interact with people who are doing research or developing products. So, most recently a lot of my effort has been focused on the internet of things, for example, (BZ: Right) which is a

huge new aspect of internet's evolution with many billions of devices likely to come. And that's driven the IPv6 initial initiatives. We ran out of IPv4 address space in 2011 and we knew this was going to happen way back in the mid 1990s which is why IPv6 was developed as an alternative to IPv4 and I've been pushing this for 20 years. Now, with the internet of things, it's clear that we have to move everything over to IPv6.

1:14:27

BZ: Do you also give advice to some other projects like Project Link? Project Loon?

VC: I was pretty, well, I haven't contributed much to Project Loon. I have worked with the Project Link team, which is now morphed into a joint venture called CSquared, I believe.

BZ: That work. Some people were cast doubts on the balloon thing, you know.

VC: Well, some, some people thought the balloon idea was loony which is why they call the Project Loon, but now it's an operation. And, so, and they found some really fantastic ways of getting the balloons to **voider** where they need to provide service disposed as circulating around the globe at 50 thousand feet.

BZ: I do understand you mentioned several times about connectivity, and especially, the next four billion people get connected with the internet and then, you sort of, like, encourage different ways to get people connected there; it is...

VC: Well, certainly, anything. I mean the, the, um, people talk a lot about the next billion users (BZ: Yes). I'm worried about the last billion users. I want to make sure that we got everybody up on the net. So, how do we get them up on the net in an affordable and sustainable way? How do we get policies to be adopted by countries around the world to encourage investment in internet infrastructure and the creation of internet based applications? How do we get content in local languages that are useful to people? So, I've been pursuing at any avenue I can find, normally to encourage this sort of investment and policy, but also to find technologies that will drive costs down and make things affordable.

1:16:07

BZ: But that's also the most difficult, you know, group of people to get a connected, the last billion.

VC: The last billion will be the hardest, that's right.

BZ: Back in 2015, you were mentioning about a digital dark age, um, to my understanding in those days, you were mentioning about so much data loss, you know, so many things that loss because of our infrastructure, of devices we use. Do you still hold the same idea like, you know, you, you define what's digital...

VC: Yes, I'm still very concerned about what I'll call the loss of digital content, and there are several different factors involved, the medium that we store bits on may not last as long as some other technologies, for example, vellum, which is sheepskin, for example, or goatskin; some of those vellum documents have lasted well over a thousand years, some of them two thousand years. And if you can still read Greek or or, or, or Latin, you can still read the content. But think about, uh, five-and-a-quarter-inch floppy disks, three-and-half-inch floppy disks, um, DVDs and CD-ROMs and now Blu-ray and so on. Uh, sometimes you can't find a reader to read the medium even if you still have the disks. Or, maybe, you have a hard drive, except it has a certain format of plug and no computer in existence knows how to interconnect with that either physically or logically; what's the control function for that? And, so, storing bits away in various media turned out not to be very long-lived. So, I'm worried about that. I'm also worried about the fact that you might need software to correctly interpret the bits that you've store. So, if it's a spreadsheet that you stored away as a file, even if you can read the bits, if you don't have a program that knows what the bits means, you're not going to be able to read.

BZ: But how about clouds? Could be a solution, so everything's in the clouds there, so, including like a software?

VC: Well, certainly cloud gives us a potential platform, especially, with virtual machines running old operating systems, running old applications. So, I think there is a possibility there. On the other hand, just think for a moment about a web page. Okay, suppose you've got the html web page and you can pull it in to a cloud-based system, then the question will be, whether all the references that are on that web page still resolve. Well, maybe, they won't, because 10 years from now on, some of the websites will have gone away. So, the preservation of all that content is a huge challenge. Not only because of the application software, but because the, uh, url is becoming unresolvable. This is what Brewster Khale was worried about in the internet archive in San Francisco. So, he's trying to copy as much of the net as he can. But I'm looking for 500 years, 2,000 years ability to preserve digital content. And I'm hoping that people will begin to recognize how critical this is. We have mobile phones with these really high quality cameras in them. We take literally trillions of pictures a year. The last number I heard was one and a half trillion photographs taken every year. Where are those going to be stored, in what format will they be stored, what about the metadata associated with them, how will we preserve that for a thousand years? And the answer is not clear. And, you know, clouds are the current mechanism. Fifty years ago, it was time-sharing machines, right, big time-sharing mainframes. Now, it's clouds. But this is 2017, what will happen in 2117, just a hundred years from now? What will this be, and I don't know what it is, but it probably isn't what we have today. And, so, we have to think very hard about how to project standards that can be, um, recognized and used a hundred years from now or a thousand years from now.

1:20:10

BZ: But thank you very much for clarifying this. I was, um, I was not realized when I first to read this one. Actually, I think we should have more concern instead of less concern. I know.

VC: It's, it's an enormous problem. And, and people are just not aware of it, until they lose what they were relying on. You know, they have a computer, has a bunch of files in it, they have all the pictures there, everything's fine, then suddenly the computer stops working; (BZ: Yes) now what?

BZ: And, you know, as we know, and you go to a very strong magnetic field and some data could totally disappear and not recoverable.

VC: Now we've only been talking about personal stuff, think about scientific information, think about all the data we are collecting from telescopes, and from the Large Hadron Collider, from the IceCube down in the South Pole, and all these at the LIGO Project. All that content is really important for scientific progress, especially the one that hang onto this stuff so that we can test against new theories. Well, we don't recognize, we have a file full of numbers, but where were they? Were they temperature? Were they pressure? Were they something else? What was the metric that was used as a Fahrenheit or Centigrade? All that metadata has to be available in order to use the data that we were collected to test against new theories. If we don't preserve all that stuff, we're in a real trouble.

1:21:32

BZ: Definitely, that's you know, that's my next question. So, we're talking about the future, we already have 50 years of internet now, in the next 10 or 50 years, let's, don't say a 500 years, what things got changed? So, how, how do you think of the internet will change the...

VC: Well, it's very hard to to project 100 years into the future, huh. Jules Verne seem to have done that pretty well, but not too many other people. So, we can, we can see the sort of the early stages right now, higher speeds, use of higher frequencies, even more elaborate uses of optical fiber about hollow optical fiber, which is now being researched at the University of Southampton. Um, so all that is almost certain to... frankly, I'm hoping that the interplanetary extension of the internet will succeed; it's been standardized by the Consultative Committee for Space Data Systems, which is the UN agency. All the space-faring nations are free to make use of that software, again, has been given away freely, it's available and source for, source forage or get help or both. Um, so, so, you can sort of see that stuff evolving over the next decade or two. Uh, in terms of, of, of the far future though, uh, it's very hard to tell; you can see some interesting efforts now with quantum communication. There are some very very interesting Chinese efforts; of recently, they were announced, they're using quantum key distribution through the satellite, that's about 1,200 kilometers orbit;

that's a pretty advanced result.

There are people who are interested in trying to literally move quantum information, uh, from one point to another in the network, in order to do distributed quantum computing. That's a pretty elaborate, uh, and challenging piece of technology and maybe, that will evolve over the next several decades. A lot of us are still very curious about this, um, spooky action in the distance that Einstein thought was pretty bizarre, and that's the notion that, that if you have quantum-entangled particles, when you separate them and then you measure one that you know exactly the characteristics of the one that's distant, because the two are, are correlated, and yet, nobody understands why that correlation is maintained over with significant distances. Distances that are too far apart for the speed of light to account, for the, um, uh, correlation between the states of these two entangled particles, so this is the Bell's Inequality that people keep demonstrating over and over again. There must be something going on that allows that to happen without being limited by the speed of light delay; nobody knows what that is, and if we ever figure it out, then we will probably have more basic understanding of how the universe works than we do today. And it's conceivable, based on speculation that hundred years from now, if we're understood this well enough, then we may no longer be limited by the speed of light delay, so that suggests some pretty advanced networking, uh, in particular interstellar kinds of communication might be feasible. And, today, it isn't very feasible because of round trip times for years.

1:24:57

BZ: Um, you also, uh, start like People-Centered Internet with Mei Lin Fung.

VC: Mei Lin Fung, that's right.

BZ: And, you know, she started finance, where, I forgot, where, um, MIT or something, yeah.

VC: Uh, I'm just thinking we're starting to run out of time.

BZ: Quick, quickly, um, you know, uh, what was the project about, is that like your vision of

VC: So, what Mei Lin, uh, argues and I agree with is that we should be asking how can we make the internet more useful for everyone? Just building more internet making it affordable doesn't make it useful. And, so, her point is, let's ask how can we make it more people-centered; how can we ask ourselves, may, having made the investment of putting internet into people's hands, how can we make it more, uh, capable of helping them in their daily lives; how do we provide more information of global use? So, maps and things like that. Also, we have to care about local languages.

Um, we have to find ways of letting people who are local to some particular area, uh, contribute information that will be of use. So, her focus of attention is how to measure the utility of the internet? Can we see whether it improves health, for example? Does it improve the GDP per capita, does it improve the other things that make our lives comfortable, can we argue that the internet's presence helps us build more resilient power-generation in distribution infrastructure, are there other benefits that that we could quantify from making internet available? Certainly, the sharing of content, sharing of information in theory, can be quite powerful. One thing I've learned from our experience with YouTube at Google, is that young people, you go to YouTube, when they want to find out how to do something, they don't even bother with a Google search, they go right to the YouTube and say how do I do X? And sure enough, there will be a video showing you how to do that. And, so, this, this generation in sharing of knowledge is becoming quite manifest in that video environment. The nice thing about this is that even if you can't read, you may still be able to benefit from a video showing you how to do something. And, so, we're starting to see a new medium of learning, showing up. Think about the Khan Academy, for example, which is showing people how to do math or mathematics. So, this medium is becoming a very powerful tool, and it overcomes language barriers, among other things, or, at least, literacy barriers.

1:27:43

BZ: Right, and, you know, sometimes YouTube can cross, you know, language barriers and they get things down and show what it is. Um, um, you have been to China quite, quite, many times there; you do go there every year, or...

VC: Uh, well this year I've been twice, turns out. I don't necessarily get there every single year but in the last decade or so, I guess, I've been there.

BZ: When did you go there first time?

VC: I think the first time I went to Beijing, I've been in Shanghai, these were ICANN meetings, typically, .and, and then I would lecture Qinghua, for example.

BZ: What year was that? The first time you go to China.

VC: I don't remember. (BZ: Okay) Do you remember? (Unidentified voice at the interview: 2002), (BZ: He remembers) 2002. Thank you, your memory is better than mine. I thought I might have been there even before that, but... well no, no. I think you're right, (BZ: Okay) right. It would have been Shanghai; do you think? Because that was the first ICANN meeting in Shanghai.

1:28:45

BZ: So, I began to say each time you go to China, you went there and your attention is

going higher and everybody cheers you. Do you feel the same way? You know, at the very beginning, I'm not sure.

VC: Well, I don't know. I mean, I certainly have met increasingly senior people in the Chinese government on those visits. (BZ: Right) At one point in one of the early visit early this year, I met with the one of the, I assume the vice Chairman of the CEC, for example. So, uh, but my interest has always been in, uh, sensing what's happening in the research and academic sign of things. China has done some extraordinary things from the scientific point of view. I mean, setting aside their rapid development of, um, uh, space exploration, for which the country deserves a lot of credit. There's also very deep work in biology, for example, in genetics and understanding microbiology, uh, cellular, uh, uh, processes and things like that. Uh, I have one colleague from the National Science Foundation who did her dissertation work in China, uh, and now services as one of the liaison from the NSF to, to the Chinese research establishment. So, uh, just watching the economic evolution there, uh, and, of course, the presence of the internet has been dramatic over the last decade; now what, 750 million people are online, that's twice as many as there are in the United States, and more than there are in Europe. So, uh, and also growth of companies there, things like, uh, Alibaba, for instance, and Baidu, uh, and Wechat (BZ: Right), among others. And, so, there's been this fascinating, um, growth of internet application and penetration in China, which I found very interesting.

1:30:45

BZ: Um, how to think the role of China it will be, the tech world, the role of China play and indeed in the tech world in the coming down...

VC: It's very visible, uh, if you read any of the current publications in networking, for example, you will find a great many Chinese names on papers that are published. If you look at the standards making activity for many people coming from China were participating in helping to create those standards. So, the country is, um, becoming quite visible on the technical side.

1:30:45

BZ: But at the same time, the government has blocked the free flow of information a lot, you, you...

VC: Yes, so, um, this is troubling. On the other hand, as a, as a country, uh, it has allowed a hundred, are typical rules to make its own rules inside the country. This autonomy is considered an important element of diplomatic agreement. So, we don't necessarily have to agree that the suppression of access to information is a good thing, but, but it is within the scope of the Chinese government's authority to do that. I've always thought that, uh, historically, uh, if you look at the, uh, regime changes in China over the last couple of thousand years, I'm not a Chinese historian obviously, but things that I had been told are that the each time you had a different dynasty, it

was preceded by a peasant revolt. And, I suppose that the Chinese government knows that, and so, then, when they look at the Arab Spring, when they see how social media cause disruption, the natural reaction is: We don't want that here. (BZ: Right) So, I can understand the motivation behind this attempt to control, what people see and do on the, on the net. I'm not sure that that, that will succeed forever; the desire of people to communicate and to know is very powerful.

1:32:50

BZ: That's what we usually say and sometimes you walk two steps at front and you have like more steps come back. He [referring to someone present at the interview] actually got quite an interesting question here. We know and you get along very well with other people, and especially your best friend like that Steve Crocker or Bob Kahn; he would like to know and do you have some disagreement and sometimes, you know, I'm, I'm a little angry at you or something, did it ever happen?

VC: Good friends always have disagreements of one kind or another, so, Bob and I have had our disagreements about technical things, usually. We discovered something in the early stages of internet design, though. When we found ourselves arguing, we realized that there might be a reason for the argument, and it turned out that the models that we had of the thing we were arguing about turned out to be different models. And, of course, if he's arguing based on this model and I'm arguing based on a different model, the two of us are not going to make any sense to each other. So, we've discovered very quickly that if we were in disagreement, we would stop. And say what model are you using, uh, to base your argument on, and if we discovered that the models were different, first we worked out what model we were going to use to have the discussion, then we would have an argument that it was, at least was, was based on the same model. And, so, there are times when we we've learned very quickly to resolve those kinds of disagreements based on the fact that we have different models.

1:32 : 50

BZ: So, that's actually go back to the godfather's famous line, "nothing personal, everything's about business". And, he [referring to someone present at the interview] also has another question, is this really want to know a little more about Jon Postel, um, you know we could no longer interview him. So, how, how, what, what's your memory about this person, and, let us know.

VC: Well, Jon was, was our resident hippy. First of all, we didn't know him. Steve and I didn't know him when we were in high school. He was in the class, class after Steve Crocker's.

1:34:21

BZ: He's a little bit senior?

VC: No, he's younger (BZ: He's younger? Ok). Steve is younger than I am (BZ: Okay), so I'm the oldest of the three.

BZ: But you were in the same grade?

VC: No, no, no, we, we were, each of us in three different classes. Steve was in the class after mine and Postel was in class after Steve. (BZ: Okay) So, Steve and I knew each other because we were involved in the math club and we became very good friends even though I graduated before he did. Uh, neither of us knew Jon Postel while we were in high school. And he, he, he was sort of an odd character, who was, you know, it was a group. I don't know if he had a beard when he was in high school; probably, no, that would have been forbidden. But by the time he got to UCLA, 4 years later, uh, he had a beard, wore sandals and, and was sort of a hippie-like character. Uh, smart, and, uh, passionate, but also soft and gentle, uh, loved the outdoors. He was a person who would go trip seeing to Yosemite, for example, backpacking and things like that. He really, in spite of the fact that he had this very important role in, in the technical evolution of the internet. Uh, he was still very drawn to basics, humanitarian things and the outdoors. So, um, he was always a trusted party, he was; didn't ever seem biased one way or another. He would, he would make decisions based on her fact but not based on either opinion or feelings, and, so, he was, uh, a trusted person in our community. You know, all his life, it certainly, all the period that since his UCLA time, he'd actually worked, after UCLA, he worked in a number of different organizations, eventually, also at SRI, um, especially with his responsibility for the domain name, managing the domain names (BZ: Right, right) and the RFC, you know. He didn't invent the domain name system that was Paul Mockapetris. But he participated with Paul in the evolution of the domain name system, while he was at ISI—USC Information Sciences Institute.

1:37:22

BZ: How he ended up to be single-handedly managing those kind of domain names?

VC: Well, at the time, it wasn't as hard to do it as it is now, and it was still an experiment. The, the, um, RFC series starts in 1969, and if you look at the, um, **rated** which RFC **were being** produced in the, in nineteen, early 1970s, it wasn't very high. Today, of course, it's hundreds of them a year. Um, so, so, it wasn't an overwhelming task to do that. The network wasn't all that big, and so keeping track of who had been allocated addresses and so on, that's not all that hard. So, he had a notebook that he kept manually for, for quite awhile. Uh, he also had help from SRI International, uh, that literally, physically, published the RFCs. There was an early period when they were on paper before everybody could get access to them online. So, Jon had some help to do what he was doing, um, Joyce Reynolds was his colleague at USC/ISI when she and Jon both did a lot of the editing of the RFCs in the early stages. Bob Braden, who was another colleague, who did the first TCP for 360s at UCLA and then moved to RSI, uh, was also, um, working, helping Jon with the **IANA** functions.

And when Jon passed away, he and Joyce Reynolds did that work together. So, it wasn't it, wasn't an overwhelmingly big task in the early stages, because it was still experimental. But, by the time 1983 rolls around, and we turned the internet on, it starts to get bigger. And, by the time, um, about 1996 comes along, now it's serious business. We are in the dot boom period. And, in fact, USC/ISI is getting nervous about Jon's running the domain name system, because they're worried that people are going to sue the university for some, you know, thing that Jon did. And so Jon was looking for a way of moving that whole operation out of ISI and institutionalizing it somehow. And there was a two-year period of debate on this subject. There was a group called the Internet Ad Hoc Committee that was trying to figure out how to institutionalize the, uh, plan of functions. Jon was even thinking of putting in an organization in Switzerland to do that. And, remember again, this is in the, in the mid-1960s, mid-1990s as the internet boom is taking off after the IPO of Netscape communications which drove prices up through the roof. So, the consequence of that is, um, um, that the White House, uh, reacted, and the Congress reacted to propositions that the some important authority about the internet be placed outside of the US in Switzerland. So, uh, um, Ira Magaziner was instructed by President Bill Clinton to get control over this problem. That's where the green paper came out and the white paper came out, and that's where ICANN gets created to respond to the white paper. So, that was Jon, ultimately that was the solution was to create this institution. The sad story is that Jon died two weeks before ICANN was inaugurated.

1:37:22

BZ; So, he sort of maintained that kind of hippy lifestyle all way to the...

VC: Pretty much.

BZ: Ok, that's interesting.

VC: We are over time

BZ: Yes, very good, you know, thank you so much, and we are going to like to make a movie out of you. And then, maybe, later on, we'll talk a bit more. I know today's at the time is really not there. How do you think about the idea; we want to...

VC: You know, I feel like awkward about it.

BZ: The film is not like and you know just dramatic types, it's sort of like documentary.

VC: Documentary would be OK; the dramatization, I think, would be a terrible idea. But, you know. I mean. we've seen those already in past with Facebook and things like that, but, but a documentary...

BZ: Thank you so much for your time

