# VINTON G. CERF
# ORAL HISTORY

## COMPUTERWORLD HONORS PROGRAM
## INTERNATIONAL ARCHIVES

Transcript of a Video History Interview with Vinton G. Cerf, Ph.D.
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## Early Years and Growing up in California

DSM: Let's begin at the beginning.  Tell us when and where you were born, and tell us about your parents.

VC:    I was born on June 23, 1943 in the Yale Hospital in New Haven, Connecticut.  I was 6 weeks premature, which caused a lot of difficulty in those days.  So I didn't actually come home from the hospital for a while. My father was off at World War II.  He was in the Navy. My mother was living at that time with her father and her mother in New Haven.  So I sort of started out on the east coast.  My father had trained in public service, along the lines of liberal arts, and my mother had a general liberal arts education as well.  They met in college in fact.  So by the time the war was over in about 1945, when my father returned, I think there was a brief period where the family moved to Tennessee and my father worked in the Tennessee Valley Authority.  Then his uncle, who owned a hardware manufacturing company called Hollymade Hardware in Hollywood, California, invited my father to come and work there.  So the whole family moved out in 1946 to Los Angeles. So I essentially grew up in Los Angeles, in the San Fernando Valley north of LA, for most of my early years.

DSM: Did you know your grandparents?

VC:    Yes I did. I didn't know my paternal grandparents, because they passed away when I was very young.  I'm not remembering exact dates now, but they may have passed away not very long after the war was over.  So both my father's mother and my father's father passed away very early on. Maybe my Mother's side has better genes because her father outlived two wives and passed away after having married a third time. He was something like in his 80s.  I did not know my maternal grandmother. I was too small so I don't remember her, but I do remember his second wife and his third wife, both of whom were very lovely women.  So I did know my grandparents on that side of the family.

DSM: Were they living in Connecticut?

VC:    It was interesting.  My mother comes from Montreal, Canada.  She was born and grew up there, but then became a naturalized citizen and moved to Connecticut at some point.  I don't remember whether she went to Chicago first, but they ended up in Connecticut.

So she had relatives in Montreal, and my grandfather moved back to Montreal with his third wife, who was French, so we visited in Montreal regularly. After my step-grandmother passed away in Connecticut, my grandfather married a third time and moved back to Canada.

DSM: Do you have brothers and sisters?

VC: I have two brothers. One named David and one named Douglas. The older of the two passed away about 5 or 6 years ago at a very young age. He was 46. He had childhood diabetes, a very damaging disease. It does a lot of bad things to your body. My other younger brother David, also has that same childhood diabetes. They both have had pretty serious medical problems of one kind or another. I'm fortunate that I don't have any symptoms.

DSM: It was very unusual for men to have college degrees in the 1940's. I think it was less than 10% or 5%, and it was even more unusual for women to have them. Both your parents had degrees?

VC: Both my parents had 4-year college degrees. They were at the University of Miami, and that's where they met. In fact I think they met because my father used to teach driving classes and my mother was one of his students.

DSM: So in 1946 you moved to California.

VC: To California, to Los Angeles…

DSM: And you started grammar school in 1948, 1949?

VC: Let's see, I would have been 5 at that point. Yes, that sounds about right.

DSM: Did you learn to read before you went to school?

VC: Boy, do I remember? It's funny, you would think that you would remember when you learned to read. I don't. But I'm pretty sure I must have been reading by the age of 5 or 6, because I've been an inveterate reader and constantly had my nose in the book. In fact my father used to bug me about that. He wanted me to go out and play baseball or football, or something, but I said, "It's more interesting to read."

DSM: California in the early 1950's must have been an extraordinary place to grow up. Tell us what was it like being a kid growing up there at that time.

VC: The San Fernando Valley was a bedroom community for all practical purposes. You would commute out of the San Fernando Valley, and of course there was no 405 freeway linking anything.

So you had to take Sepulveda up over the hills, or Topanga Canyon, or one of the others. For me it was interesting because my recollections are of a fairly intellectual community, believe it or not.

The schools I went to had a lot of enriched classes. So the classmates that I remember were all very interesting people. They were interested in science and math and history. There was a lot of intellectual interaction that took place. I look back on that now and I hope that kids today can have something as rich as I feel I had in Junior High and High School especially.

## Chemistry Sets and Rockets

DSM: Was there a best friend or best rival early on?

VC: I actually had a number of very good friends. The fellow across the street, a guy named Steve Carlson, eventually went on and got a Ph.D. in physics and worked on Stanford's linear accelerator program. I didn't even know that for a while. It's one of those things where you lose track of somebody, and find out later what they have been doing. So, Steve Carlson and I used to have a great old time around age 10, playing with the chemistry set, which back in the 1950's had a lot more things in them than the chemistry sets you can get today. We had things like powdered magnesium, powdered aluminum, and sulfur and glycerin and potassium permanganate. Glycerin and potassium permanganate are hypergolic, that means that when you pour them together they burst into flame. We used to build these great volcanoes. You would take a plaster of paris thing and you would drill a hole down in the bottom of it. Then you could plop a capsule full of glycerin and potassium permanganate down in the bottom. Then you'd pour in all this powdered magnesium and aluminum and all this other stuff and basically create a thermite grenade. You know, eventually the gelatin capsule would dissolve and the stuff would mix together and you would get this explosion coming out of the volcano. It was great!

DSM: There seems to be a tradition of blowing things up among the group. Gordon Moore tells a very similar story. I understand you also used to make rockets.

VC: Yes, from match heads. We were really stupid. I mean, looking back on this, how could we have been so dumb? We'd take these 30-0-6 shell casings, they were about that long, and we'd fill them all full with match heads. We'd tear off the things and put them in and then we'd go and light it! We would stand like 18 inches away, and there were several occasions when the thing would blow, and we never knew where it went. We had no idea. No one was hurt but the more I think about it, the more I think, "Boy, oh boy, were we stupid."

## In Search of "X"

DSM: I like to ask about teachers who've made a difference. I heard stories about this Tomazewski

VC: Mr. Tomazewski was my fifth grade math teacher and I loved that man. I got so bored with 5th grade math that I went and complained to him. I said to him, "Isn't there anything else?" And he said, "Yes," and he handed me a 7th grade Algebra book. I fell in love with Algebra. It was wonderful. I spent the whole summer working every single problem in the book. Frankly I liked the word problems the best because they were like little mystery stories. You had to figure out who "x" was, and I was always curious to find out what's "x" going to turn out to be. I still love word problems. To this day, give me an algebra word problem, and I'll have a great old time with it.

DSM: But not geometry?

VC: Geometry had its attractions because you felt good when you finally got to the QED part, but somehow it didn't feel quite as pointed. Figuring out that you could prove that this angle equals that angle, didn't give me the same satisfaction as figuring out what "x" was, because it didn't seem quite as practical. But I enjoyed the reasoning part of it, which is probably one of the reasons why I've enjoyed being a programmer, because you have to go through the same line of thinking.

## Science Fiction and Judy Garland

DSM: You said as a youngster you did a lot of reading, and I gather you had three favorite titles. Well, two titles and a category. One is *The Boy Scientist*. Tell me that story.

VC: This was a Christmas gift from one of my cousins. I was interested in science anyhow, so I got this thing and I just sat there on the floor and I read it. I don't think I went and had any dinner or anything. I just sat there and read the book. It just talked about all kinds of scientific experiments that you could do, and it talked a little bit about physics and astronomy and chemistry and biology.

DSM: The real stuff. It wasn't taught like a Tom Swift novel.

VC: No, no, no. This was a serious book about science for people who were 10 or 12 years old, and I enjoyed very much reading that. It persuaded me that I really wanted to be a scientist of some kind.

DSM: What are your earliest sci-fi memories? I know you're a big fan.

VC: Well, that's interesting. I read an awful lot of Heinlein, who was publishing in the 1940's and 1950's. I remember reading things like *Red Planet* and *Storm Trooper*. Was it *Star Troopers*?

DSM: Starship.

VC: *Starship Troopers*, right. I read a lot of Bradbury, but I didn't like his more recent stuff as much because it seemed to drift off into fantasy kinds of things as opposed to nuts and bolts. I particularly liked science fiction that was focused on real physics, and trying to extrapolate what we know into some rather alien environment, but still come to the right conclusions.

Hal Clement is another. It's a pen name, but Hal wrote a book called *Mission of Gravity*, and *Ice Planet.* There were about a dozen of them. They're wonderful. He gets into the minds of the aliens and tries to describe interactions between a human and an alien from each of their perspective points of view. Additionally, his settings are all very carefully thought through in terms of chemistry, physics, and so on. Very attractive.

Another one is Robert L. Forward, a Cal-Tech scientist who's done some phenomenally good work. Particularly one called something like *The Time Masters*, because it's a time travel story. I always like time travel stories because they get you all tangled up and you have to sit there and figure your way out. What's good about Robert Forward is that he actually tells you at the end in the appendix about how you can actually do the time travel. There are some relativistic physics that suggest that it is possible to do it if you can move around in the vicinity of an extremely dense object where gravitational fields are extremely high. I don't pretend to have enough physics to even say it's right, but I remember being mesmerized as I read through Forward's description of how you build a time machine.

DSM: Speaking of sex, you also fell in love with Judy Garland about this time.

VC: I did indeed. *The Wizard of Oz* was a wonderful movie, and my mother had copies of the original Oz books from the 1900s. Those were on the bookshelf and I read them all. Then whenever my father would go away on a trip he made a point of bringing back another Oz book for me. I always looked forward to that. And of course the movie came out in 1939 and when it was revived, it must have been around 1955, because I remember being 12 years old or something, and seeing *The Wizard of Oz* for the first time. Judy Garland was such a wonderful actress. I had a crush on her for months.

## "The Trouble with Tribbles"…and Alligators

DSM: Do you remember when we marked the transition from when we gathered around to listen to the radio to when we began watching television?

VC: Absolutely. We would listen to the radio regularly. I remember a show with a character who was up in the Yukon.

DSM: Sergeant Preston.

VC: Sergeant Preston of the Yukon and his dog King, (makes sound of wind blowing.) So we'd listen to that and the Lone Ranger was on the radio too, but then television came in. I think we got one around 1951 or 1952. It was one of those odd, round-shaped tubes, but we were all completely mesmerized by that. I remember particularly a puppet show called, "Kukla, Fran and Ollie." There was another one. Do you remember one that had a "Cecil the Seasick Sea Serpent?" Bob Clampett was the puppeteer. It might have been called "Time for Beanie." Anyway, at some point or other my father met this fellow and he mentioned my name and the names of my brothers on the television show. Of course, we were all completely blown away by this. I also remember watching Howdy Doody and all the characters that were on there, Buffalo Bob and Clarabelle and so on.

DSM: Was "Cecil the Seasick Sea Serpent" the root of your interest in alligators and crocodiles?

VC: No actually the alligators and the crocodiles were a more recent affectation. When I first came to MCI in 1982, I was responsible for engineering something called MCI Mail. This is a commercial electronic mail service, and at the time there was a lot to be done. We had 9 months to build this thing, and it felt like I was up to my rear end in alligators. I remembered the joke about the fellow who's sent off to drain the swamp. They call him 6 months later and asked, "How are you doing draining the swamp?" He says, "Well, let me explain. When you're up to your ass in alligators, sometimes you forget that your job is to drain the swamp." I felt like I was in that state for quite a long time and I thought I ought to get to know these creatures better, so I started collecting them. Now I have about 55 or 60 around the office and there are some at home.

They're also here to control the tribble population, which has begun to multiply in this office. That was a side effect of my most recent employment with WorldCom. One of my engineers' daughters makes tribbles, and one day I came into my office and there's a tribble in the middle of my desk. Nobody is telling me where it came from! The next day there's two, and the next day there's four. You could tell that this was going to be troublesome after a little while. Eventually somebody finally told me who was making these things, but I decided to increase the alligator population in order to keep the tribble population in check.

DSM:  And for graduate students 300 years from now, tribbles are characters from what?

VC:    Oh these are all from the television series, "Star Trek" and from a wonderful episode called "The Trouble from Tribbles."  Spock makes the observation that these little tribbles don't do anything but eat and reproduce. That's all they do.

## From Van Nuys High to Rocketdyne

DSM: That's great.  Now high school, you were at Van Nuys High from about 1957 until 1961?

VC:    Actually it was a three-year high school.  Junior high and high school were split into three years each.  So it was 7th, 8th and 9th in Junior High at Robert Fulton, and then from 10th, 11th and 12th at Van Nuys High.   That would have been 1958 to 1961.

DSM:  So from just past Sputnik in 1957 to John Kennedy in 1961?

VC:    That's right.  In fact the Sputnik was actually a very significant event for me. Sputnik comes in October of 1957, and our launch of a satellite comes something like January 31, 1958.  In fact it is confirmed in orbit just past midnight as I remember it.  That was the night that I graduated from junior high school, because I was in mid-year. Back in those days they actually allowed people to graduate from school in the middle of the year.  They had 2 different classes for the same class year, the winter class and the summer class.  So literally the night that we launched our own satellite, was the night I graduated from Junior High School.  That was a very memorable event.

DSM:  Can you talk with the extraordinary group of people you went to school with at Van Nuys High?

VC:    My best friend at Van Nuys High was a guy named Steve Crocker, whom I met in 1959.  I would have been in 11th grade and he was a member of the math club.  We just found many, many common interests together.  Steve went on MIT for a while then came back to UCLA for his graduate work.  He was at Van Nuys High School at least for the 11th and 12th grades, and he and I did a lot of things together that eventually involved computers.  He'd gotten permission to use the computer at UCLA from Michel Melkanoff, who was at the time, the head of the department.  The computer was a Bendix G15 computer that was fed with paper tape.  This would have been around 1960.  I would have been in the 11th grade.  I think Steve was one grade behind me, about a half a year behind me, but he got permission to use the machine.  So on the weekends we would go to UCLA in order to program this thing.  Except one occasion, we would get there and the engineering building would be locked.

So to solve this problem we would climb up to the third floor through the window and we would get in, and we would open the door and tape the lock, and we were never caught. I didn't ever say anything to anybody about it until a few years ago because I didn't know if we were really breaking any laws or not, but we did have permission to use the machine. So at least we weren't in there doing things that we hadn't been given first order permission for.

There were other people at Van Nuys High who became notable later on. I didn't know them at Van Nuys High, particularly Jon Postel for example, who was very instrumental in the development of ARPANET and Internet. I didn't know him when we were in high school because he was a class or two behind me, but Steve and John and I eventually wound up at UCLA as graduate students together. Steve and I knew each other well, but we got hooked up with Jon and others at UCLA beginning around 1967. [Robert Redford and Stacy Keach were also Van Nuys High School graduates but in classes before mine].

DSM: Did you have summer jobs?

VC:   I had a number of summer jobs when I was in high school. All of them were, with one exception, with North American aviation, something that is now called Rockwell International. My father was at Rocketdyne at that point. Rocketdyne was the company that made the big F-1 engines for the Apollo program, and the H-1's and some of the other small attitude control rockets. He was eventually in the personnel department doing management training and development for the personnel groups. So I worked at Rocketdyne. I worked at Atomics International. I worked at Space and Information Systems division. I worked at another down in Orange County, Autonetics, but I worked in about all the divisions of North American Aviation during the summer months.

DSM: Tell us about your time at Rocketdyne.

VC:   One of the things I remember most vividly about working at Rocketdyne is that the test facilities were up at the Santa Susana Mountains in the Simi Valley, north of the San Fernando Valley. On occasion I would go up there, because my job during the summer was to do analysis of the testing of those rockets. We would do non-destructive testing in order to try and figure out how long they would actually last in use. So occasionally I would go up for test firings. You cannot imagine what it is like to stand 150 yards away from a one-and-a-half million pound thrust engine as it is being fired into this gigantic waterfall to try and cool everything off. The hills rattle, your body's shaking, and I'm all of about 18 years old at this point, and what I remember thinking in 1961 was, "What might it be like 20 years from now? Will we have regular rockets going up and down? Will there be spaceports?" I honestly hoped that that would be the case. There was a certain amount of naiveté there, but here we were testing this enormous engine. They would cluster these things, 7 ½ million pounds of thrust, on these Apollo boosters. I had dearly hoped that by 20 years time we would be doing regular shuttles so to speak. Not that I imagined the shuttle design. It didn't quite work out that way, but almost.

DSM: Well President Kennedy promised about that time that we were going to put a man on the moon.

VC:   That's right, we're going to put a man on the moon and bring him back safely.  So for me the Apollo program has a special meaning, because I had a tiny opportunity to work on a little bit of it.

## To Stanford in '61

DSM:  In 1961you graduated from high school and started at Stanford.  Why Stanford?

VC:   Several reasons.  Stanford of course had a tremendously good reputation, and one of my father's friends was a scientist at what was then called the Stanford Research Institute.  In 1958, when I was still in junior high school, my father's friend invited me to come up and go visit Stanford.  He had gone there and he thought it would be a good place.  So I went up and visited, met some of the professors, came away very impressed, and I decided that's where I wanted to go. Well of course you just don't decide, right? You have to get in.

So by very good fortune I was able to win a full four-year scholarship from North American Aviation, because otherwise I would have been pretty much out of the question for me to go.  The annual tuition then was something like $2,500 a year, and I remember thinking that was a lot of money.  And it was in those days! I got the scholarship.  I had very good grades in high school, so I managed to get in, and I don't regret it at all.  It was a tremendously enriching experience.

DSM: Many of the folks I have interviewed who are west cost educated, comment on the just extraordinary atmosphere of young people after the war, in that environment.

VC:   Stanford did some very interesting things that I didn't notice when I was an undergraduate, but when I returned to teach there I realized the amazing strength of vision that the University had post World War II.  What was especially impressive is that they deliberately chose to expand their engineering and scientific activities through government support for research.  Frederick Terman, who was then the provost, was adamant about doing something to increase the total number of faculty available in those disciplines.  The way he did it was to offload their teaching requirements by getting funding for research.  That allowed him effectively to expand the faculty base by a factor of three, and of course the spin-offs from Stanford's investment in that regard has been endless. They've paid off for the University too.  The last thing that just happened is a 600 million dollar donation from Hewlett Packard, amazing, absolutely incredible.

## Learning German with Hans and Hearing Aids

DSM: Extraordinary.  Now you spoke pretty good German before you got in to Stanford, but didn't speak French.  There's a story about that.

VC:    It's true.  My father learned French when he was in college, possibly even in high school, and my mother was a native French speaker because she was born in Montreal. The two of them used to use French at home to keep secrets from the kids.  So we never actually learned French at home, but my father thought that languages were important.  There was a man working for him, Hans Friedenthal and Hans would come every Wednesday night at 7 o'clock and we would have an hour or so of German tutoring. This started when I was age 13, when I was in junior high.  It was fun.  I enjoyed it, which is amazing considering that I am hearing impaired, right?  I started having to wear hearing aids when I was 13, and so hearing the differences in the various umlauts in German was harder for me.  For someone who grew up with just American English, hearing these little ooh and ü and ooo and ö, was already difficult.  But I think it probably helped train my hearing, what I had left, fairly effectively.  So that was a weekly event that went on for several years.  I would have to recite or do some other things for my family after my lessons were over, and then we would have tea and pie or cookies or something like that.

DSM: I found out that I was terribly nearsighted when I was in the 3rd grade.  How did you find out you were hearing impaired?

VC:    It was noticeable by the time I was in the 4th grade.  I was like 9 years old, but the doctors didn't think I needed any special help.  It was about a 15dbd loss, so it was not too difficult.  By the time I turned 13 I was in the 8th grade.  This would have been right in the middle of junior high, and I always would sit in the front of the class partly so I could hear the teacher, but I found that I couldn't hear the questions in the back of the room.  So the teacher would answer the question but I didn't know what the question was.  So if the answer was "yes," it didn't impart much information.   Finally I said, "I have to do something," and I got hearing aids.  I think I started with one and quickly graduated to two, and I've been wearing them ever since.   By good fortune, although my hearing has decreased over time, the strength of the hearing aids and their quality has increased faster than my hearing has decreased.  So I have been able to function pretty much as if I were normally hearing.

## Sea Level at Stanford

DSM: Let's talk about your time at Stanford.

VC:    I went there in September 1961, and we had to live on campus because you weren't allowed to live off campus in the first year.  The most astonishing thing for me when I got onto the Stanford campus was realizing that every other person in the class was also the class valedictorian.  You were no longer special.

I felt like I was sort of the sea level guy in the middle of a lot of mountain peaks. That was a big challenge. It took a little bit of getting used to, but the intellectual level of discourse was phenomenal as a result.

I chose to join the Stanford in Germany group to go to Germany in the summer of 1962. That was a wonderful experience because we immersed in German. We lived about 30km away from Stuttgart in a place called Beutelsbach, a town of 3,000 people. Everyone knew everyone else. We often would have events to invite the townspeople in for some sort of entertainment and refreshments, and we would do these little skits about various notables in the town. Of course everyone knew exactly who was being characterized, including the postman who was a large, very lethargic, and slow moving person. Stamps would be issued like this, you know, and everyone knew what was going on. So it was a charming place to be. Our classes were in German primarily and some were in English. We learned to study Old High German and Middle High German. I can't anymore, but I used to be able to read a little bit of *Beowulf,* because it's in old English, and old English and old German are very, very similar. That was a phenomenal experience. They allowed us to go on extended trips so we spent 10 days in Rome, for example, or we went to Prague, or up to Stockholm in Sweden.

DSM: This was the first time you'd been out of the country?

VC:   I had never been out of the country. I was 18, 19, and completely mesmerized. The good part about living in Germany then was if you were 19, you were allowed to drink beer and wine. Whereas back in the states you couldn't, and Stanford especially, was a dry school. So that was a very important experience for me, being exposed to other languages and other cultures, and I think it was one of the best things that Stanford could possibly have done.

DSM: Did Stanford have a basic liberal arts requirement the first two years?

VC:   Yes. You had to take classes like the History of Western Civilization. You must take languages. You had to take a certain amount of math and science. I took some creative writing classes. So it was an important liberal arts education in addition to all the math and science that I took. I was a math major there, but I look back on that now and realize how valuable those years were. When you're a student and you have little other responsibilities then to study, you have an opportunity to read widely. Today I'm hard pressed to go and pick up, you know, Aristotle or Aeschylus or any of the other authors that I got to read when I was an undergraduate.

## Sigrid

DSM: Did you meet your wife while you were an undergraduate?

VC:   No I didn't. This was after I graduated from Stanford in 1965, when I moved back to Los Angeles to go to work for IBM.

DSM: So you had no thought to go on to graduate school?

VC:   I deliberately did not want to go on to graduate school.  Ultimately I expected to go to graduate school, but I didn't want to go right out of undergraduate school into graduate school.  I wanted to get some experience in the real world, and I was enthralled with computers by this time.  I had already figured out that I wasn't going to be a world-class mathematician.  I sort of broke my pick on Riemannian geometry, but I had taken all the computer science classes that I could while I was there.

So I got hired by IBM to be a systems engineer.  They took us down to Los Angeles and I reported into the Los Angeles data center on Wilshire Boulevard.  I took 6 weeks of systems engineering training and it was during that period, around November of 1965, that my hearing aid dealer suggested that I should come in on a Saturday.  He said, "There is somebody I want you to meet".  So I figured, well what the heck, I'll humor him.  So I came in and there was this really stunning brunette in the room there, and he introduced us and left.  Turned out she was another one of his customers, and her name was Sigrid.

We sort of chatted a little bit, and then it was lunchtime so we went off and had some lunch.  Then she said, "Would you like to see some of the paintings that I like a lot at the LA County Art Museum?  It's just down the street."  This is on Miracle Mile on Wilshire Blvd. So I said, "Sure," and off we go.  I don't want the day to end.  She shows me her favorite Kandinsky, which to me looked kind of like a floating green hamburger, and I said so.  This clearly didn't have the right effect.  I think she decided that maybe this Philistine engineer needed help.  In fact we were so fascinated by each other that she forgot that she was supposed to take her mother to the airport that afternoon.  Her mother missed the plane.  We dated pretty regularly after that.  We got engaged about March of 1966. We got married in September 1966, and we've been married ever since.  We just celebrated our 35th anniversary.

## Impressions of Nov 22, 1963 and Sept 11, 2001

DSM:  I would like to talk a little more about Stanford from 1961.  That's the time of John Kennedy, Selma and the Civil Rights Movement.  Then we move to the summer of 1965 when Vietnam is starting to heat up. Were you touched in any way by those events?

VC:   Actually I was almost completely oblivious to the Vietnam War.  I was only touched by it once when I was about to be drafted, and that didn't happen until I got back to Los Angeles after I graduated.  During my time at Stanford I was pretty much not aware of it, not paying much attention to it.  The Kennedy assassination on the other hand, is a very, very vivid memory in my mind.

DSM:  Where were you?

VC:    I was walking through the cafeteria at Stanford when I saw people clustered around the televisions, and somebody said the President's been shot.  I had trouble assimilating that at first.  The entire country was completely and totally fixated by all those events, and of course we all remember Walter Cronkite reporting then.  I remember that he took his glasses off to report that the president had died, and I remember the several days that followed, watching the funeral processions and everything else.

DSM: This is again out of order, but how would you compare the Kennedy assassination to what happened on September 11?

VC:    The World Trade Center attacks on September 11?

DSM: Where were you?

VC:    I was on my way back from Montevideo, Uruguay.  I had just finished a week of Internet Corporation for Assigned Names and Numbers meetings.  I'm Chairman of the Board of that organization and was at a board meeting.  I had landed in O'Hare about 5:30 in the morning local time, and was expecting to take a 9:20 flight from O'Hare to Washington.  So I was sitting in the Red Carpet Club, on the Internet doing email, when an instant message popped up, saying "Go look at CNN, the World Trade Center is on fire."  So I got up and went around to the television in the Red Carpet Club, and there were already were a number of people who were beginning to cluster around it.

I could see one of the towers was already on fire, but there had been no indication of what caused the fire.  All we knew was that there was a fire going on, and while we were watching, the second plane struck.  As I play this back over and over in my mind, I still can't believe that the aircraft could be swallowed by a building and not come out the other side.  My first honest reaction was, "Is that a special effect? Is this a movie?  This can't be real.  I don't believe what I just saw."  I'm still not sure that I fully assimilated it.  For those of us who were remote, I don't think the full impact of what happened could be the same.  I've talked to people who were in New York at the time, who were not far from it, and they said that the sound of all of this was indescribable, the sound of the planes striking the building and the sound of the buildings collapsing.  There was no way to even describe it except that it was this endless, low rumbling unbelievable sound.  Then of course, the dust and everything else.  In some ways this situation feels less real than Kennedy's assassination, and I'm not sure I understand why.  Maybe just the magnitude seems just so overwhelming.

## Meeting Gerald Estrin and the "Snuper Computer"

DSM:  We'll talk a little more about that later on.  For two years you worked for IBM, and then went to UCLA to go to graduate school.

VC:  That's right.  It's interesting that the job I had at IBM was to be the systems engineer for something that was called Quiktran, which was an interactive FORTRAN time sharing service.  This was 1965, which was just as the notion of timesharing is beginning to gain some traction.  The time-sharing concept gets invented by John McCarthy and a couple of others at MIT in 1961.  So I was running this system.  I was deeply involved in the maintenance of the operating system and the application software, and by the end of the two years I realized that I didn't have enough training, enough knowledge, about how those operating systems were built.  I really felt the need to go back to school.   So I went to my friend Steve Crocker, who was by that time a graduate student at UCLA, and said, "I feel the need to go back to school."  And Steve said, "Let me introduce you to my thesis advisor, Gerald Estrin."  So Steve introduced me to Jerry and he was in the middle of a project that was sponsored by ARPA, called "the Snuper Computer."

This later got us into trouble, but the idea was that you could take a smaller computer and connect it to a bigger one so it could watch what the bigger one was doing.  This was for purposes of analyzing how programs were executing; where did they go in their programs, what parts of memory did they touch, could we analyze the flow of control of the program by watching the other computer, and then could we say something about what would happen if we could take that program and execute it in parallel, instead of the serial way you would normally do?   So the Snuper Computer was intended to analyze what was going on in another machine.

There was an amazing anecdote that came out of that project.  At one point someone in the news media heard about this Snuper Computer and thought that it was being used to snoop on other people's information in computers.  I don't remember the network but these news reports started coming out, and of course the phones are ringing off the hook. Congressmen are going berserk, "What's the defense department doing, snooping on other computers?"  It was a most unfortunate choice of terms, and there were questions like, "How far away do you have to be before you can't snoop anymore?" Unbelievable.

## Connecting via ARPANET

So I start working with Jerry on the Snuper computer, and eventually the funding for that project is transferred over to the Atomic Energy Commission.  The DARPA funding ends and the Atomic Energy Commission begins to fund this program.  This is about 1967, and in the middle of 1968, a request for quotation comes out of the Defense Advanced Research Projects Agency, DARPA.  It's an RFQ for an ARPANET interface message processor and "IMP," a packet switch in effect.  It's the ARPANET Project.

Leonard Kleinrock, who had been at MIT in the early 1960s, was now a professor at UCLA and a colleague of Jerry Estrin. Len was the guy that came up with the idea of packet switching. His graduate thesis was about that concept. There were others who had come up with the idea independently and in parallel; Paul Baran in 1962 at the Rand Corporation, and Donald Davies at the National Physical Laboratory around 1965 in the UK, but Len had moved from MIT to UCLA and was an expert in queuing theory. That is the sort of thing that analyzes the behavior of people in lines at the bank, and lines of cars on the highways, and so on, but he was using this technology to see how packets would flow through a network and how they would be buffered and qued and so on. [Ironically, Paul Baran's thesis advisor was... Jerry Estrin!]

When Len proposed to ARPA to build a network measurement center, to observe the nascent ARPANET and how its behavior matched the queuing theoretic models, eventually he needed to have a group of people to work on that network measurement center. So he recruited Steve Crocker, Jon Postel, me, and a couple of others to get together to work on the ARPANET. We were working not only the network measurement side, but also the host level protocols, because when the contract was let in late 1968 to Bolt, Beranek and Newman, their job was to build the packet switching network.

But then it wouldn't do anything unless you had computers plugged into it to send and receive information, and the questions were, "How do they do that? "What will be the procedures, the formats and the protocols that the two computers that are exchanging information would follow?" Well no one knew the answer to that. Bob Kahn, then at BBN, developed the specification for the interface between the host machine and the IMP, but the end to end protocols were left as exercises for the graduate students! So Steve Crocker sort of got anointed as the head of the network working group to go figure out how to do the host-to-host protocols. Steve broke a lot of new territory. He blazed a lot of trails with almost no guidance at all from anyone, either from Len Kleinrock, or Larry Roberts at ARPA or anything. It was sort of terra incognita for everyone, but it was a very exciting time for all of us in the graduate student world, because we were trying things out that no one had ever done before.

There's another connection there, because by September of 1969, the first IMP, the first piece of the ARPANET, shows up at the network measurement laboratory and gets installed. Some additional IMPs get installed in the subsequent months, one at SRI International up in the Menlo Park area in northern California, one at University of California in Santa Barbara, and a 4th one at University of Utah at Salt Lake City. We have this 4-node network up and operating by early 1970, and two guys come out from Bolt, Beranek and Newman to test it. One is a man by the name of Robert Kahn, and the other is David Walden. Kahn and Walden were two of the key architects of the ARPANET at Bolt, Beranek and Newman. Kahn is out there trying to run whole series of performance tests, and somebody has to drive the data into the net and then measure the results that come back. That was what the network measurement center was for, and I was the chief programmer for that.

So Bob and I met and worked together on the early measurements of the ARPANET's behavior. Bob had some theories about things that would go wrong, and none of his colleagues believed that they would. They thought the probabilities were close to zero that anything like this would happen so we shouldn't worry about it. Bob was determined to show that certain types of lockup conditions could occur under heavy load. So we started blasting the network with traffic. It's a tiny little net of 4 notes and we're blasting away with our Sigma 7 Computer, and we blow the network over. And we kept doing that in various and sundry ways, different kinds of lockup conditions, and of course Bob was very happy with that because he wanted to show everybody that we needed more work on the protocols inside. I almost felt like we should put up little network symbols up on the side of the computer like you do when you shoot airplanes out of the sky during the war, something like, "How many times can you knock the network down?" That was a very intense week or two of work with Bob, but he and I just hit this off very well and we stayed in touch. Of course, later on when I returned to Stanford as a member of the faculty, Bob and I get back together again for some other things.

## "People at IBM Wear White Shirts"

DSM: We're going to talk about the transition from working at IBM to going to graduate school at UCLA.

VC: That's interesting because my first day at work at IBM has a little anecdote associated with it. I show up at the LA data center, it's the summer of 1965, and I'm wearing a sports coat, slacks, a yellow shirt, and a tie. I go into the building, I get into the elevator, and there's this very distinguished looking gray-haired fellow, a very tall guy, who is in the elevator with me. We both go up to the same floor, we both get out, and we both go to the same auditorium. I go to sit down in the chair and he goes to stand up on the stage. It's Buck Rogers, the head of the federal systems division at IBM. He launches into his welcome to this assembled body of prospective systems engineers. He tells us a little bit about IBM, the company, its styles and practices. He reminds everyone that people at IBM wear white shirts, and he fixes his eye on me. And I'm sitting here, sort of like this (slumps.) So I went home and I discarded all of my yellow shirts, and any other color shirts except white.

It took me a long time to get back to the idea that maybe it was okay to wear a shirt that wasn't white. I'm wearing a blue shirt today, but that's because we're doing this video. Anyway, I was accustomed to wearing a coat and tie to work at IBM, and when I went back to UCLA as a graduate student, I continued the practice because it didn't feel right not to do that. I was wearing a coat and tie while my colleagues, of course, were far more relaxed than that, particularly Jon Postel who was our resident hippie. He was attired in T-shirts and jeans, or certainly never wore shoes. It was either bare feet or sandals. Steve Crocker was kind of in between. He was slacks and an open shirt.

But my suit-wearing days started much earlier than that. I started wearing a sports coat and a tie when I was in junior high school, and I carried a briefcase. People used to think, "God, that's weird. You wouldn't fit in with everyone else. Why would you want to do that?" I said, "That was the whole point." I didn't want to fit in with everybody else. I wanted to look different, be noticed. That was a very effective way to do it, and it was better than wearing a nose ring, which I figured my Dad would not have put up with in the 1950's.

## The Amazing Estrin Family

DSM: So you got your masters degree in 1970?

VC: Right.

DSM: And what was your thesis about?

VC: It was on the measurement of recursive programs. This was part of this Snuper Computer project. So that thesis work was done with Jerry Estrin.

DSM: And 1972 was another big year, a time when you finish your Ph.D.

VC: Right, I finished my Ph.D. in 1972

DSM: And your advisor was Dr Estrin?

VC: Jerry Estrin. Len Kleinrock was on the thesis committee as were a number of other faculty members, but Jerry continued to be my thesis advisor.

DSM: But the Estrin family played a much bigger role in your life than academic. Could you tell us about this?

VC: Very significant role for me. First of all, Jerry and Thelma Estrin are two amazing individuals. They were married when they were 19. They both got Ph.D.s in electrical engineering from the University of Wisconsin, in Madison. That was very unusual for a woman to have a Ph.D. in electrical engineering in those days, this must have been in 1950 or 1951. So by the time I got to know Gerry it's 1967, and we would occasionally go over and meet his family. I didn't know his oldest daughter terribly well because by this time, Margo, who's now an M.D, had moved out and was in school. But there were two other daughters, Deborah and Judy. Judy and Deborah were something like 9 and 12 at the time that I first met them.

The whole family was brilliant, intense, always engaged. Today, just to sum up, Debbie is a full professor at UCLA, having gotten a Ph.D. from MIT. She served for several years at USC so that there wasn't a nepotism problem at UCLA, and she's established a reputation. Judy has gone on to become a very wealthy woman. She was a founder of Bridge Computer Corporation, which was merged with 3Com. Then she went off to doNetwork Computing Devices, and from there she went to do Precept, which was acquired by Cisco. She became Cisco's chief technology officer, did that for a couple of years, and now is running a company called Packet Design. She and her husband, Bill Carrico are legends now in the Silicon Valley. They are phenomenally bright, very engaging people. Judy was my thesis student at Stanford. She did her masters degree in my lab. In any case, the family just impressed Sigrid and me tremendously.

One of the stimuli that got me to finish my Ph.D. in a timely way was when Jerry announced that he was going to go with his family to Israel for a sabbatical. That meant that if I didn't get my dissertation done by the end of December of 1971, I would have to wait for a year because he wasn't going to be available.

So around December 10$^{th}$ I began. I sat down, and for 10 solid days I sat on the sofa and wrote my dissertation. Sigrid would feed me, change my diapers, and what have you. It was a great effort, and by March of 1972, it was all done. Then Jerry went away and we babysat his house. I had one the most wonderful experiences of my whole life. I got to walk to work from this magnificent home right on the edge of the UCLA campus. The only downside of that whole several months that we were there, is that his dog ate my hearing aids. I knew he'd feel terrible about it, so I didn't tell him for about 20 years. Then, once at some party, I said, "You know, something happened when I was babysitting your house. Your dog ate my hearing aids." It was an expensive fix at the time for me.

DSM: Was it during this time that your father passed away?

VC:   Yes, my father died on my birthday in 1971, June 23, and Jerry was extremely helpful to me. He pretty much became a second father for me, someone I could turn to for advice and help. So his family, all of the family members, we all felt very close to since that time.

DSM:  That is an extraordinary story. So, you finish your Ph.D. and get a pretty good job teaching at another pretty good university.

## Should I teach at Stanford?

VC:   At Stanford. Actually there's an interesting story about how that happened. I was asked to go up to Stanford just to lecture. It's one of those things where if you're going to be considered for a faculty position, you go up, you make a lecture, you meet the faculty, and you let the students beat you up. So I went up. It probably would have been June or May of 1972, and I made this lecture about my dissertation work, and a little bit about the ARPANET.

A few weeks later I was asked whether I would accept the position at Stanford in the fall. I thought about it for a while. I know what those students are like there. They're all really smart. I didn't know if I had anything useful to tell them. So I said, "No," and I remember very vividly the side effect of that. I said no, and then the next day I'm down in the computer lab, and there was this other graduate student who was sharing an office with me. So I'm down in the computer room doing some work, and she comes rushing in and says, "John McCarthy's on the phone." McCarthy is a legend in our time. He's the one of the inventors of artificial intelligence. He wrote the books we use as students, right? John talks to me for a while and I'm still resisting, right? So I go back to work, and this little gal comes running in again and says, "Donald Knuth is on the phone." Don wrote all the books on the art of programming. The man is incalculably brilliant, creative and everything else. So the day wears on, and these legends from Stanford are calling. So by the end of the day I'm saying, "Okay, okay, I give up. I'll come!"

## Getting the Flu from the "draft"

DSM: That's great. To put this into context, this is the period just as Vietnam has calmed down. There is a host of people who have been in graduate school. There are a number of jobs that were available, and the ratio of applicants to jobs is very high.

VC: Very high, yes. So here I am turning this job down, are you out of your mind? Well to go back a moment, you have to understand that around February of 1966, I got my draft notice. So I went down to report in and have my physical. I stood there in my underwear for a good part of 7 hours or so with a lot of other people, and I got all the way through to the end of everything and one of the doctors says, "You're deaf?" And I said, "Well no, but I'm hard of hearing." And he says, "What are you doing here?" And I said, "Well, I was wondering the same thing." He says, "We can't use you. There's no way we can keep you fed with batteries or anything else for your hearing aids. Go home." So I was rated 4-O. It wasn't the same as 4-F, but it meant that you would only be called up in dire circumstances and the world was coming to an end. So I went home and had the worst flu I've ever had in my life. Sigrid took care of me. This was before we got married, and that's how I was persuaded that maybe this would be a good person to get hooked up with, because she took very good care of me.

DSM: This is from standing in line naked for seven hours.

VC: From standing naked in line for 7 hours. So I was oblivious to the Vietnam situation really. I was so focused on the research work that was going on.

## Tangled Webs in 1973: Hooking up Packet-nets

DSM: But you did do a little work for the defense department. You published a paper in 1973 and revised it in 1974.

VC:   Let's move back a little bit.  In October of 1972, there was a major demonstration of the ARPANET in public in Washington, D.C.  It was in the basement of the Hilton Hotel on Connecticut Avenue.  This was the International Conference on Computer Communication, the first conference on that subject.  It drew quite a large crowd.  Larry Roberts, who was the head of the information processing techniques office at ARPA, and one of the key instigators of the ARPANET, asked Bob Kahn to organize a demonstration of the ARPANET for that event.  So Bob assembled a team of 50 or 60 people to put that demonstration on, and I was one of them.

Shortly after that very successful demonstration was done, Bob left BB& N and went to ARPA, and I left UCLA and went to Stanford.  So in the spring of 1973, Bob came out to visit at Stanford and described for me some of the packet switching research programs that he was involved in by that time.  One of them was Ground Mobile Packet Radio for tactical communications in the field.

The other one was Packet Satellite.  I think Larry had actually started the Packet Satellite Program while he was at ARPA.  Not long after Bob came to ARPA, Larry Roberts went back to BBN to run a company called Telenet.  Everything is all tangled together.  So when Bob came out in early 1973, and described for me what was going on, the question that came up was, "How are we going to hook these different kinds of packet-nets to each other?"  We needed all of them to inter-communicate with each other if the military was going to take advantage of computer communications in field operations.  That was the Internet problem.  So Bob and I worked on this, just the two of us, from about early 1973 until about September 1973.  We wrote a draft paper, which we presented in September of 1973 in Brighton, England, at the meeting of the International Network Working Group.  I chaired that group, which was created in October of 1972 by inviting all the people from all around the world who were interested in packet switching.   Steve Crocker was supposed to be the chairman of that group except he was going to ARPA, and he decided that he didn't have time to chair it.  Since I was going to Stanford, they figured that an assistant professor would have plenty of time.  So everybody said, "Okay, you're it."

So at this meeting in Brighton we made our presentation.  Then we revised that paper and it was published in the issue called, I believe, "IEEE Transactions on Communications." Just a small footnote to that, last September or August, a copy of that publication was auctioned for $3,000.  It was auctioned for $3,000.00 by Sotheby's.   So Bob and I immediately thought we should go look for any other copies we might have.

## First Teacher Evaluation and Students at Stanford

DSM: Tell me about the transition from Stanford. Were you a good teacher at Stanford?

VC:   Let me tell you an anecdote about that and let you be the judge. I taught my first classes, probably in data structures or something like that, and I thought I had done reasonably well that first quarter. At the end of that quarter I remember getting a request from 3 students who said they wanted to see me after classes were all over. I thought, "Gee, this is cool. They're coming in to tell me what a good job I did." So they all came in, but the only thing they wanted to know was how I tied my tie because they had never seen a knot quite like that. This is a standard Windsor, but it's more complex than a "four in hand" or sort of an overhand thing. That's all they wanted to know. They didn't care about anything else I'd done the entire quarter. I'll tell you something that was very deflating.

Whenever I tend to get a little bit too egotistical, I'm always reminded about the Windsor tie. I always hope that every lecture I give is not going to be a Windsor tie lecture, that that's the only thing that anyone would remember from my lecture is that. I thought I did alright, but…

DSM: We talked about Judy Estrin as one of your students. Any of your other students spring to mind?

VC:   There are an interesting collection of graduate students that became part of the Internet design work. They've gone on to do some pretty amazing things. We've already encapsulated Judy's history. She was sort of the low man on the totem pole when she arrived, because she came about a year after we had already started a lot of the work. So she was working there in 1975. We spent all of the previous year, 1974, doing the design of TCP protocol. There were people there like Richard Karp, whose name hasn't come up yet, but he was another friend from school. Richard and Steve and I were all part of the math club. He was in the class ahead of mine. He had the choice of either speeding ahead or falling back, because we were all in this enrichment program. I just stayed in the program, but he graduated six months ahead of me. Richard went into the Peace Corps then came to Stanford, and I brought him into my lab to work. He did his Ph.D. at Stanford and now has gone on to run a company called Catapult Communications in Palo Alto. He has done very well.

Another man named Yogen Dalal, whose father served in the diplomatic corps for India, worked in many places including a stint as the Indian Ambassador to Switzerland, Yogen was one of the key players in the analysis and design of the TCP protocols. He went on to work at Xerox PARC, Palo Alto Research Center. PARC has a role to play in the history of the network because in 1973 Bob Metcalfe was at PARC inventing the Ethernet, and Metcalfe drops into some of my seminars when we were doing research on the TCP. Eventually of course, we had to put TCP up on top of the Ethernet, which today is an extremely popular local area networking technology, which itself, has had a long history of evolution.

Another man named Carl Sunshine, was part of the team. He did a lot of the analysis work, showing whether or not the protocols were actually working the way they should.  He eventually moved down South to take a job at Aerospace Corporation.  He replaced Steve Crocker who had created a computer science division there, and then Steve left to go to USC Information Sciences Institute.  Everyone is somehow all connected.

## The Math Club and Dinner with Miss Reese

DSM: Extraordinary. I'm going to go back out of order because there's something I think graduate students in 300 years will be very interested in. You talked a lot about the Math Club.  Describe what you did, who were the people in it, what did you do, who advised you.

VC:    This was in High School.  Florence Reese was the young advisor who led the Math Club, and I had participated, along with Steve Crocker, as a junior and as a senior.  We had won first place at least once when I was there.  Then I graduated in February of 1961 and I went to work for Rocketdyne.  Of course, the Math Club continues.  Steve Crocker is in the class still because he's a half a year behind me, and at one point the Math Club wins again.  This is after I have graduated from High School, but I get invited to the celebration at the Sportsmen's Lodge.  So, Florence Reese is probably all of 26, and she has this little bevy of Math geeks that she's taking to dinner because they've won.  Steve Crocker is sort of the lead of that group, and then there's several others, but they're all of 18 years old.

DSM: This is a state math competition they won?

VC:    This is a state math competition, or it may have even actually have been a Los Angeles Math Competition.  Anyway there is this celebration dinner, and I get invited to come along as a guest.  So Miss Reese is sitting at this end of the table.  I'm at the other end of the table, and then these other members of the Club are in between.  Now I'm feeling very sophisticated because I'm 18 years old.  I'm working.  I have a nice income and James Bond is in my mind.  So the waiter comes around, we order our meal, and I order a bottle of wine for Miss Reese and me.  The guy doesn't card me.  I didn't know that Steve even noticed this, if he was watching this going on thinking, "Oh my God, it's the end of the world." What's she going to do?  If she makes a big thing out of it, he's going to wind up being carted off."  I never even talked to her about what went through her head during this thing, but I had a great old time. The waiter said, "Well, is anyone else having wine?" And I said, "No, just Miss Reese and me."

DSM: All because you were wearing a tie.

VC:    Well of course I was wearing a tie, that's right.  I always looked a little older than I was.

DSM: That's a great tale, but what you guys did was basically prepare for competitions.

VC:   That's right.  It would be weeks and weeks of just working problems, and then the morning of the event we'd all get up and have a big steak and egg breakfast at 7:00 in the morning, because we weren't going to eat during the rest of the day.  You didn't want to dull your brain with a lunch of any kind.

DSM: Sounds like Miss Reese is somebody we should talk to.  She seems to be someone who's helped prepare an extraordinary group of people.

VC:   I have no idea if you could ever find her, but I'm sure she must still be around.

## Back to ARPA and the East Coast in 1976

DSM: From 1976 until 1982 you go to work at the Department of Defense.

VC:   I go to work for The Department of Defense, although that was another example of turning things down.  In 1973 or 1974, Steve Crocker is at ARPA, and Bob Kahn has been there from 1972.  So they call me up in late November of 1975 and they say, "We'd like you to come to work at ARPA."  I'm thinking, "Well, that could be interesting." So I fly back in November, and the worst snowstorm they've had in some years happens as I arrive.  My first reaction is to get on the plane and go home, but we do our thing, and I call them and tell them I don't want to come to ARPA.  The reason I don't want to come is not the snowstorm.  I see this as an extremely visible position, because having worked on ARPA projects I know how visible they are to the rest of the community of my colleagues.  If you are at ARPA and you screw up, everybody can see it.  I was afraid that I would go there and just make a big mess, and I didn't want to embarrass myself.  So I said no, sort of like the thing at Stanford.  Well they let it drop, but then the next year they tried again and this time I was a little more receptive.  I came home and talked to Sigrid about it, and she said, "You know, we've never lived on the east coast, and you don't remember anything about Connecticut. Why don't we go?  It'll be fun."  So I said, "Well, Okay, why not. "  Of course, I don't regret it at all, but I did have trepidations about coming to ARPA and trying to run a project and just messing it all up and everybody saying, "Ha, ha, look at that jerk. He screwed it up."

DSM: So in 1976 you and Sigrid pack up and move to?

VC:   We pack up and we head east.  We bring our 3-year-old son David with us and we move into a place called Camelot.  Couldn't resist.  It's a little development that had been built in 1965, and we're there 11 years later.  It's an established community.  Some builder gets the end of the street, turns it into a cul-de-sac with 3 houses, we buy one of the houses, and we've been there ever since.  I mean, you're in Washington, where else would you want to live but Camelot?

DSM:  Exactly. So first you're working as a program manager.

VC:    I'm a program manager at ARPA.  By this time Bob Kahn is the Deputy Director of the office, and the man who is running the office at this point, is a guy named David Russell.  Dave Russell is a Ph.D. in physics and an army colonel.  The army put him through college to get his Ph.D.  He's been through two wars, the Korean War and the Vietnam War.  He's served his time and he's a phenomenally good manager.  At some point in this story, that will become important again.  He served until 1979, and then Bob Kahn became the director of the office.  So while I was there I went from program manager to eventually being the principal scientist in the office, and Bob became the director of IPTO.

## The Need for TCP/IP

DSM:  Lets talk about the work you were doing at DARPA, Internet development and data packet security work.  We were joking that your search for anonymity failed at DARPA as your work became really, really visible. Describe that.

VC:    When I got to ARPA, the projects I was assigned to were Internet.  That was the big attraction for me, to be able to operate on a larger scale than I could operate on Stanford.  But Bob also asked me to take on the packet radio, the packet satellite programs and also the packet security programs.  So I had those four including Internet and they were marvelously fun.  You cannot imagine what is like to be on the correct side of the checkbook and being able to learn from the smartest people in the country about the areas of research which you are responsible for.

I was a complete idiot when it came to radio, but I got to learn about spread-spectrum radios from some of the smartest people in the game. Particularly Collins Radio, which was part of Rockwell International at the time.  So I was flying back and forth down to Dallas, Texas on a regular basis for that.  The SRI International people were doing the system integration of the packet radio, so I would be out there on a regular basis to work that part of it.  The packet satellite people were down in San Diego.  In fact, a man who is now quite well known as the CEO and Chairman of Qualcomm, Irwin Jacobs, was what we called the SETA, Systems Engineering and Technical Advisor of the packet satellite program while that was being conducted in the 1970's.  Of course he's now a very well known, very well off person running Qualcomm.

DM.  And also the recipient of The National Technology Award.

VC:    The National Medal of Technology, that's right.  That's another thing, if you go down the list of the recent recipients of the National Medal of Technology, you'll find a whole lot of commonality there too.

Anyway, ARPA becomes a just a marvelous 6-year period for me. I'm focused absolutely on getting the Internet off the ground and running and getting people to adopt TCP. I take any opportunity I have to tell people about it, to persuade them to make it a commercial product, doing anything. We push and push, first to get all the protocols designed properly and implemented and tested. Then after we standardize them in 1978 for our community of use in the defense department, we have to get them implemented on enough different operating systems so that you could actually use it, because if it's only running on two or three operating systems, and if you have fifty different kinds of computers, you can't do anything.

So we spend 5 years, from 1978 to 1983, getting all this stuff implemented on all the different operating systems that are critical to us. It isn't until January of 1983 that we actually roll this thing out. In fact, we had to force it down people's throats.

We started the process of warning that we were going to move from the old ARPANET protocols, the NCPs that Steve Crocker and others, including me, led the development of, to the TCP/IP. Well, people already have email because that comes into fruition about 1971 on the ARPANET thanks to Ray Tomlinson and others. They've got file transfer. They've got remote login. They don't need this new TCP/IP stuff. Everything's fine. ARPANET works, what's your problem? And of course, we're sitting here saying, "No, no, no, you don't understand. We have all these other kinds of packet-nets. They all have to work together, and you have to use the new set of protocols so that we can build a much larger scaleable system."

DSM: And you haven't turned 40 yet.

VC:    Let's do the math here, in 1976 I was 33 and by 1982 I'm 39.

DSM: And your colleagues are all about the same age, or even younger.

VC:    They were about the same age or younger in some cases, because some of them are doing the R&D work.

DSM:  Did you have any sense at the time of the scope of what you were doing and how young you were to have that type of authority and power?

VC:    Not at the time. I was so focused on just getting this thing to work; making sure that it went to as many places as possible, and persuading as many people as I could to use it. So I was in active sales mode. Remember that after all that 10 years of work, from 1973 to 1983, we roll this thing out to about 200 computers. Maybe 400, but it's certainly not much more than that. So the entire network consists of a few hundred machines, that's all because even in 1983 these were mostly large-scale, time-shared machines. That's small potatoes. Now the backbone was running at 50 kilobits per second. That's what you get on a dial-up line today, but it was fast by our standards. So during that period all the effort was just on getting it to work and getting it rolled out.

Now I actually left to go to work for MCI before the rollout. I left in November of 1982. I figured I'd done my thing. It's scheduled to roll out in January, after having beaten everybody black and blue to force them to do it. So I figured I'd done my thing. Other people would take this through the next step and I would go on to different phase of my career, which in fact I did, because from 1982 to 1986 I was at MCI doing MCI mail.

## "Like Climbing Mt Everest": Developing MCI Mail

DSM: Who found you at MCI? Was there a guilty party for luring you away?

VC: This is another example of how stupid I am.

DSM: You told them "No".

VC: That's right! I told them "No" again. It was 1981. I'm at ARPA, and I get a call from a friend, Phil Nyborg, who says, "Bill McGowan would like to talk to you." Bill's the founder of MCI. Bill's the CEO, and the President is Orville Wright, probably related to the ones who did the airplanes. Orville comes from IBM. Anyway they were trying to figure out if they needed a chief scientist and Phil arranges for me to meet with Bill and Orville. So I spend about 4 hours one evening with Bill and Orville in the headquarters building down on 19ᵗʰ Street in Washington. At the end of the 4 hours we figure out that they don't need a chief scientist, because the way the company gets new stuff to happen is they go to the vendors and they dangle a quarter of a billion dollar check in front of them and they say, "If you can make this happen, we'll buy $250 million worth." It's amazing how much R&D you can get done with that kind of incentive. So they didn't have to have a chief scientist. They didn't have to have a laboratory. They just said, "Here, if you can do this, we'll buy it." That was a strategy that worked very well for them for quite a long time. So not that I turned them down, it's more a question that we concluded mutually that they didn't need me to be at MCI.

DSM: Was this when Dick Liebhaber was there?

VC: No, Dick Liebhaber wasn't there yet. Liebhaber was an acquisition as a side effect of the satellite business systems link-up. So, Orville and Bill go on to continue to build MCI and the next year, 1982, I get a call from Phil Nyborg again saying, "There's someone who's come to MCI who would like to talk to you." I ask, "Who's that?" And he says, "His name is Bob Harcharik." Turns out that Harcharik used to run Tymnet Corporation. He was the president. Eventually things changed and he was recruited away to come to MCI to get them into some kind of data business. I think McGowen especially realized that there was something going on in the early 1980's about data, and they weren't doing any of that. So Harcharik comes in and he gets this idea to build a digital post office. He and I sit down and have lunch, and he says, "I want to build a digital post office." I am sitting there thinking, "Boy that sounds like fun. I think I know how to do that."

He makes an offer and I'm sitting here doing the math, right? I'm looking at my little kids. This is 1982, so one of them is 4, and the other one is 9. I am trying to figure out how much it's going to cost me to send them to college, and I'm looking at my government pay and thinking, "You know, these don't add up." So I said to Bob Kahn, "I'm going into industry because I need to do something to afford college for my two kids." So I go to work for Bob Harcharik and we do MCI Mail. That was a wonderful experience. That was like climbing Mt Everest in just 9 months. It was amazing.

DSM: This was the first commercial email system.

VC:    It was the first commercial system to be connected to the Internet. There were other email services that were also around. Tymnet had one called OnTyme and Telenet had one, Telemail. However, MCI Mail had some features that none of them had.

We broke some amazing ground, and just to make another amazing observation, the first person I hired to work with me on the project was a guy named Dave Crocker, who is Steve Crocker's brother. Dave used to work for me at UCLA, and he was very involved in the development of electronic mail on the ARPANET. So I immediately grabbed him and he became my principal deputy in this project. What was really neat about this is that not only could you send and receive email, but you could also have this stuff printed out and sent through the postal service, or you could have it sent overnight, or you could have it sent to telex. And the same distribution list, the same email that you sent to somebody also had the postal addresses and the telex addresses and the overnight addresses in them. You would compose email, but it could be sent to people who were not online. It was all part of the normal framework for doing electronic exchange. Very, very few systems if any, even do that today.

DSM: What happened to MCI Mail?

VC:    It was a system that was, frankly, ahead of its time. We made a business of it. It's still running today, but it didn't take off in an exponential way that a lot of us hoped it would. I think part of the reason for that is that there really weren't very many people out there with terminals that could get online and use it, and businesses had no notion of why email was useful. They had no concept, it just didn't sell to the business world in any big way. It was not a huge commercial success, but it's got legs because it's still running. In fact it's probably time to put it to bed, but anything that works is hard to stop.

## Back to R&D: The Corporation for National Research Initiatives

DSM: In 1986 you rejoin Bob Kahn, out of the commercial world.

VC:    That's right I went back into R&D again.  MCI Mail had gotten to kind of a plateau in terms of development.  Four years into the program, we weren't spending a hundred million a year on it anymore, and it didn't look like they needed me to continue to shepherd that project along. So when Bob said, "Do you want come back into R&D?" I said, "Sure."  So we started a company called The Corporation for National Research Initiatives.  I joined Bob and we spent 8 years together exploring information infrastructure, and various concepts and technologies that could support it.  In fact Bob introduced that term into the language in a hearing in late1986, before then Senator Gore.  In that hearing, in addition to discussing this term, 'information infrastructure,' Senator Gore asked the question, "Should we be thinking about interconnecting supercomputers with other supercomputers over optical fiber networks?"  Nobody knew the answer to that question, but Gordon Bell who is another legend in our computing community, was then at the National Science Foundation running the computer CISE group, Computer Information Systems and Engineering or something like that, he took responsibility for organizing a group of scientists to answer the question that Senator Gore asked.  We all went out to San Diego in February of 1987, and out of that three-day debate came something called, 'the National Research and Education Network Project,' which was a major expansion of the NSF net concept.

## Vice President Gore and the Internet

DSM: I guess one of the legendary political stories is Vice President Gore taking credit for the Internet, and both you and Bob Kahn defended him.

VC:    Yes we did, legitimately.  I was very disappointed with what happened to Vice President Gore.  He never said that he invented the Internet.  In the context of a discussion about his service as Senator, he said, "I took the initiative in creating the Internet." And from the legislative point of view, he is precisely correct.  Not only did that 1986 hearing trigger an enormous evolution in the network, but as Vice President he pursued legislation together with members of Congress that would make it legitimate to use the NSF net backbone for commercial purposes. I think this was vital to the Internet's explosive growth in the mid 1990's, because up until 1988 it was not permitted to do any commercial interconnection to the Internet.  It was strictly for research, education, and of course, for the military.

About mid-1988, I asked permission from the Federal Networking Council to connect MCI Mail up to the Internet. This is while I am at CNRI, and of course I am working with former colleagues at MCI, and we're talking about what kinds of things we could that would break the policy logjam that prevents the Internet from becoming a commercial engine. I had become convinced by that time that if we didn't make it a commercial engine, it wouldn't spread very far because the government couldn't afford to keep paying for it. Certainly not for every citizen in the U.S., let alone, the world. So how can we the system self-propagating? Well, it has to be self-supporting. How do you do that? You turn it into an economic engine. So my immediate thought was let's break the logjam by getting a commercial system connected to the Internet. I got permission from the Federal Networking Council to do that in 1988, and it took about a year of programming work to get the interconnection gateway done, but in the summer of 1989 we made the link. Very quickly thereafter the CompuServe guys got their link up to the Internet, then everybody who had commercial email wanted to get connected up. The side effect of all this is that all these email systems that didn't use to inter-work with each other, suddenly interconnected through the Internet backbone. So now we've got email connectivity over a much broader scale than we ever had before.

So that was a very important move, but to come back to Vice President Gore, he deserves credit for having the foresight and the interest and enthusiasm to pursue that technology when no one else in the Congress even knew what it was.

## TCP/IP vs. OSI

DSM: I would like you to talk about founding the Internet Society, both in the context of how you got there, and also some of the difficulties that you had to overcome. I guess from the perspective of the 21ˢᵗ Century, growth and expansion of the Internet seems to be an inevitable, unstoppable evolution, but it wasn't that way at all.

VC:   It wasn't that way, and those are two very separate subjects; the Internet Society, and the general adoption of TCP/IP and Internet technology. Let's take the technology side first. Internet exists in its experimental form starting about 1975, and about that same year, when Larry Roberts went back to BBN to start Telenet, he's trying to figure out how to take the packet switching that was so successful with ARPANET, and turn it into a commercial thing. He can't figure out how to sell packet switching, but he does figure out how to sell what he calls 'virtual circuits.' That's a packet switch net that looks like it's a circuit switch net to the outside. It's cheap virtual circuits as opposed to expensive real dedicated circuits. So he and several other people in France and Canada and in England get together and they develop a standard called 'X.25,' which is the commercial packet switching standard. Of course there ensues this massive debate about datagrams versus virtual circuits. Should the network take responsibility for keeping packets in order, and retransmitting them, and doing all this, or should the network now take this responsibility and let the end host do it? I'm from the end to end school that says, you've got multiple packet switch nets, you can't be sure of what's going to happen to anything going on in between them.

You've got to assume that they're going to be bossy. You shouldn't rely on any one net's reliability. You ought to do it end to end. Of course Larry took the position, "I can't sell that right now, so I'm going to sell my virtual circuit X.25." So there emerges a whole community of X.25 networks, most of them being built and operated by the telephone companies that are owned by countries, the British Telecom, France Telecom, Deutsche Telecom and so on.

The protocols wars of the 1970's revolved around datagrams, which is what an Internet packet is, and the virtual circuit networks of the X.25 type. Eventually that particular battle sort of subsides and we build Internet on top of X.25. This leads me to observe that in general Internet runs over everything, including you, if you're not paying attention to what's going on. We simply subsume that whole technology and run packets on top of it. Now comes 1978. We've had 4 iterations of TCP/IP design. We standardized on version 4, which is what we're running today, and about that time a paper comes out on what's called 'open system interconnection architecture.' It's the International Standards Organization's attempt to get into packet switch standardization.

 So for the next 10 years or so, there's this battle between the OSI, the Open Systems Interconnection world, and the TCP/IP world. The differences are enormous. The languages and vocabularies are baroque and complicated in the OSI world. There's endless documentation, and there's very little implementation, but the Europeans are behind it and the United States government and the US Defense Department decide they're going to go down the OSI path. Starting in 1983, we roll out TCP/IP across the Internet, and the Defense Department decides shortly thereafter to go standardized on OSI, which doesn't exist yet.

DSM: Why?

VC:    Because they think it's going to be an international standard, and the people who make these decisions look at this TCP/IP thing and say, "Well, it's just kind of in the U.S., and it's just these researchers, and it can't possibly amount to anything." So for 10 years there's this battle between TCP/IP and OSI. OSI almost never gets implemented. The only thing that ever happens of substance is the X400 email service and the X500 directory service, and of those two, the directory service probably has somewhat less purchase than the X400 did. The rest of it was mostly words but no actions. So people would speak OSI, they'd talk about it, and they would count out to it, and then they would TCP because it was the only thing they could get. In 1993, 1994 or so, after I had helped to found the Internet Society and served as its first President, I wrote a letter to the National Institutes for Standards and Technology here in the U.S. suggesting that it was time for the U.S. government to re-examine its government OSI policy. After a year of blue ribbon committee debate it was concluded that maybe TCP/IP would be okay. Just to give you a sense that those wars never end, right?

Then a new technology comes along called Asynchronous Transfer Mode, or ATM, and for some years now there's been this debate, which has largely subsided again, that maybe ATM is going to take over for TCP. The answer is no, IP runs over ATM, again, and frame relay, the same thing.

So I would project out for years to come, that every time a new technology comes along for switching of data, someone's going to say, "This is going to replace TCP/IP." And the answer will be "No, it will support it as opposed to replacing it." Someday it will get replaced. In fact we already know that IP, the version 4 that is running now, needs to be replaced with a version with a much larger adjust space. So I'm not imagining that this will go on forever unchanged. In fact I hope it does change. It should adapt to new requirements.

## The Internet Configuration Control Board and the IETF

DSM: But there are all those parts of the world that haven't yet implemented TCP/IP protocols.

VC:     Most of the implementations now are just off the shelf. You buy them commercially, so it just propagates, but it's still early days. Although for me it's gone on for decades, there's only about a half billion people on the Net in 2001. We have 6 billion people in the world, so we only have 5 ½ billion more people to go.

Now in addition to the Internet Society is another interesting evolution. Around 1991, CNRI had a contract from the National Science Foundation to run a secretariat for this very important standards-making group called, "the Internet Engineering Taskforce."

In fact, let's go back a little bit in time to when I was still at ARPA and the Internet program was only about 4 or 5 years old, in 1979, Bob Kahn raised the concern that if he and I were hit by a truck, who would lead the effort and what would happen? He wanted to make sure there were a group of people who all knew what was going on. So he said, "Please go organize something so there's a group of people that can be drawn on." So I started something called the 'Internet Configuration Control Board.' We wanted it to sound as boring as possible so no one would want to serve on such a thing, then we'd just bring in the key players that were doing the research work. So we did that.

Then I left in 1983, and a guy named Larry Leiner came in to replace me at ARPA and took the ICCB thing and turned it into the Internet Activities Board with a set of about 11 task forces, one of which was the Internet Engineering Task Force. When he first started it there wasn't an Internet Engineering Task Force. In fact, I was just looking at some history about that, it was another task force or group, but eventually one of them morphed into the IETF. So the IAB, then called the Internet Activities Board, was the final authority on what happened to the protocols. They were the standards deciders, and there were lots and lots of working groups that would develop and evolve these protocols, but the standards would be agreed to by the IAB. Anyway, CNRI had a contract starting around 1988 to support a secretariat for the burgeoning IETF, the Internet Engineering Task Force. I think it first got formed in 1986, that one of the first meetings of the IETF came about that time.

So in 1988 it was big enough that it needed professional support. So CNRI was running this thing. We were getting money from NSF to do it, and then NSF and some of the other research agencies said, "You know, we can't really support this forever. You really need to be self supporting." So I got to thinking, "How are we going to do that? Where will the money come from?" A bunch of us thought maybe we should start something called the Internet Society, and that organization would have as one of its primary charters, the responsibility for supporting the IETF secretariat.

In June of 1991 we announced at a conference in Copenhagen called INET, that a man named Larry Landweber had started some years back, although that might have been the first year it was called the INET, that we were going to start the Internet Society starting in January of 1992. We did that, and I served as its first president. People joined as individual, and I went out begging for money from various members of industry. We ended up as an organization that has persisted now for over 10 years. Its primary job has been to support the IETF and to do the RFC editing and all the other apparatus that's associated with this standard thinking.

## Starting the Internet Society

DSM: I want to talk about 1996-97, because it's not only you and Bob Kahn being honored by the President, but 1996 is also an extraordinary year for Sigrid.

VC:     Oh yes, especially for her cochlear implant, that's true.

DSM: Yes, if there's any satisfaction for being in this industry, that's got to be it. Let's talk about the Internet Society's task force and the concerns that you're trying to address there.

VC:     One of the things that characterized the Internet Society was a strong focus on the technical side of things. Support for the Internet Engineering Task Force was a primary leg of what we did. Educating people about how to make the Internet work was another major activity. We had workshops that the Internet Society sponsored every year. They were very satisfying because we would bring people in from a hundred countries. They would all work together intensely for two weeks learning how to plug pieces of Internet together and run them, and a lot of them would go back and start companies to make Internet services where they had come from. There were some very good success stories that we could tell. Sometimes these people would come back and teach the class the next year, and it was just a wonderful piece of work.

Several thousand people got trained in the network workshops that were sponsored by the Internet Society, but what was missing from the range of things that we looked at was a focus on the societal and economic effects of Internet. A number of people noticed that, and in 1998 we started to agitate. At that time I was the chairman of the Internet Society, and I was agitating to open up more activity to look at, analyze and try to understand what the societal and economic effects were.

The rubric under which this work was done was, "Internet is for everyone," and the point was, that not everyone had access to the Internet, and there were governments that were resisting the use of the Internet. So there were all kinds of questions that were economic, social and educational. There were policy questions about what would get in the way of propagating Internet everywhere. There were countries that did not have telecommunications infrastructure that could support it. There were countries that had weak economies. There were countries that had no one trained who could actually run a piece of the Internet. There were countries whose governments were agitating against the Internet because they didn't like the free flow of information that it could produce. So there were just a blizzard of reasons why a societal task force should work on those questions to try to make them more visible, and to try to make at least constructive recommendations for how to spread the Internet and why it was an important thing to do.

I would have to say that we've had only limited success in trying to make that happen, to create that task force and get it to do that job. But there have been enough other activities around the world focused on that, the 'digital divide' being the most common phrase used to describe that. So I feel as if at least action is being taken. I have to admit 'digital divide' bugs me a little bit and I'm going to take a moment to soapbox on this. It's almost as if people say, "It's your fault for creating the Internet. You created this digital divide." So, I'm sitting here thinking, "What is it you want? Would you like us not to create the Internet, so it's not available to anyone, and that's nice and even and fair?" My gosh, those of us who have been involved, and it's hundreds of thousands of millions people now, have done everything you can imagine to try and drive the cost down. The computers cost less and less to use the net. The software was available for free, we didn't patent it or license it or constrain it in any way. We have done everything you could possibly think of to increase availability of the Internet. So the fact that there is a digital divide is important, but I don't think it should completely subsume the fact that we have managed to grow Internet's population of users by 80% a year since 1988.

## The Value of the Internet

DSM: The larger obstacle to growth, if I interpret it correctly, is really less "can't" than "don't want to."

VC:   I don't know. I hear anecdotal reports of people who say, "I used it and didn't like it, and left again." Maybe I run in the wrong circle of people, but no one in my circle wants to give it up. Some people will complain, including me, about too much email. Yes, this is true, and they hate SPAM. I don't like SPAM either, but as a basic utility this is really hard to beat. So I think the real problems right now are partly economic and partly infrastructure. If you look in Africa for example, there's very little telecommunications infrastructure, and there's a lot of work to be done to create it. Without that, and without at least a reasonable economic engine, it's hard to make Internet very useful to someone.

In spite of all those constraints, restrictions and everything else, you'll find stories about magnificent uses of the network in every country in the world. Africa included, especially if you're looking for healthcare information or other kinds of economic data. Of course, in today's world, as we're seeing a tremendous transformation now towards the use of packet switching as the underlying technology for everything, including voice, Internet looms very large in literally all aspects of the telecommunications world.

DSM: What's going on now, after the 11th of September and the concern about fundamentalist regimes, their opposition to information technology. Doesn't it seem to you to be insurmountable?

VC: I don't think it's insurmountable because the Internet is not inevitable in any way. You have to work at it to make it go, but the utility of information sharing is impossible to underestimate. I'm sorry, is that right? I never get over and underestimate right. The point is, it's powerful stuff. You really, really cannot imagine what it's like to work without Internet now. If you're a scientist, shared databases are critical to your work. The ability to publish online and trade information back and forth in almost real time accelerates the pace of everything. So, yes there are going to be regimes that will try and stop the Internet. It won't work. You might as well stand in front of the ocean while there's a tidal wave coming in, saying "Stop!" It won't work. They may impede progress for a while, but as the costs come down for the capital equipment, and as more telecommunications becomes available, Internet will just naturally roll out.

DSM: Can you talk for a minute about your relationship with Tim Berners-Lee?

VC: Tim Berners-Lee did his work initially at CERN in Geneva around the late 1980's. 1989 is the common start date that I remember, and he was building this thing mostly for his own personal use. He called it "Enquire," as is "Enquire within." His idea was to collect a lot of data, imagery, text and everything else, from physics experiments and make it easy for colleagues to exchange that information. Eventually he settled on the term World Wide Web. I didn't actually get to meet Tim Berners-Lee until we both got the Jack Kilby award one year, I think in 1995 or so. In the meantime, of course I was very exposed to the work that he did because when Marc Andreesen did the Mosaic version of the worldwide web at the National Center for Supercomputer Applications, that Mosaic version propagated like wildfire through the Net. Every person who saw that application, saw the client, immediately understood what was going on said, "Oh my God, this is really something. It's a new, simple, wonderfully fast interface to the Internet, which up until that time had not been so easy to use. So by the time 1994 comes along and Marc and Jim Clark have gone off to start Netscape Communications, of course, the world now is in a huge fulminating boil. By 1995, even Bill Gates has figured out that the Internet is important, and the rest of the world has too. So suddenly you see www.dot almost anything, anywhere. I remember being stunned in a taxi in Japan driving down the street. I can't read anything that is on this thing on the back of the seat, except in the middle it says, Tokyotaxi.com.jp. At that point I said, "Boy, this thing is taking off."

## Rejoining MCI in 1994

DSM:  It's arrived.  Now this also about the time you rejoin MCI.

VC:    That's right.

DSM:  Tell that story.

VC:  This is really ironic, because the first time I join MCI, I'm working for Bob Kahn at ARPA in the information process techniques office, and Harcharik hires me away. Then I go back to join Bob in 1986, and then I get a call from Harcharik who had retired from MCI and had gone off on his boat, and was hired back to get MCI in the data business again.  So he starts in 1993, and I'm consulting for him on things like frame relay.  Finally he calls at the end of 1993 and he says, "I need you to come back to MCI again to get us into the Internet business."  So I struggle for several months over whether I want to do that.  I'm having a great time doing R&D, and I'm enjoying CNRI, but the opportunity to do something on the commercial side and have a direct impact by presenting and offering a service that people can use, as opposed to doing kind of basic technology work, was almost irresistible.  So finally I told Bob Kahn that Bob Harcharik had done it again.  He was hiring me away.

## The Miracle of Cochlear Implants

DSM:  Two stories I want you to tell related to 1996 and 1997.  You and Bob were honored by the Smithsonian, and then by the President of the United States.  Then on the personal side, a wonderful thing happened.  Would you tell us these two stories?

VC:  Why don't we do this in chronological order?  Around 1996, my wife Sigrid started to get curious about the state of the technology of cochlear implants.  She and I knew that the research had been going on 25 or 30 years.  These were electronic devices that could replace the function of the inner ear.  Sigrid, who was born with normal hearing, lost her hearing in 1946, when she was 3 years old.  In fact she even went to the John Tracy Clinic in Los Angeles.  So incredibly Sigrid and I were both in Los Angeles in 1946 at the same time, but of course our families didn't know each other, and we were only 3 years old at the time.

DSM:  So her hearing loss was much more serious than yours.

VC:    Much more serious.  She essentially was profoundly deaf by the time she lost her hearing. Spinal Meningitis, with its very high fever, just destroyed the ciliar hairs inside the cochlea.  She wore a big body aid, but she got very little sound from it.  She had a 95 to a 100 decibel loss compared to my, at that time, 10 or 15 decibel loss.  For many years we had followed the story of cochlear implants, but the news had always been very mixed.   Then in 1996, she got onto the Net, started poking around to see what was going on, and the reports were getting better.

So she went and tracked down people on the Net who had had recent implants and corresponded with them for several months to follow their progress and how it was working out.  She was persuaded finally, that she might present herself as a candidate for an implant at Johns Hopkins University.  So she called through a relay service and didn't get any response.  She sent a fax and didn't get any response.  Finally she got information from a guy in Israel who had the email address of the surgeon who does this at Johns Hopkins.  She sent him an email and got an immediate response.  So now we know how to reach these people, it's by email.  Sigrid went up to be tested, and they said she was a good candidate so they scheduled the surgery.  It's an outpatient operation.  You go in in the morning, you get the implant, then you come home.  Her head was all swathed in bandages and everything, and they don't actually turn it on for several weeks until everything is healed.   They want to make sure that the implant that goes around inside the cochlea doesn't move before they hook everything up.

So several weeks after the actual surgery, she went back to Johns Hopkins.  They were going to activate the system.  It comes in two parts.  There's the implant in the ear, with about 16 different electrodes that touch the auditory nerve inside the cochlea.  It's actually imbedded into the nerve tissue.  Then there's a little transducer with some electronics on it that is also imbedded inside the head.  Then you have a speech processor, which is about the size of a large pager, and it is taking sound in from a microphone.   It's doing a 40A transform on the sound so that you know what frequencies are present and with what amplitude.  Then it decides which of the 16 little implants it's going to stimulate electrically in order to simulate what the auditory nerve would have detected from the inner ear's ciliar hairs.  The simulation is so good that for all practical purposes, it's like being able to hear normally.  So Sigrid has this thing turned on and….

DSM:  Were you there?

VC:    No, no.  She sort of doesn't like me to hang around at hospitals.  I'm not good in hospitals.  At the first sight of blood, I'm gone.  So I'm at a board meeting here in Washington. Sigrid's gone up to have her implant activated, and about twenty minutes after they turn this thing on she calls me in the board meeting.  It's the first time we've talked to each other on the phone in our 30 years of marriage.  It was unbelievable!

DSM:  What an incredible story!

VC:    It wasn't a very terribly deep conversation, I can tell you that!  But it was an important one.  Of course, now what I have is a 58-year-old teenager.  I can't get her off the phone.

DSM:  Music?

VC:    Everything, every possible db of sounds, Sigrid's going to grab.  She carries patch cords that connect to every possible sound source.  She can wear a Sony Walkman and plug into it and listen to prerecorded books.

When she goes on an airplane she carries a patch cord to plug into the armrest.  What is neat about that is that the screaming kid is completely cut off, because the only sound you here is what's coming from the sound system on the movie.  She's listened to 350 recorded books now.  She uses the phone, listens to the television, the radio and goes to plays.  When she goes to lectures she carries an FM transmitter with her, puts it on the lectern, and that transmits a signal to the receiver that she plugs into the speech processor.  When she's at restaurants we've got wires scattered around with microphones on them and she can plug back and forth. It's unbelievable.  It's incredible.

DSM:  Extraordinary.

## The National Medal of Science and Technology dinner at the White House

VC:  So that's the 1996 wonderful event.  Now, you asked about 1997.  In 1997 the National Medal of Technology is awarded to Bob Kahn and to me for our work on the Internet.  It was at the White House, and there was a peculiar thing that happened at that particular event.  It's like being in 3rd grade again.  They line up all these scientists who are getting recognized for their work, the National Medal of Science and Technology, and they give you a number to make sure you get back in line in the right order, and you practice going in and sitting down.

Comes the day, we file in and the President is going to come in after us.  We come in first and then, "Ladies and Gentlemen, the President of the United States."  So Bill Clinton walks in, of course everyone is standing and clapping, and then it isn't clear when we're supposed to sit down.  The program starts and we're all still standing up.  No one knows quite what to do.  Finally the President says, "Sit down," and everyone sits down and we're all feeling like idiots.

DSM:  That's great.  Tell the millennium evening story you told me earlier.

VC:   Oh my, okay, well there are several things about that.  We got a call I guess in October 1999, asking if I would come and participate in one of Hillary Clinton's Millennium Evenings.  The subject was going to be genomics and informatics.  The representative from the genomics side was Eric Lander from MIT.  So he and I sat down together and talked about what we were going to say. We talked on the phone about it, and we met at the White House, and the President and Mrs. Clinton were there as well.  It was an unbelievably magic evening.  The two of us were completely engrossed in our conversation.  I think we frankly ignored the President and Mrs. Clinton for a portion of the three hours that we were on the stage, but we were going back and forth about all this.  I wanted to call this evening "DNA meets DNS," for the Domain Name System meets Deoxyribonucleic Acid, but the people who put this thing on said it was too "geeky."

During that evening I also told people about Sigrid's implant, and introduced her surgeon, John Niparko, and the President was completely mesmerized by all this.  But what was truly ironic about the evening is that after the show was over, we went for a reception and Sigrid was talking to the President.  Her surgeon was there.  We had invited him to come along.

So the three of them were chatting and I was off doing something else. So I didn't hear this part of the story until about two weeks ago. Apparently they were talking about how the implant works. Sigrid was wearing the speech processor clipped into her bra, and she was going to show the President the speech processor. This was after a lot of the Lewinsky stuff and everything else, right? So according to Niparko, as she reaches into her blouse to pull this thing out, several of the presidential aides come rushing over as if to say, "Oh my God, what's he done now!" And the President says, according to Dr. Niparko, "Oh I guess I'm not allowed to see any underwear around here anymore."

## 1994: Focusing more on the Internet at MCI

DSM: That's a great tale. Now back to 1997 for a second, when you're in Data Architecture you're promoted to Sr. Vice President for…

VC: Internet architecture and technology, right. Actually I came back in 1994 as a Senior Vice President. I was Senior Vice President for Data Architecture and then I focused more heavily on Internet.

DSM: That was the change I wanted to talk about, the significance of changing your title from data to Internet.

VC: It's just because the Internet was taking on such a larger importance. So I handed off the other data technologies, ATM and frame relay, to someone else and focused strictly on Internet.

## Into the Future

DSM: This has been an extraordinary time in the history of the information technology business. Through the best of times and the worst of times, there's stuff going on that has been tremendously exciting and it's been difficult as well. What excites you most about what you're working on now, and what do you see as the big difference?

VC: The thing that I'm most fascinated by is this continuing subsumption of all telecommunications services onto an Internet base. We're seeing more and more use of the Internet for telephony and now video conferencing. We're seeing multicasting and streaming audio and video, and as the data rates continue to increase and as access speeds go up, more and more of this will be common and prevalent. There is a deep sense now that information is becoming a thing in it's own right. Information objects are becoming things that you manipulate in this environment like we used to manipulate arrays and spreadsheets and things like that. Now we're making information itself be an object of some stature. Intellectual property management is becoming very important because so much of it is online, so much of it is digital. So there is a continued evolution there.

I also am seeing an increasing number of devices that are Internet enabled, and what that means is that we can do things with them that we couldn't do before. For example, a videocassette recorder that has been Internet enabled could be on the Internet as well as plugged into the cable system, but I could be talking to a speech understanding computer on the Net saying, "Please record Star Trek at 10 o'clock on Sunday night." That can be translated once it's understood into the correct instructions to get the VCR to do that, so I don't have to go find an 11-year old to program it. The idea of being able to interact conveniently with all kinds of devices that serve you in an automatic way, is very appealing to me. We're starting to see this happening in automobiles, with literally dozens of computers in the car capable of gathering data, reporting information, accepting control and the like. So that's a trend I expect to see continuing. In fact, now we're expecting many, many billions of such devices on the Net, more than there are people. And that means we have to expand the address space, and that's why there's a big push to go from the version 4 protocol we use today that was standardized in 1978, to the version 6 protocols that were standardized in 1996 and are having a tough swimming upstream time being adopted. But that's no different than the early days of TCP/IP. No one wanted to do that, and we had to beat them into it. So I see that happening as a continuing process.

Perhaps the most fascinating thing right now for me is a side effect of an appointment I have with the Jet Propulsion Laboratory. I'm a visiting scientist at JPL, and the project I started there with my colleagues is to expand the Internet to interplanetary scale. So we now have a design for the interplanetary Internet. The Jet Propulsion Laboratory has been reorganized by its new director, Charles Elachi. We're now taking the deep space network, this is the big antennas used to talk to the Mars vehicles and the Rovers and the various flyby spacecraft, and we're transforming that into the basis of the interplanetary backbone. My colleague there, Adrian Hooke, is managing the program along with 5 engineers that we networked together for three years to develop the architecture and the protocols, and now we're the process of actually implementing it. So over the next 20 or 30 years we will see the network expand to cover interplanetary space. There's even some discussion right now of the possibilities of an interstellar version of the system. It's not as crazy as it sounds, because if we can get a spacecraft to go 1/10 the speed of light, which we can't do today, but if we could just get to that point, it will only take 40 years to get to the nearest star. Once you deliver the payload, it only takes four years for a radio signal to come back. So you could have within one person's lifetime, an interstellar mission, in which you launch the spacecraft, it gets there in 40 years, and you get the signal back in 4 more. So from age 20 to age 65, you could, if you were interested, encompass an interstellar mission and get information back. That could be pretty amazing. So here it's only 2001 and we have a hundred years of this century to go. What will it be like in 2101?

## Defining Integrity and Honor

DSM:  One of the questions I've asked all our interviewees is about their concepts of integrity and honor.  You've been in a position in which, especially considering the dot.com mania of the past few years, during which you must have been subject to many, many temptations.  What's your definition of honor and integrity?  Or is there a person (real or fiction) that comes to mind, who you feel really represents high standards of integrity or honor?

VC:    That's actually a harder question to answer than one would think, until you've been asked it.  There are several things.  Integrity for me is kind of brutal honesty, in a way.  When it comes to scientific integrity for example.  If you fake your results—I can't think of the bad words I would want to use.  So being honest about your research work is really critical.  One of the things I admire the most about some researchers who are brutally honest with themselves and others about what works, what doesn't work, what things were successful, which were not, and why not.  There's someone named John Shoch, John was at Xerox PARC in the early days of the TCP/IP development work, and he was actually working on a competing design with Bob Metcalfe, called the Xerox Data System.  But he and Bob and others would come to my seminars at Stanford, and they were pretty forthcoming with experiences that they were having with their designs, and what worked and didn't work.  Even though that was being kept as a proprietary protocol, they sort of managed to skirt around and not release all the details, but they were able to say, here's why things didn't work and why they did.  And I remember being very impressed by his sharing of successes and failures of their work.  I've always admired people who were capable of doing that.
I guess another important element for me is that some of the smartest people I know are also the most modest.  Don Knuth is an example of that. The man is brilliant, but he doesn't behave as if he thinks he's smarter than anybody else.  There are a lot of smart people who don't behave that way, who immediately let you know how smart they are or how dumb you are, and I have less respect for people like that.  I can accept their brilliance and intelligence, but at the same time I  think that I find that to be less satisfying because they don't recognize the strengths in other people that they could. For some reason they don't seem compelled to do that, or they don't feel they shouldn't recognize other people's strengths.  I can learn from everyone, because everyone knows a lot more than I do.  I've never found someone that I haven't been able to learn something from.  I'm much more worried about having anything of substance to say to someone.  In fact, I was giving a keynote talk yesterday, and I had admitted to the assembled crowd that the two worries I always have whenever I'm doing public speaking is that I won't have anything of substance to say to anyone, and the second worry is that they'll figure that out.

## The Origins of Innovation

DSM:  Or you'll continue on at length.  The second question is about innovation, from whence it comes.  You've have worked with some of the brightest, most innovative; not only in an abstract sense, but in an applied sense of putting that knowledge to work, of anybody in the world.  Where does innovation come from?

VC:    Part of it is being willing to think literally, out of the box.  In other words they think about different ways of actually doing something.  A lot of it comes from deep understanding.  The people I find most creative are also the ones who really know a lot about what they're doing.  They either know a lot of physics, or a lot of math like Kleinrock, he's a good example.  He is a phenomenally good mathematician when it comes to queuing theory.  I remember vividly watching him derive all these equations on the board at top speed, and I know that he was doing it on the fly.  He wasn't memorizing it, because every once in a while he would make a mistake and we would have to correct him.  So I know he was doing the work on the fly.  But after we'd get done, he'd put out the formula and then he would go through every term of the formula, and he'd explain what it meant intuitively.  This is why, when you look at the way these expressions are put together, this is why it blows up.  The "Y" goes to infinity here because of that term, and the reason for that is…and he'd go on from there.  So depth of understanding is like that.   Bob Kahn is another one like that.  He has enormous breadth and knowledge.  Danny Cohen is another colleague who has expertise in so many different areas.  He was very instrumental in doing voice over the Net way back in the 1970's.  Today it's a big deal, voice over IP.  Danny was doing it in 1975, along with a lot of colleagues at Lincoln Laboratories.  But innovation comes from people who have a lot of deep knowledge, who can draw on that understanding, and come up with ways of doing things that few other people can think of because they just don't know enough. It's not that they're stupid.  It's not that they don't have any creativity.  It's just that they don't have the ingredients.  So a lot of innovation is a consequence of knowing a lot.

Innovation is also a consequence of circumstances being ready.  The ability to build the ARPANET was very dependent on the fact that companies like Honeywell and Digital Equipment Corporation were building low cost, medium-sized machines.  Instead of having to pay a million or two or six or ten for a computer, you could pay $100,000. Today that's outrageous, right?  You can buy a much more powerful processor for $300. But in that time, in the late '60s, buying a machine for $100,000 was really important. So, things happen when it's possible for them to happen.  And when you see things like worldwide web going on, and you know that Doug Englebart figured out the same thing in 1965, but all he had was one machine to do it on; and I don't mean to take anything away from Tim (Berners-Lee) because Tim made it work in a highly distributed way, but Tim's idea wouldn't have been very interesting unless we had hundreds of thousands or millions, and today, hundreds of millions of computers on the Net.

So you often find innovation happens only when it's time, when it's possible to do it. All one has to do is look at daVinci's drawings for example, to realize that the man had ideas that he could not realize because the technology simply wouldn't support it. He had wooden gears that just likely wouldn't hold up. He didn't have the technology to create it. Look at Babbage, when Babbage was doing his difference engine. He had to do it mechanically because there were no electronics. It took the invention of the transistor and the vacuum tube and so on to make computing what it is today. So even if you understood how to do it, unless the technology is ready to support it, it won't work

DSM: I've heard the kind of intuitive grasp in mathematics compared to the soul of music, the feel you get because you've practiced and played so much. Seems to me that was sort of what was going on in that Math Club experience. You were constantly practicing and doing stuff.

VC: That's interesting.

DSM: Did you ever find yourself noticing that you had made that transition to the point that you didn't have to crunch out?

VC: It comes less from mathematics than it comes from the design of computer communication protocols. The real crucible for the TCP/IP work was the work Steve Crocker led on the networking group, the NCP protocols. We had to slug our way through those. We had no idea where we were going. This is completely unknown territory. Having gone through that experience, prepared me for analysis of what didn't work, and what things wouldn't work as we changed the environment. So today as I deal with computer communication problems, I do feel and call upon an intuitive sense of what works, what doesn't work, and why it doesn't work, and you can see the problems. They just pop out at you. Somebody will say, "Well, this is what happens." And I say, "Well I know why that happens, because of this and this and this." So for me anyway, that's sort of like the physics of my world. It's knowing what and how these negotiation protocols behave, and how they can misbehave, and what can go wrong is more intuitive now than it was when we were doing this work 30 years ago.

## Will Anyone Remember Vinton Cerf?

DSM: Last question: We hope that graduate students 100, 200 or 300 years down the road will look back on the crude technology and people at the turn of the century, and think that's we've done a good job and made a contribution. My own prejudice is that this is an extraordinary and important revolution that we're a part of. When your children's children's children look back on you from that perspective, how would you like to be remembered?

VC: It would be nice if I were remembered at all. My sense of all these things is that we, who live through this, know about the individuals and their stories and the interactions and the conflicts in detail.

Then as time goes on there's less and less of that knowledge, and there's only the recognition that something happened. Like the telephone today, we still associate that with Alexander Graham Bell, but there were some other parties, like Elisha Gray and some other folks who had contributions. Like Marconi in radio, there were a number of people involved. We mostly remember the telephone got invented around 1876. Television starts to show up around 1952, and how many people remember who were the parties who invented it? I don't expect to be remembered in 100 years as Vint Cerf, or even at all, but I think people will remember that something happened in the mid to late 20th century that transformed telecommunications and that thing's the Internet. And I do believe they'll remember that, even if I'm just a dim memory in somebody's history book.

DSM: Modestly said. Thank you very much.

## *Bindings*: The Book

VC: So now you have more material than you could possibly know what to do with. Speaking of archives, I've now become very good friends with John Carlin who runs the national archives, and the reason is that he and my wife are closely related. They're all part of the family of Swedes who came through Wichita, Kansas in the 1800's. John used to be governor of Kansas before he was selected to be the National Archivist. I'll tell you, there is a book that I want to write. I'm dying to write this book. When I got the Marconi Award, I told people what I wanted to write. The book is called *Bindings*. I am fascinated by how many things are bound to many other things, some of them for a long period of time, and some very brief. When we go to a hotel, you're bound to your room number for a short period of time. And you're bound to your marriage partner, for as long as you're alive, at least. You're bound to your colleagues. I'm bound to this company and this room. Looking at how many different bindings and linkages that there are in the community that I work and live in is absolutely fascinating to me, absolutely fascinating.

The longer I live, the more linkages I discover, and I wonder, how much of what actually happens is a side effect of who is linked to whom? In the whole story that we've been taking about the last several hours, the same names keep popping up and relationships to each other. So everywhere that I turn, I see all these various relationships. And I'm thinking, in respect to innovation, that a good deal of it has to do with the human capital, the human raw material that is there interacting and exchanging ideas, testing, pushing, debating and so on. It's like what we watch happening today on the Net. It's so accessible. The technology is so open and transparent that a million people try a million experiments every day, most of which don't do anything interesting. But there's so many experiments going on at the same time, that at least something happens every day, or three or four things. It's like an ant colony. There are a million ants running around, most of them don't find anything, but every day there's so many of them out there that somebody finds something interesting to bring back to the colony. So a lot of what's happening on the Net is a side effect of enormous amounts of creative attempts happening in parallel.

DSM:  Next to sex, I guess genealogy is one of the major uses of the net.

VC: There's a very peculiar observation to be made then, because the reason that genealogy has been so enabled is a religious belief in the Mormon Church that you need to baptize all of your ancestors so that they too, will go to the same place you're planning to go to.  So in order to do that, you have to keep track of them all, so you can get every one of them.  The side effect of the Latter Day Saints' interest in that particular practice has been an enormous blossoming of genealogical interest in the US and elsewhere, because it's accessible online.  Here we are taking these two very disparate, independent things, the LDS practices and the Internet, you wouldn't think they had anything to do with each other, but you put them together and all of a sudden, everybody wants to know, "Where did I come from?"