Oral History of Jerry Burchfiel

Interviewed by:
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Marc Weber: I'm Mark Weber of the Computer History Museum and I'm here today it's Friday June 5, 2009, with Jerry Burchfiel networking pioneer at BBN, and we're here at BBN. And thank you very much for sitting down with me.

Jerry Burchfiel: Well, thank you for having me. I've been here at BBN for 41 years now came directly here from MIT just moved up the street, and never moved on. I like to say that I came to BBN before we invented dirt, and everything else since then.

Weber: Going back to the very beginning, where were you born and raised?

Burchfiel: I was born in Tulsa, Oklahoma, and raised there -- went to MIT never went back.

Weber: And were you interested in technical things as a child, what lead you toward computing?

Burchfiel: I was doing all kinds of electrical hobbies when I was back in junior high school and from then on building citizens band radios they called them children's band radios in those days. But I'd always liked the electronics. So I went into it when I went into MIT.

Weber: Were either of your parents involved in technical field?

Burchfiel: No, well my father was a reporter, so that's some kind of technical field.

Weber: So you knew you wanted to be an engineer?

Burchfiel: Yes.

Weber: Then in high school did you do a lot of science courses?

Burchfiel: Science fair projects, yeah.

Weber: What was your major at MIT?

Burchfiel: It was electrical engineering. Those were the days before there was such a thing as computer science. Nowadays they're still electrical engineering department, but it's all computer science. They don't bother with voltage current, that kind of stuff anymore, passé.

Weber: When did you first get interested in computers?

Burchfiel: Actually it was when I was working on my doctorate I was working part-time out at MIT Lincoln Lab, and trying to develop a program for calculating electromagnetic waves, and wave guides. And in those days it was punch cards old Fortran, job controlled decks, and it was utter misery. So I decided if something really needed work it was the computers not the electrical engineering part.

Weber: What was the first computer you remember?

Burchfiel: Well it was PDP-1 here at BBN when I came. They use to play Space War on that and developed an initial early time-sharing system. Then once I was here I worked with Ray Tomlinson, and Dan Murphy on a new time-shared operating system called TENEX that was both economical, could run on a half a million dollar machine as opposed to a $5 million machine like some of the other time sharing systems. And it was highly networkable. In fact that was one of the first big jobs was getting TENEX onto the Arpanet. Actually I want to say a word about the Arpanet as long as I've got that topic open. Some people say that the Arpanet was developed to help the country survive nuclear war, but it wasn't that at all. I got to talk with Bob Taylor who was the Director of IPTO, Information Processing Techniques Office down at DARPA at the time who was the force behind it. And his complaint was that outside his office in the hall he had a Model 35 teletype to talk to SRI and a different teletype to talk to UCLA and a different teletype to talk to BBN. And the hall was filling up with stupid teletypes, so he wanted to have one machine he could use to talk to all his contractors, and that was the genesis of the Arpanet.

Weber: And also <inaudible>[perhaps Licklider] had done there was the intergalactic network idea which I guess fed into that.

Burchfiel: Yeah, he was working at Project Mac at MIT, and they had kind of competing operating system the Multics, but it was running on computers 10 times more expensive. So we were getting an affordable solution it was the first time that virtual memory paging was put into a PDP-10 computer then later became DEC's Tops-20 operating system.

Weber: Give me the chronology of it, so you went to Lincoln Lab right as soon as you graduated?

Burchfiel: No, I was at Lincoln Lab part-time in the summers. And I actually had a Radar Group out there, and part-time here as well.

Weber: As a student?

Burchfiel: Yes, and then I went full-time once I got my degree in '68.

Weber: And so you got PhD?

Burchfiel: ScD actually at MIT it went straight through Bachelor, Master, Doctorate. They call that a lifer.

Weber: So how many years then?

Burchfiel: Just over eight.

Weber: Still three degrees. So you've done a number of summers at Lincoln Lab, and here?

Burchfiel: Yes.

Weber: So you knew people at both places?

Burchfiel: Oh, yeah.

Weber: And why did you choose BBN or why did they choose over Lincoln Lab?

Burchfiel: BBN was much more exciting with all of the new technology bubbling up in the computer field. Lincoln was kind of a slower pace, and they had a $100 million a year out of the Government no matter what. Whereas at BBN it was kind of dog-eat-dog, you had to compete it made it much more exciting.

Weber: The cultures, what were the two institutions like were their differences in the two places?

Burchfiel: Well for many, many years BBN was a place of gentlemen scholars. Walk down the hall, and everyone you bump into has a doctorate. Lincoln wasn't quite that way it was more engineers building radar systems, so it was more intellectual here.

Weber: So the kinds of conversations would be different, chatting in the cafeteria?

Burchfiel: Sure, engineering versus technology and science.

Weber: So then you took the job at BBN, and tell me what happened then.

Burchfiel: Well, as I said the first project was this TENEX time sharing system Bob Taylor successor at DARPA it was actually it was ARPA in those days, and only became DARPA later on, was Larry Roberts, and he was the guy who was sponsoring our TENEX work, and also pushing the Arpanet at the same time. So that all worked out very well together, in fact, we two groups here at BBN that were somewhat synergistic that on this side of the building was the Arpanet group building the network. And over on that side of building was the host group TENEX, for instance, building computers to go on the network. It was kind of a love/hate relationship, and saying that, "Hey we need more out of the network. Hey those shouldn't be doing that kind of a thing."

Weber: Ray Tomlinson said that TENEX originally conceived as kind of an internal support function in a way, you needed a system like that.

Burchfiel: Yeah, it was for the speech research there weren't any computers big enough or affordable enough to do the amount of computing that they needed to do for us with understanding. So we used PDP-10, and then turned it into--the trouble in those days was that it was impossible to get enough memory to do these big problems. A 16k words memory unit was the size of a refrigerator, so it was all impossible to get enough real memory. So that's why the push was on for virtual memory that let us keep all the big data out on disc, and automatically bring it in for processing as needed. And that was one of the first big projects on there was speech understanding.

Weber: Who initiated TENEX, were you asked to do it?

Burchfiel: Well, it was kind of mutual between us, and ARPA coming up with ideas, and then negotiating back and forth, what could we do, what schedule, what money, and we agreed that this was worth a shot.

Weber: And so it was you, and Ray that were assigned?

Burchfiel: Ray and I and Dan Murphy were the three people that worked on TENEX.

Weber: And your respective roles?

Burchfiel: I was focusing on hardware, Dan Murphy was on software, and as usual Ray did everything--he was on both sides.

Weber: And what was like working with those guys?

Burchfiel: Oh, terrific. In fact Ray was amazing. Developed a lot of new hardware, and in the evenings often would come in to try and debug it, and get it working. And so the most powerful tool that we had in those days to debug the hardware was a quart bottle of Miller beer, and that's what we used in the evenings. So we had fun.

Weber: And so you became friends with these guys?

Burchfiel: Oh, yeah.

Weber: And you were all single grad students, just first job?

Burchfiel: Yeah, that was also the time when I got to start working with Bob Kahn. In fact he was here at BBN I was in the office next to him, and we were always talking about host computers, networking, how to make it all work together. And many evenings we would-- I was commiserating with him, he was really concerned about his architecture, and algorithm and protocol design on the Arpanet that there was--he saw a flaw in it there was a danger that the host or sorry the IMP (interface message processor supporting the host) could hang up with reassembly buffers that couldn't be put together in order, A can't be done until B done, B can't be done until C is done, C can't be done until A done. One IMP hangs up then it would immediately spread, and hang up the whole network. Bob came up with that. Other people viewed that as just a theoretical problem nothing to really worry about, but of course Bob was right, and then there was a great Christmas crash that brought down the whole network with exactly that reassembly buffer lock-up. And at that point then everyone decided, well this is more than just theory it's something we've got to fix, so Bob was vindicated.

Weber: And so you came in '68, and so yeah that was really when the, I mean, the IMPs finished in the fall of '69 [were] first installed. But you were really there during the most intense period you were over in the other building?

Burchfiel: Right doing host side at the same time as the network side was coming together, and then trying to make it work together.

Weber: Any particular memories of seeing the IMP team work were they very frantic?

Burchfiel: On some things we worked closely together; like Dave Walden, you mentioned, was working on the TIP Terminal Interface Processer, that lets you hook up terminals directly to this device on the network without an intervening host. And Dave and I were going back and forth on the protocols all the time would see reliability problems, hang ups, and so on. And so we were working from both sides of the interface figuring out how to cure the problems, and coming up with new standards that then would propose to the IETF Internet Engineering Task Forces [undoubtedly Jerry was really talking about the Network Working Group at that early time], standards documents, and it carried a lot more weight when both of showed up talking about both sides of the interface how to fix the problem, so that worked out well.

Weber: And after TENEX what was your, well I guess that continued for quite awhile.

Burchfiel: Well TENEX got proliferated; Larry Roberts was pushing to see general use of the technology he developed, and TENEX actually got propagated to 12 different sites on the Arpanet, universities, researchers. And so it was the most populous system on the Internet [ARPANET]. And at least in that sense big success and Larry was behind it all the way pushing that he saw that this was an opportunity for computer to computer communications which was the way he viewed the Arpanet, so what that was going to do for him. When Bob Kahn, two years later, went down to DARPA himself he then founded the packet radio project that was BBN, Rockwell Collins, and SRI working together on different components of that system. The packet radio project went on and on had incredible life in different guises became the low cost packet radio, became SURAN, Survival Radio Networks. And then it grew into military applications with NTDRm, Near Term Digital Radio, the DARPA, SUOR Small Unit Operations Radio, and now those same algorithm are in the JTRS Joint Tactical Radio System that's being deployed as we speak. So we've got a 35 year long genetic path from the algorithm here to the algorithm there.

Weber: The last one is Ray Tomlinson was saying there's a current project for extending a network from without any central host of any kind just by putting in the little nodes is that the...

Burchfiel: That was the philosophy of the Arpanet in the first place there was no central control where everything is completely distributed.

Weber: But there's a current radio project like that, that's not what you're...

Burchfiel: Oh, you're right the initial packet radio project did have centralized controller called the station, but then as soon as we went to these successive generations it became fully distributed because that's a lot more reliable.

Weber: But there's a current project doing something similar?

Burchfiel: Well, all of the projects for decades now that BBN has done have been using fully distributed protocols because they're a lot more survivable. Now you mentioned Ray: one kind of a significant event happening he was working on, not only on, the TENEX operating system but on applications for it. And after a long weekend I came back, and Ray said, "Come over here I want to show you something." And

he demonstrated a message, an e-mail message, going from one computer to another one across the Arpanet, and I said, "Oh my God, don't tell anyone we're not supposed to be doing that under this contract. Don't let the information leak out that you've got that kind of a thing." But of course it did leak out, and it was really fault of Larry Roberts. Ray wrote the send message program for generating the e-mail figured out the character to use to separate user names, and host names by looking around his keyboard, and right there on the top row was the at sign so he put that in. And then Larry Roberts wrote… started receiving this e-mail, and he needed to organize it, and so he wrote a program called "read mail" that would let him sort and file and so on. Those were the days when a DARPA program manager would jump right in and write code, and distribute it to everyone. Larry did a lot more then write the code he decreed for any of his PIs to get funding they had to communicate with him via e-mail. So suddenly the whole world jumped on e-mail, and that ignited the virus.

Weber: Do you remember when that was roughly?

Burchfiel: Seventy-one or seventy-two something like that.

Weber: Wow, okay, and the client he wrote he distributed them?

Burchfiel: Yeah, that was just an application that ran on TENEX.

Weber: And is that any idea of any surviving code from any of this?

Burchfiel: No, the machines turn over every few years, and the old punch cards and deck tapes and reel-to-reel mag tapes all get trashed.

Weber: Or printed source code sometime.

Burchfiel: That too, after Ray did that first e-mail system then Larry sponsored us to do some deliver[able] e-mail [system] rather than accidental. And we did a system called Hermes Internet mail, and military message system where we installed it out in Hawaii for the military to use. And then we got into the standards business working with the IETF RFC 822 standardizing mail formats. And then it really became Internet standard.

Weber: And the ARC lab at SRI was also using e-mail a lot where they contributing to the standard?

Burchfiel: Yes, almost all of the DARPA researches were working on the standards, and giving contributions there. We were the ones that were actually writing the code and distributing it although, they did as I remember make a few changes to it in their copy of it.

Weber: This is from many, many years ago when I interviewed Doug Engelbart, and I remember him talking about sort of e-mail wars in the '70s. There were some people wanted much longer headers, and shorter headers.

Burchfiel: Well, that was all finally standardized in that RFC 822 that we had put into the ITEF, and that kind of nailed down the text, and header formats that everyone adopted after that. As I remember SRI did

some key innovations, one of them was a predecessor to the mouse it was a little like five finger key board, and you could play cords on that, and put in inputs; and they had a thing called NLS Online System that was a predecessor to the web; you could click on a link, and it would take you there, so it set up the web idea in the first place. So they've made some nice contributions.

Weber: Leading up to the final standardization do you remember some of those issues that people were, what were the different camps around e-mail?

Burchfiel: There were some arguments over whether it should be in binary form or text form, and we won that one because everyone wanted to be able read anything that came to them instead of having binary interpreter. I don't remember fights so much as just a polishing, and refinements there were endless meetings, and lots of people contributing ideas. And they mostly worked their way into the standard, so it's gotten better and better over the years. And now it brings us hair re-growers, and body re-shapers, and everything you could want.

Weber: Who was working on the standard?

Burchfiel: Okay, for e-mail by that time I was running the Interactive Systems Department had about 25 people working on variety of programs many of them were applications of TENEX. And actually we had a group that was working on the e-mail stuff the Hermes group, and they were actually pushing ahead with standards not only the IETF, but also at the International Standards Organization ISO, and they had pretty much parallel development on the standards.

Weber: Did you go to Geneva, and stuff?

Burchfiel: No, but some of the people in the group did attend at all of those meetings.

Weber: And so you had become a manager by this point.

Burchfiel: Yeah.

Weber: Tell me a little bit just the path of your career, so you came in and who were you working for first?

Burchfiel: Jerry Elkind was my first boss here, terrific guy. Maybe that was the reason I came here instead of Lincoln Lab was Jerry, inspirational.

Weber: Had you known him before when you came in the summers?

Burchfiel: Yeah, from summers, I finally decided hey if I'm going to work full-time this is the guy.

Weber: What's he like?

Burchfiel: Very smart, very pleasant.

Weber: And so it was you and Ray and the third fellow?

Burchfiel: Dan Murphy.

Weber: Dan Murphy were all working for him?

Burchfiel: Yeah.

Weber: How long did you stay in that role?

Burchfiel: I don't know it was the early '70s that I became a department manager and then collected like 25 people an assortment of projects including the packet radio which was a Bob Kahn initiative when he was at DARPA, and seeded that here.

Weber: But there were steps in between that because that's a four year period, right, three or four years?

Burchfiel: Oh you're reaching back into the dim mists of antiquity now. One other guy that I should mention that I enjoyed working with was Vint Cerf. I remember when he was a Professor at Stanford. And at one point I got to actually give him tutorial on how to write a DARPA proposal, all the hints and techniques and so on to suck them into giving you their money. And I had no idea that two years Vint would be down at DARPA those days reviewing my proposals with a great deal of skepticism, so I'm not sure that worked out right.

Weber: You met him when you were out there on a visit?

Burchfiel: Part of the TENEX program we were going around to all of the sites nationwide. Vint was certainly involved in the Stanford work.

Weber: I mean a lot of important things happened at these meetings, and travels. So what were some of the main offside events that you went to where you met the Arpanet community?

Burchfiel: We had a kind of traveling road show once every six months to a year we would go around, and visit the various TENEX sites, and the researchers would come in and tell us what they liked, and what they didn't like. Spent a lot more time telling us what they didn't like then what they did like. And so that gives us a lot of suggestions for the next round, and of course that could get turned into the next DARPA proposal as well, so that all worked out pretty well.

Weber: So how many of you would go around usually?

Burchfiel: Two or three depending on whether it was big meeting or smaller meeting.

Weber: And then you had TENEX regular conferences or larger meetings rotating or different places?

Burchfiel: Yeah, well it was telephone, and e-mail mostly I mean now that we had the network why not use it. Why not avoid some of that travel.

Weber: And early use of e-mail do you remember when things you did early on with e-mail?

Burchfiel: It was DARPA projects, Larry had sort of forced all his PIs on to that, and of course Bob Kahn, Vint Cerf followed up with that e-mail was the way DARPA did its business, did all of its communicating and proposal acceptance, and so on by e-mail, so it was very efficient. At that point after Vint went to DARPA he took over as program manager down there of the packet radio project. And so he was sponsoring us as we were doing packet radio, and then a little later towards the mid '70s got into the Internet we were calling it gateway, but today it's called a router connectivity between multiple heterogeneous networks. And Ginny Travers was involved in that, and created the first router, and installed it over in Norway in 1976.

There we were struggling with the concepts, first question was, what if we want to get traffic back and forth between these multiple different networks do we build a node on this network and a node on that network and then somehow hook them back to back with twist pairs to push the data through? Well that wasn't what we did. After some struggling we went with a layered approach. So we had in one box the gateway router, a layer two module that would talk to this net, layer two module that would talk to that net, and then layered on top of those was IP; the layer three module that would carry packets back and forth between the two networks and also talk with its peers to do routing to figure out how to get across network, network, network, to the far end.

Weber: And who came up with that design?

Burchfiel: Ginny Travers, and me, and Ray Tomlinson we were all working on how to connect those multiple different networks together. But she was the one that actually implemented it and installed it. Now Vint Cerf was the theoritician oh, and Kahn, theoriticians behind that deciding what should be done and they came up with the TCP/IP protocol. And of course, we had a lot of kibitzing and inputs to that. And in fact, one personal role there was at one point Vint asked me how big should we make the IP address? And I said, "Vint, 32 bits, no one will ever want more than 4 million hosts." So now the world has me to blame for this IPv6 mess of having all the torment of trying to go to a bigger address. But I did do one good thing, at that point TCP and IP were all interleaved into one single protocol, and I convinced Vint to pull them apart so that we had an IP network layer and TCP separate module that would do the end-to-end reliability. And that architecture survived since then gave us the advantage of having a place to put UDP, the transaction protocol, also on top of IP and parallel to TCP. So that was one good thing I did at least.

Weber: To make up for the...

Burchfiel: ...to make up for the 32 bit addresses that I talked him into.

Weber: And so you would've been talking to him, when you say talking, probably over e-mail and occasional meetings?

Burchfiel: Yes. I would meet every few months about in person but multiple e-mails daily. I had the theory that Vint was sitting right by his computer at all times waiting for an e-mail to show up so he could answer it instantly. So any time I sent him an e-mail then within a few minutes there was an e-mail back saying, "Now do this, now do that." So I kind of deliberately slowed down my inputs to Vint because he had such a fast turnaround on them.

Weber: In the '76 and '70s there was the two-network and the three-network experiment. So did you go out for any of those?

Burchfiel: Yes, we had a big meeting in '76 in Oslo, Norway, and that was an excellent meeting. There were people there from all over Europe, representatives from the University, College, London, Norwegian Defense Research Establishment, and people from all over Europe and the U.S. representing all three of those networks for the first time working together.

Weber: Right. And why was--I mean I've interviewed Paal Spilling from NDRE but why were they part of the first?

Burchfiel: Well that was where one of the early routers was being installed in Oslo, Norway.

Weber: But why was it being installed there?

Burchfiel: Actually I don't know. It might have been part of foreign military sales, corporations, Hands Across the Sea, DARPA, and foreign military, oh, both part of NATO, so they may have been pushing that as a NATOism.

Weber: Because in '76, in California, there was a connection of two networks together and in '77 the three network experiment with the SRI packet radio event. So you were very involved in that.

Burchfiel: Oh, yeah. I got to ride around out there in Menlo Park in their bread truck watching the radio signals come and go about like that on an oscilloscope.

Weber: Because we have the bread truck you know that?

Burchfiel: Yeah. It's like an e-ride at Disney World. You get to ride in the bread truck.

Weber: Vint sort of described it being filled with generals.

Burchfiel: Well sure. That was at demo time and just before then it was full of nerds trying to get the connections to work.

Weber: Because the description was this unmarked truck full of strange equipment and men in uniforms sort of cruising through the streets. Do you remember it like that as a sort of...

Burchfiel: Maybe I wasn't there when it was demonstrated for the generals but they were certainly doing that day in, day out trying to get the reliability of the network up and it succeeded. It worked okay. Another project that we worked on that had some legs was called by a strange acronym of BCR, black-crypto-red. It was a IP internet encryptor and the idea behind it is that a user packet would come in on the red side, it would get encrypted in the crypto, the whole IP packet, and then the encrypted result would get encapsulated in the data portion of a new IP packet over on the black side, and then wiz off across the network. The nice thing was that it was end-to-end and so even if some intermediate nodes got captured or subverted, the user net traffic was still safe. It had been encrypted and stayed encrypted all the way through until it gets to its alternate destination. Now since then, that grew. That was for DARPA, an intelligence agency, and since then that grew into Steve Kent's standard for IP Sec., IP security, that's now used all over the internet and subsequently grew into NSA's HAIPE, High Assurance IP Encryptor. It's providing type one security in the GIG, Global Internet Grid. Yes, Global Internet Grid that's used for military applications world wide securely, type one security. So that was another thing that got incubated here and then now it's grown to worldwide use.

Weber: And the dates roughly for...

Burchfiel: Seventy-four about when the BCR project got started. And, as I said, it's got a genetic thread to goes through till today. Another project that we did was called Cronos and the idea there was to create a distributed operating system. We had all of these different TENEX systems so the opportunity was try to make them work like one single computer across the internet and that was Harry Forsdick and Bob Thomas that came up with the protocols that let you write a program and let you initiate it in one place and then the program would effectually run on all of these machines in parallel. So the user would be unaware of exactly that this function was being done here and that function there. Today it's turned into something like cloud computing and the protocols have evolved into what's called COBRA today, Common Object Broker Request Architecture, for distributing computing. So that's another one that grew and grew.

Weber: And again dates?

Burchfiel: That was in the late '70s maybe early '80s when that was going on. And then in the '90s, one big, big project that we had here was called SIMNET, Simulation Networking. And the purpose of that was to help train the army people who are going to be fighting in tanks and helicopters through simulation. So one of our co-contractors created a mock-up of the inside of a tank and what we did was network multiple of these together in multiple sites so that when you fired a round out the main gun, then that calculation would get distributed everywhere and a tank somewhere else, maybe at some other site, an enemy tank would blow up. And it was typically opposing force and your force fighting against each other, and it was all in real-time, and it all required multi-casting. Because anything I do could potentially be seen by anyone out there so everyone had to be aware of that. As that project evolved, it moved into classified information, what are the newest weapons and the techniques for using them. And so we developed a classified version of that that was similar to the BCR in that it was using a red side crypto, black side. But in this case the crypto was developed by Motorola and it was type one so we were able to do real classified, real secure, real-time exercises that were stretched across the globe. No one had ever done that before. And in fact to do that the internet at that point wasn't quite up to the job so we created yet another network called DSI, Defense Simulation Internet, that was optimized for doing high speed propagation for the real-time interactions so that you were able to interact with another vehicle in milliseconds. And almost everything was multi-cast. When you do something, everyone's got to see it

anyone who at least conceivably could be affected by it. So that was a different flavor of network. In fact, we had our own protocol. They called that IPv5 which is unknown today. No one has every heard of it.

Weber: But that's why it's six.

Burchfiel: That's why they skipped over and went to six with the next generation because we had IPv5 along the way. The SIMNET also became standardized in the DIS protocol. There's an IEEE standard. There's an organization called SISO, S-I-S-O, standards organization that helped develop the IEEE standard run by Duncan Miller who used to be my boss here at BBN. And so distributed simulation now has a standard as well that grew right out of SIMNET.

Weber: I saw in some of the materials Jennie Connolly is giving us there's some brochures with tank simulations...

Burchfiel: Oh, that was us.

Weber: That would be it. And I'll ask about the software. Is that around?

Burchfiel: I don't think so. When the computers go obsolete and you chuck them, then the software decays in a hurry too. Talking about networks, one other thing that happened here was getting in on the commercialization of networks. There was the NSF network that was bringing together regionals and we started one of the regionals called NEARnet, New England Academic and Research Network with MIT, and BU, and Harvard. We had originally called it New England Research and Development Network but the name NERDnet didn't fly at MIT for some reason so we had to rename it NEARnet. And that collected a lot of users here in the Boston area and other regionals were popping up all over the place. At one point the NEARnet had welded together a dozen or so of these regionals into one big net. And then BBN acquired the NEARnet renamed it Planet and started providing internet service for pay, and that eventually became the Genuity Internet Service, and then that eventually became the dot.com crash. I'd just assume you not give me credit for that one.

Weber: Not if you don't want it. In the '80s when it was NSF that really built the internet up and...

Burchfiel: Well they built their own separate one.

Weber: NSF did.

Burchfiel: The Internet really grew out from the ARPANET adding more different networks all around the sides. Oh, actually I should say it split into two. There was the ARPANET and then at one point the military was concerned about having all these crazy researchers on their network so they created a parallel network called the MILNET and then put blocking gateways in between the two to make sure that their traffic stayed their traffic.

Weber: But were you connected to-- there was the backbone, yeah, that was the NSF backbone right?

Burchfiel: Yeah, BBN was on all those networks. I remember the ARPANET grew up to about 64 nodes. They were having a hard time there with scaling algorithms, efficiency problems, and even six bits in a header kind of problem, they were exceeding the format. And the MILNET grew up to 256. And so that's why I felt really confident of telling Vint that 4 million's going to be plenty, don't worry about it. But as usual I was wrong.

Weber: And then after that any...

Burchfiel: Just an ongoing stream of smaller projects and some of these had fall out that continues today like JTRS. BBN is working on the networking protocols through multiple generations of that; the JTRS2C that we did. The networking is a sub to BAE. And then the JTRS GMR, Ground Mobile Radio, where we were subbed to Boeing to provide the networking protocols. And that's still going on. They just ran a big exercise this last weekend. SPAWAR ran an exercise this weekend in Charleston with 30 nodes running around and communicating, and I heard it was a success. So the JTRS is finally moving up. It's interesting to see all these threads that stretch over maybe decades from a crazy idea to actually getting out in the field.

Weber: Yeah, that sounds like out. So you had the group starting in the early '70s and just give a brief kind of overview of your career, your positions.

Burchfiel: At one point I was part of the BBN communications company and there the hope was to commercialize the military technology; the various switches and routers that the military was using hopefully sell them commercially as well. And that project went on for some number of years but didn't really catch on commercially so much until Cisco picked it up and ran with it. So we could've been rich if we had done the right thing but somehow we didn't.

Weber: And how much do you see that-- Well I mean Ginny did really the first router.

Burchfiel: Yes.

Weber: Between the kind of '76, '77 period and Cisco's emergence, so go into more detail on this.

Burchfiel: Well I think Cisco really cranked up in '85 or so. So a lot <inaudible>

Weber: So if you could go into a little more detail on the birth of the router, the period between '76 or so and the early '80s.

Burchfiel: Well it gradually spread wherever there was a piece of ARPANET and somebody wanted some other network like even an Ethernet attached to it which pretty soon everyone wanted. That was '82 I think that Intel, Xerox, and DEC came out with the Ethernet standard. So that began proliferating like crazy because it was so cheap and such a great high bandwidth way to hook up hosts that pretty soon everyone said we've got all these hosts and we've got this Ethernet and this ARPANET, we want to get them together and what was needed in the middle was of course the router. So that was the early initial use on that. The protocols stabilized after a few years. Vint Cerf was of course the great theoritian deciding what should be done, how it should work. We gave him some back pressure on practicality, implementation, performance, and so on, and so some of things got twiddled along the way. But then

with the TENEX's out on these 12 research sites and everyone wanting Ethernets, then the routers started rolling out to all of those locations or locations with some other network like at SRI where they had the Packet Radio Network, over in Europe where they had the Atlantic Satellite Network, any place anyone had two networks in the shop, they needed a router in between and so they proliferated. As usual we were doing things that were 15 years or so ahead of their time so this didn't take off commercially at that point. It was just a tool for the researchers to build an internet and the early internet was used mainly for e-mail communications between the DARPA and the researchers. It wasn't until some time in the early '80s that Cisco took off and started providing commercial products. And everyone knows the rest of that story we got the internet.

Weber: And did any of the early routers survive that you know of?

Burchfiel: The earliest were on LSI 11's, which of course like all computers became obsolete in a few years, so I doubt that there's any of those around unless you find Tony Michelle's [ph?] junk box. Who knows what's in the bottom of that.

Weber: Yeah. I'll ask him. And we're actually going to have some sort of a display on the SRI van. We have the thing itself but its kind of big to put inside the building. What would you say to a sort of target museum goer which could be someone who's not technical, they might be down to eighth or ninth grade, just why was this important? What are some of the key features?

Burchfiel: Well the...

Weber: I don't mean just the van but...

Burchfiel: It's hard to say much about the network because it's invisible. If it's working well, it's just like that power plug in the wall. You don't worry about what's behind it. What you care about is what's up on your screen? How long does it take to download that next page of web information? So it was an enabling technology that then permitted the web to sprout and take over the world. So pointing at the network people will wind up scratching their heads probably saying what is this for? And you say, "Well do you use the web?" "Do you browse?" Without the network you wouldn't.

Weber: And the importance of interneting?

Burchfiel: Oh, connecting different kinds of networks. Well one big important thing is fixed infrastructure. There's a worldwide GIG, Global Internet Grid. The land part of it is built on fiber now so it's a very high communication across the military bases across all the continents. There's a satellite part of it so that they're running IP bouncing it off the satellites and back. And now more recently there's the technical IG [ph?] out in the front where the troops are with mobile radios where things are much tougher. You can't afford high bandwidth. Things are noisy. There's interference. There's jamming. And the internet protocol still ties them all together whether they're out in the mobile tactical arena, or back in the strategic, or just commercial; that they're all working over the same IP. IPv4, some day IPv6, to fix my mistake.

Weber: Any advice you would give to young people considering a career in related subject?

Burchfiel: Yes. Go to work in a place that's full of crazy people just like BBN. That's what attracted me here to the-- Newton had some comment about standing on the shoulders of giants, I haven't done that but I've gotten to rub shoulders with all of the giants of the Internet and it's been great.

Weber: Anything else in particular you'd like to talk about?

Burchfiel: No, I made it through my thoughts. I'm dry. Come back in another 40 years.

Weber: All right. Well thank you very much. It was really good.

Burchfiel: You're very welcome.

END OF THE INTERVIEW

