

Dave Walden Oral History

David (Dave) Walden (DW) interviewed by Brad Fidler (BF) and Len Kleinrock (LK) on August 21, 2014.

[The transcript of the recorded interview was reviewed by the interviewee. Words that the transcriber didn't understand correctly were fixed. Lots of punctuation was added to the transcription to clarify where (originally spoken) sentences, clauses, and phrases begin and end. Some words were slightly changed or dropped, for instance where the interviewee made a false start in a sentence, gathered his thoughts and then started again. Commentary has been added in square brackets: sometimes this was to clarify something that was already there; sometimes it was to add small amounts of additional information.]

BF: This is an interview with Dave Walden on August 21st, 2014. Dave, thank you for taking the time to speak with me.

DW: You're welcome.

BF: I would like to begin with the process by which you ended up at BBN.

DW: Well I graduated from San Francisco State in 1964 and was lucky enough to be hired at MIT Lincoln Laboratory to work in Frank Heart's group. Maybe two and a half years after I was at Lincoln Laboratory, Frank was recruited to BBN; and sometime after that I wandered down one day to BBN. Frank had been very good about not poaching or recruiting from Lincoln; but if you arrived at the BBN entrance (apparently from my one experience), he invited you in showed you around and then make your job offer; and so I went to work at BBN two weeks later. I left Lincoln because... When I went to Lincoln, I was a non-staff member, that turned out to be an important distinction at Lincoln because I was a computer programmer rather than an electrical engineer, physicist or a mathematician or something. I felt so very junior, and Frank treated me like a staff member. He had me share an office with Will Crowther. Mostly non-staff members share three-person offices; I shared a two-person office with Will, which was fantastic. And so when Frank left, they didn't quite know what to do with me. They had me write a Fortran program for somebody [rather than me participating more deeply in the project as I had with Will under Frank], and so I got a little dissatisfied with my non-staff status. And so -Frank hired me although he didn't really have anything for me specifically to do, which was the BBN way. If you know somebody was a pretty good person, hire them and then figure out later how you're going to support them. So I did this and that for a while and then did some more specific things. Particularly in the pharmacology area I worked on the formulation of the system called PROPHET which was for research chemists and medicinal pharmacologists to do graphics programming and data management in that world. And then the ARPANET RFQ came along.

By the way, before the ARPANET RFQ I met Bob Kahn for the first time because he was over in a different division doing whatever he was doing and I was in my division doing these little things I was doing for lack a more focused thing; and they sent the two of us to review a database management system built by SDC. We went down to Washington, to Andrews Air Force Base I think; I can't quite remember -- maybe Bob would remember. We heard some presentations [at the DC area airbase]; then we went out to SDC and visited Clark Wiseman and some other people; and then we wrote a report. So that's the first time I worked with Bob, which was well before, I believe, the ARPANET RFQ. [I believe the data-management system was the TDMS system (for time-shared data-management system.)]

BF: Was there any other work you were doing at BBN before the RFQ arrived?

DW: I don't remember. I certainly worked on the PROPHET system -- did a lot of work there -- formulating our proposal and helping kick off the project. That, by the way, is covered in the BBN computing history book in Paul Casselman's chapter. I was pretty interested in programming languages at that time: macro processes, that sort of thing -- so I probably spent a little bit every day doing self-study. (I was working on a Master's Degree at MIT at the time, which Lincoln had let me start and BBN let me continue. I never finished it; I finished all the coursework but never turned in a thesis.) Frank taught one night a week for Northeastern (some kind of an introduction to computing course), and he invited me to give a couple of lectures [one year] at Northeastern (not at the campus down the street here, but at a suburban campus out around the 128) on language processors and how compilers operate, as I remember.

BF: And you're referring to the 'Culture of Innovation' book?

DW: When I speak of the BBN computing history book, I'm speaking of the book that Raymond Nickerson and I edited called 'The Culture of Innovation', which is freely accessible on the web at walden-family.com/bbn.

BF: Why don't we move to the arrival of RFQ at BBN?

DW: Okay.

BF: Could you tell me about that?

DW: Well, I don't know too much about the actual arrival. (I've tried to sort that out with Bob Kahn recently for a paper I was writing about Leo Beranek for his hundredth birthday.) BBN had two divisions at that time in the computer area (they had some others in the acoustics area). One was something like "information sciences"; the other was something like "computer systems". Frank and I were in the Computer Systems Division, of which Frank was the leader; and Bob was in the Information Sciences Division where the AI work was going on with people like Jerry Elkind and Danny Bobrow and so on. I kind of have an impression that the RFQ came to Joe Mankowitz, who is a psychologist, who maybe had the assignment to look at the government weekly publication of instances where the government wanted to solicit bids; and then we perhaps wrote away for it. So I have a slight feeling that somehow it got to Joe

Markowitz. (I don't know this from the time.) I know from talking with Bob later that the RFQ eventually got to Frank Heart. So somebody in the company -- probably Elkind or Barbro or John Sweat, some of those people -- had concluded that Frank Heart would be an appropriate leader for a proposal effort. He was a very experienced manager, a manager with lot of real-time system building experience and with the relationship already with some of the people at ARPA, such as Larry Roberts who he had known at Lincoln Laboratory. [For more on this, see the CHM interview with Frank Heart where he describes where Larry first told him that a request for bids would be coming out.]

Bob tells a story of Frank arriving at his office one day with the RFQ saying do you want to work this, basically. Now the other thing I've learned from Bob is that Bob had come to BBN and was already thinking about computer networking and was sending memos to ARPA, and in fact visited ARPA, but didn't know when the RFQ was coming, he told me. And then when it came, he saw some tracks of things he had sent to ARPA in the RFQ. Thus, Bob and Frank were the initial pieces of the RFQ response team and Frank invited Severo to be the hardware guy working on it and invited me to be the software guy working on it: my way of thinking about it is that there were basically four of us who stayed with the project working on it. There were other people looking at it too, such as Holly Rising, Bob Jacobson and others who were doing various things, but certainly of the primary team then ended up working on it was Bob, Frank, Severo and me. I was doing the original software design; Severo was doing the hardware design; Bob was thinking about various things and definitely was educating us about what packet switching was, since he was already thinking about packet switching. The rest of us knew about real-time systems, but hadn't been thinking about packet switching. And then we drafted a proposal. At about that point I was feeling in over my head because I wasn't confident enough about my abilities, I was really only four years out of college at that time. We had often talked about and now maybe we should recruit Will Crowther to come from Lincoln to BBN. I'd shared an office with him, he was my mentor there, so I went to Frank and said maybe it's time that we try to recruit Will, who unquestionably is smarter than I am by a good bit. So Will came, Will reviewed the proposal that we written, and we probably made some changes, and the proposal went in. I think the essential thing about our proposal was that it was a complete system design including being kind of a complete system design in some ways independent of what the RFQ called for. We proposed things beyond the RFQ...we weren't just simply saying yes, we can do A, we can do B, we can do C [listed in the RFQ]. We did a complete system design.

BF: I want to get back to the...

DW: ...If I could just say one more thing before we do that. When we were far enough in the selection process that they wanted to interview us at ARPA, I believe Severo, Bob, Will and Frank went down. I didn't go, because Will was the more senior guy. (Although I was first on the project, it was clear Will was the smartest software guy on the project [and should represent the software side of things at the meeting with ARPA.

- BF: There is a few things that I wanted to draw out and the first is the priority that was placed on it [responding to the RFQ] supported by BBN. I understand that there was more resources placed on this than usual, in fact even a record number?
- DW: The numbers I remember and I won't swear to them, but BBN put \$50,000 into writing this proposal and I heard it was the most money BBN had ever spent on a proposal, so I don't quite know what that means.
- BF: What was the thinking behind putting...?
- DW: I don't know the answer. Surely Beranek and Bolt were involved. [Sam] Labate was the president. People like that were thinking about it, and certainly they went ahead with it I'm sure that Elkind had a role in that. John Sweat, perhaps. I've recently communicated with all of them, trying to understand things for this paper that I wrote for Leo's birthday, and mostly they don't remember. They all say, "I'm sure I was supportive of that." So I don't think I know. And I certainly have never gone back and asked Bob or Frank who might have had the vision. My vision was pretty local. We have to do a system design and it's got to have software that has a good design. The part where you're thinking, this could change the future of communication ... I wasn't thinking at that level. Bob maybe was. Larry Roberts at ARPA maybe was. Bob Taylor at ARPA, Len Kleinrock maybe was. Many other people might have been thinking at that level. I was thinking of how we get the bits to go through the computer, so I don't know what the motivation was.
- BF: Speaking about these other people that were thinking about it on other levels, you mentioned Bob Kahn as one conduit connecting you with the broader thinking about packet switching, for example; and I hope you can tell me more about where, how those ideas were transmitted, because there have been research on this before but the you're in this very fine setting... **{Brad: perhaps you can review the recording and understand what you said here, e.g., "fine setting", and how that gets to "very applied phrase" in the first line of my response.}
- DW: I don't think I can help you. I think your very applied phrase was the correct one. We were sitting there trying to think about a design, and Bob would explain stuff like: here is where you use a cyclic redundancy check, here is what packets and messages are about. Now not a lot had been invented in this domain by that time, so the total amount of prior knowledge probably wasn't that much. You know that Bob has vast prior knowledge in information theory, communications theory, but for the most part that was being applied. We were making up how would you acknowledge packets...and some things when we sat down to think about it fresh are, such as, that if you sent a packet from one computer to the next and you send an acknowledgement back, depending on a negative acknowledgement, doesn't work as some of the [existing] IBM telecommunications devices did. It's pretty obvious that doesn't work -- that you have to wait for positive acknowledgement. If it doesn't come soon enough, then you have to say to the other end again: "Did you get this?" And you have to keep doing that until something comes back and says, "Yes, I got that." Because you don't know if you lost the packet going that way, or you lost the response coming this way. And then it's pretty

obvious right after that that you potentially now have duplicate packets in your network because what was lost was the acknowledgement, and so then you have to sort that out. So we were busy inventing on the fly and often successfully and sometimes not so successfully such as the whole memory allocation system fundamentally didn't work and we can come back to that.

BF: And this...when we get the acknowledgements is that one of the areas BBN response departed from what ARPA was asking for?

DW: I don't

remember. I would have to go through it case by case. I can give an example of what I do remember. ARPA suggested a routing mechanism which as I remember would have central control. It was more or less fixed. It was not nearly as dynamic as what we developed: Will Crowther came up with this very clever algorithm for doing what today we might call RIP routing or what was the other name... distance vector routing and it worked in cases that weren't too big, worked in the early days of the ARPANET.

BF: Is there anything else on the difference between...

DW: Well, let me just say again (and I don't know what everybody else [other bidders] did); but we certainly didn't just submit, "We can do it, and here are credentials. Severo submitted, as you can see in our proposal, complete schematic diagrams -- not at the level of [being for a] manufacturing factory, but "here is exactly how it works." We did the same on the software. We had a flow chart for the whole program showing all the components. For the speed of the program. Crowther and I counted the instructions in the inner loop. We wrote instruction for the inner loop, we counted the instructions of the inner loop, and we could say how many packets per second [the IMP] was going to process. So [it was] a very detailed design. I emphasize that partly because I suspected it helped us win. Okay, then the other part was that because we had done that much design before we got the contract, then when we did get the contract in, where the first step was to design [the system]... in effect we were doing a redesign already and then you have to implement, of course. During implementation you design some more, so by the time the implementation happened, we were sort of in the third iteration. Not always dramatic changes, but the third iteration of thinking about things, which I do believe is part of the reason that it all more or less worked by October of 1969, when we had shipped the first machine in September 1969 to UCLA -- then the next [three], one a month.

BF: So you link BBN's ability to make that function right to the beginning.

DW: I do. I do and let me stop a second and think about that again. A while back, a few years, for some reason BBN was being proposed for some award. I don't know what it was and Bob Kahn was somehow helping pull that nomination together, and so he came to me for my memory of things. In my memory of -- not of originally, but for what Bob coming to me -- what we talked about was how having a complete design was a very important thing, presumably from the government's point of view, but definitely from our point of

view. I can certainly imagine that there were other quite complete designs done. I can also imagine there are other system-integration designs done. Certainly that's how big proposals are sometimes done by the big aerospace companies – cobbling together existing components, and its called system integration rather than system design, at least in my mind. I don't know what a company like Raytheon might have proposed.

BF: And before we move forward is there anything else on BBN's unique contributions, things that were put into this response that you want to bring up?

DW: Well yes, I think so. Certainly the acknowledgement system [dropped some confusing words here] was a good idea. The initial routing algorithm [was innovative] which was dynamic and did not depend on any central control and very explicitly you could take a node out of the network and network would discover that it was gone and redo the routing, and you can put a node in the network [and it would be discovered] This was terrible important for putting new nodes in [the net]. You didn't have to go reconfigure anything; it just took care itself. The downloading from one machine to the next, which happened fairly early (it might have been already into 1970, but maybe was already happening in '69, I have to go back and think about that) was very important. And therefore pretty early we were able to do releases across the network. As soon as we had a network that went to the East Coast, you put the release in our machine; then you tell the next machine to download it; and then you tell the next machines to download that; and it goes out. Certainly the end[-to-end] message control and message reassembly was an innovation which didn't work. We made it up and it had troubles and it had to be fixed so we did that. Frank Heart's enormous intensity on making the machines [with their IMP systems] run robustly (whether it's an innovation or not, I wouldn't say, but it) was certainly a component, I think, of making the system work early on. He shipped hardware into those original sites, that had the watchdog timer that would restart the program if it something got hung-up and so on. Frank just was... zealous is probably the right word, there may be a stronger, better word. "This machine has to continue working all by itself out there in places where we don't know what is going on." Specifically , we would laugh about that the IMP is going to sit next to graduate students and who knows what they're going to do to it. And I think that [reliability concern of Frank's] was important. I'm sure [or maybe not really sure] that a 24-bit CRC hadn't been used before but that was an important component. I don't remember if it was in the RFQ. In doing reliable transmission, we had to adapt our implementation to the level of reliability of the telephone circuits at the time. You don't want to put too much error control on, because you waste a lot of channel capacity. You don't want to put too little on because now you're retransmitting packets all the time. You find the right amount [to put in the CRC hardware in the modem interfaces] and that's certainly in the analysis that Bob Kahn did.

But, but finally I think ... Oh, I have another one, which is the idea that we came up with fairly early. The original IMP was supposed to have a host on it. My memory is that the RFQ asked for an IMP with a host interface. Almost immediately we got the message that we need to have more than one host on the packet switch. So we looked at the data channel possibilities, machine interface possibilities, and decided you could have

up to 7 combinations of hosts and modems. [In the end, we decided implemented things so an IMP could have 1 to 4 hosts on it, and 1 to 5 modems on it with the total not exceeding 7. We provided bits in message address fields for host-side software to specify which of 4 hosts on an IMP was being addressed.] Once that instruction came to us and we tweaked the code (which was well before the machines were originally shipped) so that now it was (not re-entrant but) parameterized so it could have the same bunch of codes deal with whichever host a particular packet was for, then it was a very easy next step to have all of the routines in the background of the machine, such as debugger, statistics program and the trace program, also be hosts but so-called 'fake hosts'. There was another bit which said, it's one of the four real hosts or one of these four fake hosts. Well, using all of the mechanism of the fundamental packet switching network for the control [and study of the network] I think was an important innovation, just as having the routing be part of [the basic network function] There was no out-band-signaling in this network, which was often a tradition in other networks before. Everything [control and application data] went through the ARPA network, and we managed to do it in a way was very tidy and clean; so for instance, the Network Measurement Center at UCLA could send a message into the IMP to one of the fake hosts and turn on statistics. At BBN we were able to inspect [and change] memory of any location in the network including the memory bit that you tweak to say reload from your neighbor and so on.

So I think the important thing -- to get back to what I was going to say -- the important part was it was a coherent complete system design. It wasn't a bunch of miscellaneous components cobbled together. It was very coherent and that may have helped ARPA be convinced to hire us. It may also certainly have helped us run the network over the years and help the people who were experimenting with the network do their experiments. Jim Forgy at Lincoln laboratory did very, very early experiments with what today we would call Voice over IP (VoIP) (then it was just Voice over Packet) using some of these capabilities.

BF: How did the particular people on the team at BBN, as well as how they were organized, contribute to that kind of design in that success, you might actually start with how that team was initially brought together?

DW: Well I already described how the first four came together -- Bob, Frank, Severo and me, The RFQ was given to Frank, as I understand it, to manage the proposal effort. Bob had been thinking about networks already, and naturally he came together with us. I was added because I was a software guy who Frank appreciated and wasn't doing that much else, as I described earlier. He might have taken me off something else anyway. Severo is an outstanding engineer and can really make things work. The next two people that were added were Ben Barker [and Bernie Cosell]. Severo was at the time teaching a course in circuit designer, digital logic, or something at Harvard, and Ben Barker was a student there or a graduate student at Harvard and so Severo invited Ben down to join

our team and be Severo's colleague in actually implementing this. Now I'm not sure about what I'm about to say, but I think it's true that while Severo is an outstanding engineer at a certain level, Ben is probably a better engineer at the level of actually putting the probe in the computer and making it work. Ben had been... I don't know for sure... he was the head engineer at the Harvard radio station and stuff like that. He had taken Ivan Sutherland's courses, I believe, so that's how Severo got there, I mean how Ben got there. Bernie Cosell is a genius debugger and the hospital computer project (which had supported the group [including Bernie] and for which Frank originally came to BBN) was shutting down and burning[?] sort of loose ends, so Bernie sort of joined Will and me on the [IMP] software side of things.

DW: And the way it ended up. I don't quite know how Severo and Ben organizes their lives; they worked side-by-side all the time. ... I want to digress and go back to one thing. Severo and Bob probably put the biggest effort into actually writing the proposal response and tweaking and rewriting and all of that. All [five] of us contributed, all of us read it and a lot of other people read it. I did flow charts, and Will and I did instruction counts, but as far as looking at the final document, Bob and Severo, I know, spent a lot of time one day, more days maybe, at Severo's house making it even more coherent. [end digression] ... Back to putting the team together. So [on the software side] it ended up that Will did the network, the IMP-to-IMP stuff, the IMP code that includes routing, that includes the source IMP to the destination IMP, that includes acknowledgement. Will did all of that, okay? I did the host-IMP code both ways, implementing that. And Bernie was doing development software and the debugging stuff [to reside in the IMP code]. For instance, he implemented the DDT; he implemented the statistics; he implemented the trace; he implemented those things. So Bernie did the fake hosts, I did the communication with the real host and with the fake hosts, and Will did all the stuff that was either between adjacent IMP or source and destination IMPs. Having said that, we all talked to each other all the time about everything... we all knew all the code. And so for instance when Bob and I... I guess we can't remember how many machines we had running -- were there four already when Bob and I went up to UCLA to check out the source IMP to the destination IMP lockup troubles?... I went along. Bob was going to run the experiments. And I handled any piece of code that needed changing because I knew all that. So that's how we divided things. And when I say software development, we very early on switched to using the PDP-1 time-sharing system to do our software development. We did editing in the TECO editor on the PDP-1 time-sharing system. We used the PDP-1 Midas assembler to assemble the program for the Honeywell 516 computer. Bernie and I tweaked that assembler so it knew about the instruction codes for the 516, and then we punched out a paper tape, which we loaded in the 316, so we did our development work on the PDP-1. That was something that Bernie and I did one weekend, quite literally, when we were fed up already with the Honeywell software that came with the Honeywell machine. And which we did without asking Frank Heart,

because Frank was against tool building. He always worried that tool building would become a goal itself and therefore you wouldn't focus on a real project. And we weren't too interested into tool building for its own purpose, but we were interested in having a better development environment, so we did it and didn't ask Frank. And then later on we told him, look at this nice thing we've done and it really works better. [Regarding doing development on the PDP-1, I think we always used the PDP-1d time-sharing system for typing our draft 516 assembly language code into TECO. Initially, then we punched out the assembly language code on paper tape, and assembled the code from paper tape into the 516 (or perhaps had the 516 punch out the binary for the code so we could load it into the machine over and over). However, what we did that weekend was modify the Midas assembler on the PDP-1 so it could understand 516 assembly language instead of PDP-1 assembly language and output the assembled binary for the 516. Thus, we could both edit the assembly language and do the assembly processing to binary on the PDP-1 and carry the binary paper tape to the 516 to testing. This was *lots* better than trying to use the 516 assembler on the 516 which wasn't very powerful (and Midas was very powerful).]

BF: On that note, was that a common thing when you're working with Frank to do things without necessarily asking and in fact while we're on this if you can tell me more about how the team worked with Frank and more even about his management style?

DW: Well certainly in areas you were going to do it, and you knew he was going to argue with you, there was no point in having that argument, so then we would just do it. Frank was very involved in this design; he was running the rest of the division at the same time, but we had design reviews and we sat together, he went over things, and we had team meetings and all that. So Frank was very involved, but he was not the one, minute by minute, doing the software or hardware system design. Frank is a fantastic manager is the answer, and what does a fantastic manager do? He puts together a really good team. First, he monitors them all the time, but not too much. He trusts them enough that they are going to come and find him if he needs to be found, and will report in what they'd done if they haven't told him first. As I said he had a real, real need to have this machine be robust and that certainly had big impact on system, so he is a great manager and I worked with him in many capacities. I worked with Frank from 1964 for decades quite literally, either for him or with him and he is terrific manager... but he is a manager who wants to control things. He doesn't control things because that will stop everything from operating, but he wants to control things and that's a problem for him. Probably, in his mind, he is trying to control everything, but he can't. So when I ended up Assistant Division Director a while later, one of my jobs -- I believe, Frank never told me this -- was to take stuff away from Frank and to assign the things to other people, because Frank couldn't be the PI for everything and he trusted me to be running it, and then it was done and it was now reporting to Bob Bressler or somebody. So curiously Frank was PI for bunch of stuff and then people working for me were PIs for a bunch of stuff. I was never an ARPA PI because I was always taking it away and spreading it out and this is the way I believe I helped BBN grow, and I was terrific at going to Frank and say, Frank here is what I'm doing [so he was always aware]. Another characteristic of Frank is he is very

adamant that we shouldn't do some particular thing, but if we all ganged up on him he would relent. So Severo, Will and I and Bob would all go to him and say, Frank you're just wrong about this. He wouldn't like it, because none of us like to be told we're wrong, but he would say okay. So I think he put in the right amount of resistance to get good results and the right amount of giving in even though it felt uncomfortable sometimes to him to do give in.

BF: Do you get a sense with people who worked under Frank that they had a unique experience at BBN? To put it in other words, were there other Frank Hearts at BBN or was he a unique guy?

DW: No! There was nobody else exactly like Frank at BBN but there are plenty of unique people at BBN, but nobody else exactly like Frank and one of the characteristics of Frank is that he had a loud, squeaky voice and you could (and I say that fondly), if you were a timid person or a non-confident person, you could be afraid of what he said. It turns out Frank likes when people argue with him, so you catch on fairly early that if you argue to make a case, and you debate it back and forth, and in the end, even if he told you 'no', he'd have greater respect for you than if you gave in. Well once you figure that out then life can work pretty well.

BF: I want to move to some particular cases...and I think over time from what you said, your relationship with Frank in terms of working under him and then working in other capacities, so when we start here I think you were a computer scientist at BBN from '67 to '70 is this correct, this was off your CV so...

DW: I guess, yes! Okay, I was probably hired into BBN in a position called computer scientist what that meant was I was a computer programmer and I use computer programmer in the most exalted possible sense of the word, okay? A computer programmer is not a coder, a computer programmer is a person who takes the problem, thinks about, figures out the design and then codes it.

BF: We will make it a note when we're going through these different projects that once you hit like for instance Assistant Division Director maybe we will stop to see how that changed the amount of managing you're doing and the way you're managed by the people. But lets go back to, I think we've broached this a bit, but the IMP code itself and the development of that, can you walk me through that process?

DW: I can, but before we do that let me say something that's going to lead to this other topic you'll want to talk about one day, which is, early on, it was the three of us on the software side and Will was clearly the most senior person, okay? But we were partners, the three of us, in this. Will is not a manager, so he had his ideas, we argued with them and whatever we agreed was a better idea would prevail. So there was no real software leader other than Will. He had a lot of great ideas, some of which Bob Kahn would argue were "too clever by half," to quote Bob Kahn, but he is a genius. The guy's just so smart, so clever.

Another thing I'm going to digress now about Will: Will is very clever and could put on a prototype thing that really worked surprisingly well really fast. But Will is not finisher and more generally at BBN we would live off Will's brain. He would come up with an idea like for the Butterfly Switch and the Butterfly Computer that might not have been original but the way he was thinking about it was. And then you do something for many months until something basic would be going, and then other programmers would have to be brought in to finish and do more. So than he really provided jobs for a lot of people over the years.

BF: Except, from what you said there is, at least in retrospect, a really keen understanding of everyone's strength and weakness?

DW: Absolutely!

BF: That was present then as well?

DW: Yes sure! I think Frank probably understood that I caught on to things quickly. To step back, I went to work with Will at Lincoln Laboratory and in my memoir that you read I list some of the things I learned from Will, some terribly important things such as write it down: Will was never a writer; he didn't voluntarily write big papers; but he would always make sure something was written down and as a consequence that was documented and the idea was now tangible rather than hand waving. We understood that he could have great ideas [and do amazing analysis and coding]. We understood that Bernie was a terrific debugger. We can understand that I write easily so I ended up doing a lot of documentation because I could whip it out. Certainly Bob Khan in the early days, because he won't either an engineer or a software guy did the 1822 interface write up and stuff like that. But yes everybody was a great awareness of who could do what and I think that's good management. I think that's a key thing -- using people in the way they can contribute.

BF: If you like you can go back to these...

DW: Sure ,but we can talk about your IMP program, if you want' whatever you want to do.

BF: Yea lets... I think this might be interesting ways to elucidate some of those elements in the concrete cases. So in regards to the IMP code there's...it's developed and then there is changes over time.

DW: Yes!

BF: And I'm curious not only about the development but then also how you learn and decided that changes needed to be made and how those are implemented themselves.

DW: Okay, well so in 1969 we delivered four nodes. We kept delivering nodes in the 1970 and I ended up kind being the software maintainer for that system, I do not quite remember what was going on with Will at the time...oh yea! I probably do. He was doing things like when Bob and I discovered the trouble with the reassembly lockup; Bob and Will figured out how to fix that, and then Will went off to implement the fix. [He was doing] stuff like that. So some of it [the necessary chages] came to our attention

because the network would not operate; It would operate with low utilization and there was a way to break the network, but in those days we'd tell the host sites "here's the way you can break it, but please don't do that" and they didn't. They were not trying to hack the network in the bad sense of the word; they were working along with us, so I ended up maintaining it. And I had the listing on my telephone table at home so I could answer the phone any time of the day or night.

BF: How did you get that job?

DW: I just took it and don't know how I got it; it was a natural for me well a lot... I guess probably a piece of it was that a lot of interaction with the hosts was the host interface and I was the host interface guy; that must have been a piece of it. So I did that. I mention this because in September of 1970 I left BBN and went to Norway and I lived in Norway for a year until September of 1971 when I came back, so I didn't quite know what went on during that period. What I do know is, for instance, they changed the IMP to IMP acknowledgement system to piggyback eight acknowledgements in each packet, and other changes. They also worked on beginning to develop the network monitoring system during that period. By the time I got back John McQuillan had joined the group. Alex McKenzie joined the group well before I left and began working on the kind of managing the host (person to person) interface side of things. John McQuillan had joined the group, he had come from Harvard and it ended up that John and Bernie and the others were maintaining the IMP. I was a little bit involved after I came back. What happened after I came back was I started working with Will and Bernie again and after a little while, Frank or Frank and Will (I'm not sure what the combination was) came to me and said: 'How would you like to be the leader of the software here because that's not what Will does?', and so I was and was forever after for a long time Will nominally reported to me. That was no problem, because I knew Will was smarter than I was, he was having good ideas, I can write them up, we could work together, so....

BF: Let's talk a little about the routing algorithm.

DW: Sure!

BF: So I know in 1979/1980 you and...well, there's two papers with John McQuillan, and you are on at least one of them talking about a new routing algorithm. I curious about that change, and also before, like how was it built in the first place, and then small changes and any major ones that occurred throughout the 70s for example?

DW: So the initial routing algorithm was this pretty clever idea which has later been called "distance vector routing" which in some way tried to add up the time across the network on some path and then find the shortest path and that was made more complicated by the fact that some lines were faster and some lines were shorter, some lines went over satellite link, some didn't and that algorithm worked pretty well, and it was copied and used in other networks, especially in some of the local area networks. But as the network got bigger and bigger, it didn't work that well. It was a terrific idea for getting something going quickly. I'm trying to remember what Bob says about that, I think Bob thought it [the original routing algorithm] always had problems. I know he

always thought this whole end-to-end thing always had problems, and he couldn't convince us because we kind of thought that Bob's the theoretician, we're the programmers. He was right on the end-to-end stuff and showed he was right very easily when time came. On routing I think that he also thought it wasn't quite adequate. I think he would agree there that wasn't a bad thing to have running in the first year, because you could get something going and it ran pretty well but it had troubles. It had loops, it had banging (let's call it that) where if things would switch from one thing to another route sort of suddenly... I can't remember all of it.

John McQuillan began to write his PhD thesis at Harvard while he worked full-time at BBN on an analysis of network routing and he published his PhD thesis. Sometime after that we got a contract from ARPA, I guess from Bob, to redo the network routing and John and Ira Richard and Eric Rosen worked on that for, I don't know, a couple of years, figuring out what to do, how to do it, trying it, putting it in the network, releases guide [I don't know what that means]...remember I told you we did cross network releases; it get really complicated when what you're doing is changing the routing algorithm and there may be an error and you have to take it back. If you put out a new routing algorithm, and let's say you discovered it didn't work: how do you get back to the prior working version of the routing algorithm? So they have to do interim releases that just had hooks that will let you do something and undo it and then they get a new release out and then they decide maybe it didn't have to come back and then they put out another release and take out that interim stuff. So John led that and he wrote an article... he wrote an anecdote (perhaps you read in the *IEEE Annals of the History of Computing*) on doing that routing algorithm. And he makes a point there, and it's true for both routing algorithms, both the original one and the later one: the theoreticians in the introductory courses to the network routing all brush them off as the first one being just the Bellman-Ford algorithm, the second one was just Dijkstra's algorithm. However, exactly which algorithm you used probably isn't the big deal: the big deal is actually making the whole complex work in real life. That is the big deal, and to say "Dijkstra's algorithm for shortest paths" is the way to go that makes links state routing work is just a terrible over simplification and very dismissive of the ton of work people did actually to make this work in real life, And they could have used some other shortness path algorithm's than Dijkstra's algorithm; that's not the fundamental part. Back to the original algorithm there. The theoreticians as called it Bellman-Ford and I think that's just plain misnomer, because Bellman-Ford weren't thinking about parallel processing at all; and yes, this is kind of way you might do Bellman-Ford if you did it in a parallel system, as we did it in the ARPANET; but I think ours was the first implementation of a parallel thing... which somebody can retroactively call Bellman-Ford.

- BF: You have a piece on that? I think it's called 'How mathematician's misunderstand the routing algorithms' or something like that? [It is called THE BELLMAN-FORD ALGORITHM AND "DISTRIBUTED BELLMAN-FORD"; google on that title and "Walden" to find it]
- DW: I do have a piece, I have an unpublished piece that is on my website because I thought it was too complicated probably for a recreational mathematics journal and too

unscholarly for an actual math journal, so I did write this up. I went and talked to people and tried to figure out how somebody began to call this Bellman-Ford. I believe, if I remember correctly, it was Bertsekas at MIT who first started calling it that. And he in his writing...and he would know about that because he worked for McQuillan part-time one summer. He was a MIT professor and he came and worked for the McQuillan group and he says "this is a quite complicated thing these guys did and then calls it Bellman-Ford, and there were a lot of people, I think, after that who didn't go back and figure out what it really was. I can give you the URL for that...not out of my head, but later. I would like the world to see my paper on why Bellman-Ford is not the right answer for what that is. [<http://www.walden-family.com/public/bf-history.pdf>]

BF: Just kind of reminded me of that outside input, we might call it, and I'm curious on the work on the routing algorithm, the identification of its difficulties in the major, second iteration... Were you working with or talking with groups at different places at BBN or outside BBN?

DW: Well, certainly with the original routing algorithm. I don't know what Will Crowther might have known from the past. I never did see Will rushing to a library to do much library research. So my guess is he mostly just made it up. And in terms of when McQuillan did it, he did a massive study for a PhD thesis of routing and then implemented what he implemented, when he got the ARPA contract and I don't know who he went to talk to but I can give you his email address and you can ask him.

BF: BBN did have some...was involved in the host-to-host protocol and I'll like you to speak to that if you can?

DW: Well, we were certainly involved in the host to host protocol in the sense the host protocol had the interface to the IMP, so for the piece of the host protocol which talked to the IMP, which is specified by BBN report 1822, we were definitely involved in that. The Network Working Group which very quickly came into being (I guess was in being before we got our contract, although it didn't put out the first RFC until after we had our contract) was the people who around the network were interested in the stuff; we attended those meetings and we kibbitzed those kinds of things too and we had implemented to some extent. I'm not sure of what I'm saying right now, but maybe for test programs and so on, testing the network [we had to implement parts of the host-to-host protocol]. As soon as we had the TIP, and we had the host that was the terminal handling host inside the IMP box, then we were certainly having to implement the host-to-host protocol, and we were working on that. The TENEX system, which was in a different department in the other division certainly had to work on that for interfacing TENEX [to the net]. So BBN as a whole, but not the IMP group, was working on the host to host protocol and just more generally we were involved in host protocols just trying to facilitate all of this moving ahead. In some sense, we were better prepared or better able than a graduate students at UCSB [or whatever] and we had an editor. We could assign an editor to edit a report which was charged to our ARPA contract, and we could hold the meetings and we had a meeting facility [where protocol meetings could be held]. And we went to meetings at host sites. We flew out to UCLA, for instance ...

Bernie and I, for Telnet discussions. People came to BBN for FTP discussions, people were going down to MIT for some other discussions; people were going around; but BBN was just participating in that trying to facilitate when we could. Got to get all these things working because then this thing that we're doing would be useful.

BF: This is actually an opportunity to talk about BBN relationship with the Network Working Group, can you speak to that?

DW: Well not much more than what I just said. We participated, originally in the Network Working Group, RFCs were done with paper and somebody kept a list. Eventually that list got kept at SRI at the Network Information Center but I don't know who kept it earlier on. Maybe it was SRI fairly earlier, but we wrote these RFCs, they got a number, probably early on they got their number from Steve Crocker, after a while probably got their number from Postel or SRI or somebody. And then you send out a report, a memo, saying, "here is what I propose to do, I'm soliciting opinion of this, here is IMP change coming, it's coming Tuesday morning in two weeks, be ready." So we participated in that way. We are engineers and engineering problems come up and you want to work on it. The whole idea of the Telnet negotiating connections was clearly a place which Telnet hadn't addressed in its first implementation -- dealing with the fact that all these hosts were different in all these ways. So we went to a meeting. Cosell had an idea on an airplane; we presented the idea at UCLA; everybody said this was a good idea; we went back home and I wrote it up; we sent out a RFC; we got feedback. So eventually I went back and modified the Telnet spec and sent an addendum in, I guess. I remember sitting at my typewriter typing on one Saturday and Sunday. Why? Had anyone assigned this task to me? No, not really, but we now needed to have examples of various instances of negotiating an option, -- negotiating an option for this, negotiating an option for that -- so we wrote'em [the examples] up.

BF: I was going to ask you about Telnet next, so that was a good transition. Is there anything else about the development of Telnet and your role in that?

DW: Well, we had implemented it in the TIP. Bernie and I kind of pushed negotiated option although it was Bernie's idea, done on a cocktail napkin on an airplane flight, and when we got to UCLA, he presented it on a blackboard. We came back and we tested the idea out on Burchfield and Tomlinson at BBN, the TENEX guys, to see if they agreed that they could implement it. Then there were four of us that thought we could do it, we went and did it for the TIP later on and then [as mentioned above] wrote up a whole bunch of options for the Telnet spec later on, and I'm not sure why. Later we had an opportunity to present a paper somewhere and it seemed to me that a lot had happened in the Telnet world and deserved a kind of summary, so I decided I would pull that summary together and found people on a bunch of different sites to write about what they had done with Telnet -- sent out a request for them to tell us, drafted a paper; and in the end Bob Thomas, who was in another division of BBN as well, and I, fundamentally, wrote that paper, which has a whole bunch of authors, starting with John Davidson. John is the senior author of the list because it's alphabetical. That paper is the best

summary of Telnet and all the steps, of all the RFCs that related to Telnet at the time. Why did I do that? I don't know. I thought Telnet's development needed to be documented. My computer history interest was coming out already.

BF: Did it working on Tenex bring you into contact with people across these sites?

DW: Certainly writing that paper did, but what I would say is the work on Telnet, working on the TIP brought us in contact with people all the time, because if you think about how the TIP worked, the TIP implemented those protocols and the Telnet protocol, so the terminals that were attached to the TIP could communicate with hosts other places and networks well. So immediately, you end up dealing with hosts at other places on the network about why some connection is not working or whatever. And then there were complaints about the TIP, I can't remember what; so we implemented methods that somehow figuratively rang a bell when something went wrong, so we could know to fix it because we didn't want to be yelled at because the TIP at NASA Ames, for example, was not working right. And then pretty soon there was a whole issue of password control; but I don't know who did that, exactly -- Bernie or Bob Thomas or some pair of people like that; maybe you've studied this a little bit.

BF: There is a '75 paper that you were an author on that talked about TIPSTER TIP ----- is that the password control we're talking about?

DW: I don't know what that one is, but there is TACACS and something else I can't remember -- any of those names. Certainly we were involved a whole lot because of the TIP I think.

BF: What's a... ????

DW: And I'll go back to just a more general comment, which is: It was in BBN's interest and our own engineering and prior interest to see this whole thing work, and so we can work on stuff and hope it works great; and I think probably the same thing happened in other places. Some were more active than others. I think UCSB was never very active after being an original site. At SRI, UCLA, MIT there were all kinds of people contributing because they're trying to make a big deal bigger, something they felt that was important that they were trying to make it work. So we certainly participated in that sense.

BF: So that's a broader theme in terms, when you go through different things, if we have more time, because the participation was more often be that sort.

DW: I think so, I think so. And we had our ARPA contract, and they were getting bigger. I know earlier on -- this is something I talked to Alex about -- but I know earlier on we would get a message (networked email got demonstrated and immediately ARPA was using it and we were getting instructions from Larry Roberts that he wrote at quarter to three in the morning). We'd come in at seven and there was [a message that] "so and so is having a problem, go help them." So ARPA, I'm sure, was conscious that we had staffed up to be able to help and because of what we were doing, running the network, nobody was in a better position than us to help. We couldn't help with everything, but we had full-time people, not grad students who have other things to do; so I think we

were just in the central position to work on whatever needed to be worked on when the calls came.

BF: And in that way let's go back to the TIP and the idea for it. Like, was that something BBN was instructed to do as a complete picture?

DW: You would have to ask somebody else. I simply don't remember and it began while I was in Norway, as I remember it. My guess is -- and this is slightly more of a guess; it's almost an impression -- is that we got the call from Larry saying [to do it]. But you should ask Frank Heart or Ben Barker or Tony Michel, maybe Alex, how that came about -- perhaps Severo. By the time I got back from Norway, that [the TIP development] was happening. Ah! And Will Crowther was working on software for that, so that's another reason I took over the IMP software.

BF: You mentioned briefly the access control and TACACS was in the early 80s, did you have continuing involvement with the TIP project?

DW: Hmm, let's see. Well you have my resume, when did I get to be Assistant Division Director?

BF: 1975, okay so from '75 to '80.

DW: Well from '75 to '80 I was certainly involved, although probably someone like Bob Bresler was the PI by that time. Jack Haverty worked on that a little bit; I'm not sure, but he was probably working for Bresler. So yes, I was pretty deeply involved in our networking stuff until 1980, but not at the level I had been involved in 1971/2 with the TIP, where I was took Will's draft of the user guide and rewrote it.

BF: When do we look to email, this was really significant application for you?

DW: Yea it was!

BF: So let's start with it emerging at BBN.

DW: Well, what year was that, '72?, when Ray did the demo?

BF: I was going to say late '71, but if not that, it's '72.

DW: Okay sometime in that period Ray had, I guess, two PDP-10s. Email was a concept that was around; certainly it had been implemented at MIT before, on single machines. It existed in single machines and Ray figured out a way to tweak that so that the email systems in two different machines could talk to each other, and he made up the outside and he selected the memo format to, from, subject, dates and originally, I think he had two programs, SNDMSG and READMAIL, although this is all a little vague and none of that matters that much, other than that shortly it really took off and many people were writing more integrated email things. Larry Roberts, I believe wrote one in TECO which is an amazing accomplishment, to write an email system TECO, with TECO macros. Other people did it, ISI was doing email systems, other parts of BBN were doing email systems, but mainly email was happening all the time. People were sending email, we were getting instructions from ARPA by email, we were communicating what was happening

by email. Simultaneously we had commercial work, for instance for Citibank, when we saw how good it was to be able to not have to wait for some kind of progress report meeting, but to communicate day by day without having to synchronize for a phone call, with our ARPA client, we immediately went to Citibank and said "Citibank, let us set you up with telephone numbers so you can use email to communicate with us."

Because what that does, is now the client knows what's going on, and if the project begins to slip a little bit or is having a little trouble in this area, it's no big surprise, they can adjust their world, they're adjusted to your world, we can go fix it. Having open communication happening day by day with email makes projects run better. ARPA was using it on us, we were using it...we were getting people who were in the ARPA position to us, in other words clients, to use it with us, so we would be better managed... so our contracts with them would work better. It was at that point when...as I said, people often ask me when they find out I was involved with the beginning of what they now think of it the Internet, which was actually back on the ARPANET: "Did you know what it was going to be, what it is today?" And my answer is always "no". Some people, Larry Roberts, Bob Kahn, Len Kleinrock, they might have had the vision. The vision I had was, this is an interesting project and it's going to be fun to work on. Then after it was done, we had it running with four nodes and I began to hear the phone company people saying it can't work, it shouldn't be allowed to work, when it was working. I began to think 'hmm', the establishment doesn't want this, maybe this is an important thing. That was the first glimmer I had, when the phone company in various ways.. you get rumors that they didn't like it, they thought it was a bad idea.

Then I went off to Norway. Then I came back and by that time email was running and at that point I said "Wow, this networking thing is going to go everywhere, the machines are getting smaller." I'd never heard the words "Moore's law" by this time, but some day, and we said this literally back then in the early 70s, someday there's going to be a packet switch in every toaster and door knob. Turns out there is[laughing] there are packet switches everywhere, there are packets everywhere, at least. And that's when I knew it was going to be a big deal. Well then what happened, when BBN tried to start a company, decades went by, and the world didn't catch on to this revolution that by '72 or '73 I believed was going to happen. We would be way ahead of our time and then when was it late 80s, early 90s sometime, the World Wide Web got invented and then the network became usable. There were a lot... Internet was very big by that time, but it wasn't ubiquitous in the popular world by that time World Wide Web happen with point-and-click interface, the URL so you could go into a file on another computer without having to do a FTP. With HTML, you had a little more formatting, then email, then the Internet became ubiquitous.

BF: Before you move on to move general observation I would like to ask you about TCP and what you observed in its development?

DW: Okay! Well certainly it was in the air that NCP wasn't... had some difficulties in some ways and also wasn't going to be what was needed for inter-networking, so there were a lot of people thinking about that. At the time, BBN had a consulting contract with

Louis Pouzin at IRIA, so we could teach him all about what the ARPANET did, so he could do it differently. I didn't understand that originally, I thought we were teaching him about this technology, because it's a good technology and it worked. As we consulted them, either Alex or I went to Paris quarterly for a couple or 3 years to consult to those guys and we saw Vint Cerf there who was visiting maybe out of ARPA or Stanford or wherever Vint was at the time, other people there. So we went there, I thought we were teaching about this, but they kept coming up with design that didn't include anything we were doing, so I asked Louis one day, "Why aren't you using what we're doing that works?" "No, no if we adopt what you adopted, that would become the standard. If we do something different then maybe our thing will be chosen as the standard."

During that period I was thinking about internetworking. I don't remember the exact year but Randy Rettberg and I wrote a paper on gateways coming back on a plane from one of my visits to IRIA. I wrote a very long handwritten memo to Vint about everything I thought TCP should have - or what they were working on - should have, the next protocol. Unfortunately, I don't have a copy of that, I have regretted it ever since. I kept a copy, but somehow a sent file box off to storage to BBN and that file box was never found again. And my guess is, it was that memo that got me acknowledged in the Kahn/Cerf paper. There were four of us that was acknowledged as "contributions by". I didn't go to the meetings at Stanford that's kind of famous, when they did a lot of design, and the reason I didn't go to that is because Frank didn't want TCP to happen, okay? Frank... another characteristic of Frank is if you got something, then it needing to change must say we did something wrong. He didn't want change. So I didn't go to the meeting because it was overtly working on changing NCP. Frank didn't want change, even though he didn't invent NCP or the network. We shouldn't change it. And I should have gone to the meeting because I tend to write things up. I might have been the writer with those other guys, but I did send my memo and contributed in that way.

BF: During our break you made an observation about oral history and the nature of memory.

DW: I'm not sure I said anything quite so fancy. What I said is that my memory... everything I say has to be in the context of who knows if I'm remembering correctly or not, this is one thing, but I have thought about this a bit, and this is one of the things I like about Katie Hafner's book on the early days of the ARPANET - I guess it really didn't get into the internet much - is that she is terrific, even though she is a journalist rather than a historian, she was terrific in interviewing everybody and with email she would put us in touch with each other and say: "Steve Gregory, you say this about the time you were at ARPA and trying to get BBN to give out the IMP system listing, and Dave Walden, you say this and Alex says something else and somebody else says something else, would you please discuss this until you come up with a consensus answer?" And that's enough to motivate people to dig through the files and you end up discovering that nobody's memory was right, we actually find the document... there is an interesting bit of ARPA management, by the way, if you interested in hearing more about that?

BF: Definitely...

DW: Which is that we viewed the IMP program originally as proprietary, because while it was done with public money, that doesn't necessarily - as we read contract law - put it in the public domain. The government can use it for any purpose they have, is our interpretation. But that doesn't mean any commercial company can have it, so companies were coming to us and we were saying no-no that's proprietary, in fact we had a proprietary line on top of the listing. Steve Crocker was at ARPA by that time and called Frank Heart and me down there one day we went down to see him, and we made our argument about what we thought contract law was, and he made his law argument about what he thought was moral. That it was done with public money, everyone should have it, which isn't how the law works and we said "It's not how the law works." And he said "Okay, well, lets put it this way, we can stop all your ARPA contracts while this goes to appeals court. Probably it will get decided in a couple of years, or you can give out the listing to everybody." And we said, can we charge a modest handling fee for making the mag tapes? And we started sending out the listing immediately to everybody, and in retrospect it never mattered, because if I couldn't get my engineers to do what I wanted then other companies certainly couldn't get their engineers to copy our code. So always... our code was never used by anybody, but we were busy shipping it out to DEC and Packet Communications and other people who asked for it for and this was what the discussion with Katie was. Whatever the handling fee was, was it one hundred dollars was it fifty dollars, there was no debate that Steve Crocker had coerced us into doing this.

BF: Let's actually, let's stay on the relationship between ARPA and BBN and before we go forward when we talk about ARPA and BBN relationship, is there a particular relationship between the people working on the ARPANET and ARPA is different from kind of a broader relationship between BBN and ARPA, or is it effectively the same thing?

DW: Well I would guess that within the IPTO office, it was pretty much the same thing, okay? BBN was probably doing contracts for other parts of ARPA, for instance acoustics work and navy work, and that might have been far enough different that it was a different set of relationships. Within IPTO then there... for a while there was a separate office doing a similar thing, Craig Fields was either leading or was setup trying to compete with IPTO. Chuck Buffalano was somehow a leading guy on that, I can't remember what the story is. Bob might, but there was a another IPTO group setup for a while. I think, you know, they all knew BBN, we all knew each other. Sometimes we would...people from the other division would have one of us work on their proposals, go to ARPA with them especially if it required network stuff, and the reverse. A piece of that that's a little bit interesting is, the two divisions at BBN competing in this area, they got the big email system work. There was debate about who should do the UNIX work when that started happening, like TCP on UNIX. And I think that might have been a little bit of a struggle for ARPA sometimes to have their client competing with itself, to them. Eventually that got solved because when I got be, in 1982 I believe, the President or Chief Executive or

whatever I was, the title changed a little bit of BBN R&D division, I talked to Bob Kahn, he was a little bit tired of all of this and I merged the two divisions.

BF: So if the, in the 70s there was the Information Sciences and the Computer systems and throughout that time both was BBN?

DW: Well certainly the network area, the AI area were weren't competing in that area, but in the networking area...there were these two networking groups being built, one was doing packet radio...what was the name of the email system they did...they did a big email system, I can't remember its name right now, Mercury or something, and we were doing the network stuff. We had to work together a good bit, but there was internal debate bitterness, a little bit, about why did they get the contract rather than we get that contract and as I said, maybe 1982ish a little bit later, I merged the two divisions.

BF: And the reason for merging them?

DW: They have always been competing with each another and that was unnecessary, Bob didn't like it. I certainly talked to him about it and he was giving lots of money to both divisions. There was no reason we shouldn't be working across the two divisions on something like making UNIX have TCP.

BF: So you said it was unnecessary and also Bob Kahn didn't like it... was there anything positive about having two division compete?

DW: I don't know probably, probably there was for all the poor people who didn't want to report to Frank Heart, there was an advantage. it was a blow to Ray Nickerson who was leading the other division, by that time that I made Frank the Division Director and Ray the Deputy Division Director and Ray eventually left. Ray is the same guy that edited the book with me, but you know Frank was better qualified to lead all of this than Ray. Ray is a psychologist and came from that side of things, which was a component, but it wasn't a big system component and BBN was increasingly moving towards systems.

BF: You last said of the ARPA/ BBN relationship, when you were speaking with Julio in 1999 said that ARPA was the manager and BBN was the operator of the ARPANET...you never said that, did you?

DW: Well, I think Julio might have been asking the question "Here you are somehow the central group managing the network..." and I probably said "No we are not managing, we were getting instructions every morning from Larry Roberts." Later on, Craig Fields called me down and said "We are gonna switch this over to DCA and you are gonna make it happen. ARPA was running it and we were contractors. Now we were again a more central contractor, I will argue, than some, just because of what we were doing, and we were managing the network. We operated the network day by day for sure and technically our manager always was somebody in the Air Force. I think, you know, ARPA was a contract officers' technical representatives. As I remember, ARPA didn't have a contracting arm, and so your contract had to come from somebody else.

BF: In addition to specific duty in terms of contract for example were there areas of the timing you can define formally or informally?

DW: Well again, I think we were pretty centrally involved and we were doing what we thought was best and we were reporting in all the time. We did formal cordially report but we were in communication all the time, I will think we were taking the initiative, if that's the question? There was a kind of an autonomy of where you don't wait around to be micro-managed you just do what you think the job is and ARPA had us doing the job, but technically they were the manager and we had to do what they said of course, and we were keeping them informed. It's a good way to be a subordinate, just keep your boss informed about what you are doing, it might prevent you from getting fired.

BF: Where there instances where ARPA stepped in and stopped you from doing something?

DW: Well, they certainly stepped in in the case of us not having handing out the IMP system (Laugh) they definitely did that, they stopped us from doing something? In a sense, Bob Kahn said stop arguing among yourselves. I am hard pressed to find anything technically specific because of course we probably wouldn't do it right and if you got a hint that ARPA didn't want you to be doing it, you go talk to them and try to find out what they want you to do. The whole relationship with ARPA, the way ARPA ran, is a very collaborative relationship and I think ARPA had been managed that way ever since Licklider days, you know, hire smart groups, if they perform, keep them, if they don't perform, don't keep them. There are technical persons, contract officers, technical representatives even our person, who became the PI, negotiated the follow on and it's some combination of what they wanted done and we wanna do. And much of what we did was so-called unsolicited proposals, if you are familiar with that phrase. So the RFP for the ARPANET, originally RFQ, was a formal bidding process, but once we had our first one then it tended to be unsolicited proposals. We would discuss with the technical person what we wanted to do what they wanted to do, then we would write a proposal unsolicited because we hadn't gone through a procurement process. Here is the stuff we think we should be doing, and put in justification for why a sole source procurement could be done, such as we are the only ones in the world – I am making us an example - that knows how to run the IMP System, so you get us to follow another contract, to keep doing more of those, so a very collaborative relationship. And ARPA seems... and I don't know how it is today, you have contract officers there, so you probably should know. They tended to have relatively young people who rotated in for some years and rotated out. it wasn't career bureaucrats although I have great respect for the government career bureaucrats who tend to really know their stuff. But it was people from our community in some sense, you know Ivan or Larry Roberts isn't a lot different from the people at BBN or Lincoln laboratory or UCLA or SRI. It's part of that community and we go back to that community perhaps. And I think that those are not there to be heavy duty managers; I don't know what Larry ever managed before he went to ARPA, maybe a project or something, had he ever managed this big a deal? No! How did he manage it? He managed it like a technical guy, this is what needs to be done, and he had somebody like Al Blue there who was keeping track of who was spending the right

amount of money, and he had somebody like a Air Force contract officer that can show we are following regulations.

BF: So at BBN, did you have a clear sense about an ARPA way of doing business?

DW: Yeah, I think have been describing it. Hire smart groups, if they keep performing find a way to keep them hired, and if they don't keep performing, don't hire them back. And we worked collaboratively with them to figure out what the next sensible step is. Something that's pushing the state of the art a little bit, but not going too far, not being too far from what the ARPA person can justify, not being too far from what the contactor was interested in doing, but far enough that's actually a useful step in technology development. I think that's how they operated and I think that's how they were set up, right? If you read the Norberg and O'Neil book, ARPA was set up to operate that much to the services' dismay. I don't know if you talked to anybody how technology gets to the services from ARPA but I have an opinion. Well, my impression is the services mostly don't like ARPA, why are we spending money on this far-out stuff when we could be buying another tank, another aircraft carrier or another missile or something, or another airplane. So they are not happy with ARPA, certainly back in those days because they were wasting money on this stuff. So you invent something, you do prototype, ARPA was not with us funding...what are the levels... 1,2,3 and 4. We were doing 2 ,

BF: 6.1, 6.2?

DW: That's right, it's a number. We were doing 6.1 research, we were doing 6.2 development, so something, a prototype like a packet switching network and what happens with that? When they all...because it's done with government money, whether it's classified or not...and many of them we were doing especially on the Navy side of things, were classified. We would go into a place where people from other companies could come to read it, and 6 or 7 years would go by, maybe 8, and one of the big aerospace contractors will now see that the time is right to push a big procurement with one of the services and they convince the services and the services will discover on their own or jointly, they will figure out, you know, we need to have a procurement for something, let's call it (Inaudible). I expect that was not one of those services, that was DCA, but we need a procurement for an undersea radar that could find Russian submarines, well here's is all this technology on the shelf that had been written up, that we either read in the classified vault or in the public literature, and they push it, so the path from an ARPA funded to the services, seems to me often has been via a time delay and then the aerospace companies, the big system companies taking it and pushing it as their idea.

BF: Okay. I am curious about the relationship between BBN and other contractors that were working for ARPA on the ARPANET and for example there's the Network Analysis Corporation, can you tell me about that?

DW: Well in the very earliest days of the ARPANET, there was Larry and BBN won the competitive procurement to build the IMPs and UCLA had a contract to become the network measurement center and he hired Networking Analysis Corporation to do the network typological layout, and he hired the people at SRI to be the network information centre. And I don't know how those other contract happened. My guess was they weren't competitive procurement like ours was, we won our competitive procurement and then joined that other set of people. You know, did we have enough to do with network analysis? No. We turned in to get the instructions of – I can't remember exactly how this happened, whether we did it or not. Bob will remember, because Bob did the interface to the telephone companies for us during the time he was there, but you know, go to long lines (laugh), lease a circuit or get whatever (inaudible) contract group. That's letting contract to lease the circuit from here to there, order another packet or an other machine, from a Honeywell, modify it and have Honeywell modify it, load this software and deliver it, so we mostly saw that at a pretty high level at PI meetings. I suppose Frank saw...who was at Networking Analysis Cooperation?...Howie Frank and Mario Gerla, of course I ran into Mario Gerla, when I saw you at UCLA two summers ago. You were sitting in an office next to Len. I am sure we bumped into them at ARPA meetings when we are all out presenting this technology. For instance, we went to this meeting in the UK. I know that Howie and I gave a presentation at the same time, Len might have been there, I don't know and then we got republished in some big volume of stuff, so we bumped into him then, certainly when John McQuillan and I quite early on taught a graduate seminar at Harvard ,where we had graduate students cross registered from MIT as well, I don't how many people, let's say 20 people in it. My guess is, this is my supposition, that it was probably the first course on packet switching network implementation ever given, and we gave it one time at Harvard. (Inaudible) invited John, and John invited me to give that course. We didn't do it again for curious reasons, we just... kind of funny...but we had three sessions in that course that we hadn't planned for our lectures. We wrote a whole set of lecture notes, a lot of them became the pape, John and I wrote later, called the ARPANET Design Decisions, maybe a 60 page paper. We had three sessions opening that course where, after a while, we invited Mario to come up from Long Island and give one of those lectures. I believe we did that and then for another one of those lectures, we invited Stu Mathison who was at Telnet at the time, he was kind of an expert in communication policy, to come up and give a lecture. The third one was going to be the next last session of the class, so we came in the third to last session and said this is open, we don't have a guest speaker, who would you like to get to speak to augment ourpresentation, and they said we already scheduled the Harvard grad student bus to make a field trip to BBN that day. We want jobs! (laughs) And we hired three people out of that class so yes, we knew Mario.

BF: Did you have much interaction with NAC in terms of their work om topology changes?

DW: Not that I remember. For two reasons maybe one is they were working on whatever Larry's problems was or who was going to be on it and all the way up the network in a sensible economic way, we probably had interactions on it, because once we knew it

was happening, there was a higher speed line, we had to put that into the IMP code. One of the things about the IMP code is that it all ran the same in all the machines, when it's just the 360 IMP code but all the configurations weren't the same, they don't have same number of lines, they don't have the same line speed and stuff so it's part of initialization on research, the imp code sent what its configuration was and went through to rebuild the program to deal with that configuration. So we would have had to have known about that sort of thing, and again I don't quite know, I don't remember who was ordering the modems, but obviously we would have to know what size modems was been specified, what size line speed was being specified, so I would say not a lot the communications, always was very cordial. Who else was down there? A guy with kind of a Dutch sounding name Ben Slake was there, there were three partners kind of in it Howie, Ben Slake and I don't remember who else. The third guy wrote a book... anyway, very cordial, but I don't remember having a lot of interaction with them. We had much more interaction with the network information center.

BF: Let's move on to the sites, so there was network information center, the network measuring center?

DW: We had a lot of interaction with the network measurement center, sending them stuff. We would produce documents and so on and we needed to communicate with them about putting out RFCs, I think, and all of that. And we had from the very beginning a lot of communication with the network measurement center. On the one hand we had to help them, originally, get going doing measurements and we did experiments from there and Bob and I demonstrated the big bug that Bob was sure was there, and when things went wrong, they had a team of people, many of them students, writing papers on the implication of this or how this might never have happen, whatever. So we had some critics -- there were people who did critiques of our work and we had interaction with that once in a while. We sent memos, letters or emails or phone somebody up to try to make sure they have the right data , we were sending out networks maps all over the place to anybody who'd ask for them for their own papers because we had an art department who knew how to produce network maps and Bob Brooks who knew how to edit them from Alex McKenzies' writing, the sketches. And so we had a lot of communications with the other sides and I said before, there were certain numbers, I don't remember how many, meetings we had at SRI, but we certainly went to meetings at UCLA , California meetings started to happen at UCLA, and people from other places will fly there to discuss whatever It was it was, maybe it was Telnet, maybe FTP, maybe it was something else.

BF: So as far as the network measurement center goes there was a lot of meetings there and also you have been hearing from them with the analysis of...

DW: I can't say that what they might analyze about the network ever influenced us much day to day, in modifying the network. Partly, that's just because operating a network day by day is a kind of a different job then writing a report or a paper - research paper - on "here is what we have learned about networks". I am sure that there were instances where some of that data got to us and we took action. My guess is mostly we are well

aware of what was being written about before that paper was published because its pretty obvious when Harvard is saying, send all traffic to me and all the network is down (is it against the rules to discuss this with Len or not? We could?) Len is here in the room, he could answer this question with me. He was clearly writing papers, students were writing papers, we were in an interchanging relationship were relatively cordial.

BF: We're going to interview Len later and talk about this.

DW: Okay, relations were relatively cordial. We were always completely happy with publishing all the stakes. That was a small matter compared to all the stuff that was happening. By this time we have all realized we were doing a big deal.

BF: How about the network information center?

DW: I think I mentioned everything that I knew about that. Alex did much more communication with the network communication center than I did.

BF: Let's talk about BBNs culture and you got a chapter in your book in culture revelation talk about the aspect of the culture of BBN. The perception was that BBN was a place for people as their standard of work, they were hired and somehow they found contract to work on, can you explain that?

DW: Yes, I can. I think that was true for some of BBN. That was certainly true in the original cost of business. They're basically consultants, so they had to find work so they can charge more. That was also true to some extent in other areas, like the human factors area. That was true in the educational technology area. They were small contracts, it's personal... a handful of other people. It's probably very much like the professor at the university who gets a contract or grants that support a few graduate students. Well, yes that person went out and got a contract, we didn't take grants for the most part. We did a few, and they have some workers work on it and one of those workers might get pretty good at getting contracts on their own. In the system division it wasn't really like that, at least not in the medical installation system part of it or the networking system part of it, because they were much bigger contracts and so you got a bunch of PhDs, one of whom is a phenomenal leader...a few PhDs and they are seeking work to support their research. There is a manager and some lead technical people who are seeking work, there are some other managers, there are some individual contributors, like a few of them maybe. So it's much more...in our division it was much more like a company running a product line or something like that. There certainly wasn't issues of chargeability across BBN and that's one of the things, that if you are leading a big group, a department, you have to work on it getting enough contracts in to support your people. If there aren't enough contracts temporarily, maybe one of your people have to go work somewhere else in a company for a while to keep chargeability up. That is the way it was set up, but in the systems division it was really much bigger than that and most of the people didn't have to find their own work, and those of us who got good at talking to the customers tended to get promoted to the leadership positions, while others, who might be smarter, technically, didn't. We had a nice career path, nice career

ladder, a technical ladder that got well paid, but they weren't the ones they went after to get the contracts .

BF: You also know that BBN reward disciplinary and professional achievement in addition to more institution loyalty?

DW: I wonder what I meant by disciplinary in that sense. BBN certainly cared about and supported people's professional societal activities and so on and that certainly counted for something in how they were treated.

BF: Did you find comfort in that?

DW: Absolutely! In that sense, well if it's good for the company, its good for everybody, right? It's good for the person, because they need to go talk to people at other places, it's good for their CV, it's good for keeping them, if they are a good person, you wanna keep them, so if they wanna be into professional activities, you want to let them deal with it. It's good for writing proposals, but now they have got more connections on their CV, although the vice chairman of the society... They have got all these published papers in that sense BBN was kind of a cross between the university and industry. We supported academic kinds of activities to keep people happy and developing, in addition to running the systems business, so yes, absolutely.

BF: We looked at one example of contract that they sought and won, first ARPANET one. In general, for seeking out and making proposals for contracts...how would people end up participating in that more broadly? If for example an employee used needs to be able to charge time will they have any kind of role going on in getting these contracts or was there more professionalized with a small number of people working on it?

DW: Okay, let me think about this a second. First, we tended to have a lot of the same customers over and over. So it's reoccurring business. It's like a pizza shop. As long as they got me a good pizza last time, I will probably come back and buy the pizza the next time. As long as we deliver to ARPA or the Navy or whoever, they will come back to us. And we weren't working on the big system competitive procurement, for most part we were working on mostly sole source procurement with people I knew across BBN. I've got some good stories to tell all about the Navy part about procurement, If you can make a note, very smart procurement in the navy, so there's that. So if you have a good idea in the area where we're already working or was kind of natural for an existing customer, well sure, the person who's dealing with that customer will bring the engineer along to present it. The government people came to visit less often too, and some of us would present stuff and we would have ARPA present new idea and that would be discussed. By the way, here is the story. When Steve was at ARPA early on in the ARPANET contract, he would come to visit us, probably for the national software works, I am not sure. He called up one day, saying, "I know that you guys are not dressing up when I'm not there. Can I dress down when I come to visit you?"

So there is another, we would put on suits to visit ARPA, but they would put on their jeans to come and visit us. Not Vint Cerf of course, Vint Cerf always has his vest and his

tie. If somebody had an idea that was in a new area then they'll present it to the division. If the division they felt it was a good idea and we would fund it with our RFD (Research & Development Money), and RFD money is a category of money, not a super big category from a government contract, that allow us to charge their share of our total contract as... like overhead. So you bill them for your actual cost, you add overhead and you add a percentage IR&D and... So we would work on something like that a little bit. That was not very big, mostly because there isn't that much IR&ID and then some good stuff was coming out of it. And directly trying to find a customer for it... again you probably didn't wait for a competitive procurement, you went and found somebody for whom this was relevant technology. Occasionally we did IR&D just because it was flashy, like the three-dimensional display that we did. "Space craft" it was called. You never could have found a customer like that and we would demonstrate it every time they came to visit. Funded by IRI&D. When Frank got to BBN, by the way, originally way back then, he was hired to be the division director for what was the health systems area. And we had the contract that had came out of the initial time sharing system that Jordan Baruch and Leo...Leo directed Jordan Baruch, I think, to somebody, Leo Beranek. Jordan Baruch went there to get a contract, and we both did this hospital thing that Frank came in to lead that. The next thing Frank did (I don't know the next immediate thing, but I know some other things that Frank did after that) is he and Paul Castleman went down to NIH and tried to get a contract and developed an activity which came to be called the PROPHET system that I told you I was involved in. So when the software guy was needed, eventually I did some software design and I wrote the report about all different kind of programming languages as they could be modified to do chemistry. So he went and found somebody that was interested in this -- that case was gonna be Bill Ralph who was maybe a deputy director or division director at NIH and we got funded to build this combination of a display, and then the management programming language system that research pharmacologists and chemists could use, and it became a very big deal. It helped change that world, I think.

BF: I want to characterize the kind of work that BBN did and you can tell me if this makes sense or I am getting it wrong, on the one hand there is, and this is created in 1967 I think, some document related to a shareholder meeting.... On the one hand, there was creating new knowledge of specific problems for clients and this is consulting research and development where this happens. And then on the other hand there's marketing industrial services and products and this was two categories that showed up...

DW: That sounds like it's very early...

BF: This is 1967. It reflects and earlier time...I am curious about how that would have changed for the period let say the 1970's and what does that do now?

DW: Very early on, after BBN was founded and incorporated, they were trying to find ways to leverage what they had done, license technology to joint ventures, things like that. Leo and Dick were very connected to MIT, so for instance, there were a fuel cell company, when I first got to BBN. there was a system called Otter Products which was a teaching machine, mechanical teaching machine business, and they were looking

around for other ways to do stuff because, I think, Leo thought the acoustics area, the acoustics consulting for architecture couldn't continue to grow although it'd grown very fast in the early years after 1948, because there was no such company before BBN. So they were a whole bunch of little things. I will say none of them were particularly successful...that might be an overstatement we owned Wood Flong for a while. Do you know what a Wood Flong is? Wood Flong is a piece of paper that you use to make a cylindrical piece of metal for type setting, for printing. A Flong is that thing you use to cast something circular in, I guess. Eventually, BBN got pretty big in the non-architectural acoustics area; Ship quieting, ship detecting, undersea acoustics and all that on the one side of the company and the other side of the company got pretty big in the networking area and so on. And as a result of that, later on, because they were filled with an urge to capitalize on things, exploit technologies, companies were started. Some of which got bigger, like Telenet that Larry Roberts went to be president of, that BBN started. BBN Communications Corporation got separated out as a standalone subsidiary - not so standalone - because it was delivering commercial networks all over and as well as operating the government networks. Or the PROPHET system turned into a system called RS1, which became a package software product for workstation kinds of machines. Eventually it got put out of business, I think, by the PC business, although I'm not completely sure about that. A parallel processing, high performance computing business, an ATM's switch business where ATM doesn't stand for your money machine but stands for some communication protocol. So BBN did a good bit of that. And Levy's paper in the book 'Culture of Innovation' really talks about that whole history. But from the beginning, Beranek had been interested in licensing, exploiting and of course the big thing he did, was bring in Licklider, because he thought the acoustics business wasn't going to grow indefinitely. He needed to get into the computing business, he recruited Licklider and Licklider drew in people like Fredkin and had McCarthy and Minsky from MIT come down as consultants and kicked off the whole computing area at BBN before Lick wrote his paper on the...what is it... the man/machine symbiosis, which is somehow is a hint at the world of today's networking and personal computing just as Walter describes in his book "The man who made computing personal"... something like that.

BF: I would like to ask you about the

DW: Let me just finish that. So Licklider came and hired bunch of students like John Sweat and Gerry Elkind and all those guys and they were the ones that started the information system business, but Barbro was hired and that got us into the AI business. So that whole move into computing in a big way came from Licklider, who some sense I suppose when he went down to ARPA did the same thing, he found a bunch of people, gave them vision, didn't manage them very much and eventually wandered away and they continued without him.

BF: Frank Heart wrote in 'Culture of Innovation' that there was on one the hand projects such as the ARPANET and on the other there were attempts to commercialize them and spin them off - create some subsidiaries. Can you talk about that?

DW:

Sure. As I mentioned, from the early days there were projects like that but during Frank Heart's time, I would say there were three big ones. The spinning off of the computer activities out of Franks division, the MBB computer activities (Microprocessor Building Block is MBB) and that was spun out as a separate division, separate subsidiary, which tried to go into some kind of Unix computer business and that was failing. So the rest of communications activities that wasn't really R&D that was running networks in Franks division was spun out to join that stuff and it all became BBN Communications Corporation instead of BBN Computer Corporation. And that was very successful for a number of years, but let me back up. Started Telenet to commercialize the packet switching technology, hired Larry, and sent a couple of our staff members down there carrying the software. They eventually rewrote the software for the computer that Holger Opderbeck designed (one of Leo's students) and we ran all the software, Larry pushed X25 as the communications protocol and that had an impact on the world for a while. BBN invested in that itself and Steve Levy was the chairman of the board and Steve brought in some venture people to put up some more money. When that was ultimately sold, BBN made some money. So BBN couldn't sustain their involvement anymore and it was sold I guess to GTE, I think that's right and then BBN made some money, a few millions. That money was used to start BBN Computer Corporation, so BBN's activity in trying to commercialize the switching company carrier funded the spin-out and they started BBN Computer Corporation. That was able to sustain itself because then BBN moved the entire big government contract support business into that, when it was failing and at that time the other two procurements had failed and the government had come back to BBN to do another competitive procurement to BBN and Western Union chose BBN and now BBN was spreading the ARPANET as DDN, spreading that technology as DDN, and that did very well and pumped up stock price a whole lot. Then the PROPHET system was spun out, selling the package software version of the system that has been running on a workstation kind of machine as a software package and that did quite well. And that helped the stock price. In thatm BBN got some kind of an investment fund, sold shares and an investment in BBN and that activity... and you have to look at another chapter to remember exactly what those are called, but we got some money to build some kind of AI statistics thing to go on to the system which we called the RS1, and that have pretty big impact in its world. And then we got another one of those investment fund things to fund spinning out BBN Advanced Computer Incorporated, ACI. And that never really got off the ground. That high performance computing thing never really took off. Eventually some of that was funneled a little bit into some of our government stuff, That was a thing we could do occasionally... Like Infomail, that's another one. We started Infomail and it never really took off and we funneled BBN Computer Communication Corporation and sold it to all the government customers as the email system, and were delivered as part of the network system we were doing and we didn't even charge them separately for it. And they liked it a lot and it was a good one and then everything began to fall apart. ACI really didn't take off, the government support for networking tailed off and we installed high commercial networks, and at that point all of them eventually one way or another went downhill, got sold or something. But the argument has often been, when we are looking at BBN,

they could never do anything, they tried to commercialize something and it never succeeds. In fact some of those succeeded for quite a long time and they made quite large profits and pumped up the stock price for quite awhile. I sold my stock, used my options at BBN and paid off my mortgage on my house in the back bay, so I thought it worked out quite well. We certainly missed the boat with routers, too. Packet switches cost, let's say, 50 thousand dollars, routers are gonna cost less and those people at BBN who were saying routers is gonna happen couldn't convince the management of BBN Communications on why they should capitalize their packet switching market by building routers. We had the first router and instead Cisco won that business, that's not a new story. DEC didn't see the workstation coming, the workstation companies succumbed to the PC. Nobody is particularly good at having their own product replaced by the next one.

BF: If you were to compare, let's say, on the one hand early 1970s working for Frank Heart on the ARPANET or with, say, mid-1980s with the Defense Data Network in the BBN communications corporation was the style of management that you were seen around you or exercise yourself similar between those two different periods?

DW: Well, certainly a lot of the people who were at BBN Communications Corporation and then department leaders and something like (inaudible) and others in Frank's division and it certainly wasn't the same as it was done there. And some of it was just doing the same thing. They had been operating the defense data network and out of Frank's division, and now we're operating it out of BBN Communications Corporation. Ket's say Paul Santos went from one place to the other. Alex didn't go, he stayed with Frank. I will say this probably some of that, okay? BBN, in selling the commercial network, developed a pretty strong sale and they traveled around the world and sold networks and that was different than the kind of selling that we had ever done with the government. And they were pretty successful. I am not the right one to really talk about this, because I was not at BBNCC, but by this time the packet switching program that originally for the 516, then the 316 and then the MBB and versions of that, was getting very complicated, X25 have been cobbled on to...then it has been redone to rebuild the internal memory allocation system and so on, it was getting pretty old and tired, and you can read about that in my paper in the second issue in the IEEE Annals of the History of Computing of this year, 2014. So that was a big struggle and I think there was a certain amount of dismay among the engineers, but this is so hard, we should start over, we were missing delivery dates at some new network monitoring center and then they developed, bickering within the management of BBN Communications and Rubin Gruber wanted to do something small and I talked to Rubin or Jeff Mayersohn or and other people wanted to do something else you know the gradually the whole business kind of went away. So I would guess in the latter days of all of this it wasn't as joyous a place to be.

BF: What do think about when you think of the latter days?

DW: Early-to-mid 90s, when I was at BBN Laboratories, BBN Systems and Developments, up until '90, I sometimes got called to help with sales calls because I knew the stuff, so I

gave a good presentation. By '93 and '4, Ben Barker was pulled back from whatever we were doing to go there and basically get rid of it, and he took a piece and had it sold to Cisco. I took another piece and folded it back into the R&D division, so by 1993-94, BBN Communications was on its way out or close to gone. And in 1981 I went over to BBN Communications to be the chief operating officer to sort it out. That was at the time we began.... Ah, so that's the story, BBN Communications was having big trouble, losing money. I went over there too with Michael Lavina to help get that sorted out. We sorted that out, then I moved to BBN to take over all the R&D and that's when I and Lavina and Levy agreed to move the communication activities out of Frank's group and over there to make that group viable and Frank was not happy with that.

BF: I'm gonna return to this question I just asked about management and see if you can comment more broadly on all these different positions and throughout the time span...if there is more you want to say on BBN management style, that would characterize the firm...what we discussed earlier

DW: I think that the one characteristic was, almost all these schemes from the technical side of things and we tended to... you know...by the time we got to the management stuff, we weren't technically competent anymore and we were dealing with our counterparts and our customers, getting contracts. We could beg our people to explain what they were doing in simple enough words that we could understand and we were managing people in not a very hierarchical way, a pretty collaborative way. There was not a lot of 'I am the boss, you're the assistant, you do what I say', because you knew by the time you got to be a technical manager that the people working for you now knew what you did. Because they were still doing it full time. People would sometimes come to me and say, well I wanna be a leader, I want to be a project leader, division or group leader or something. And I say, well, okay, we can try to work out a way to try that out if I thought they had a chance. And you could do it for a year or two, but you would have to decide if you're gonna give up technical basically completely and become a manager, or are you gonna say "this really isn't for me" and go back and be a technical person, because you can't compete in BBN's environment with the technical people doing it half time, you can't stay at the level of the technical people, you have to hang in there for a year or something but ultimately you have to decide. Are you gonna reach technical incompetence or are you gonna stay technically competent?

BF: You wanted to come back to Navy procurement...

DW: There is an interesting contract for a system, to do acoustics in the Atlantic Ocean, I believe. And I'll remember its name in a little bit, it had some initials. In this area BBN and Bell Labs were probably the strongest in the world at developing technology. You can read about this in the Ed Starrs chapter in the 'Culture of Innovation' book. FDS! Fixed Distributors System or something. As I remember the story, both Bell Labs and we and probably perhaps others, had been doing technology development kind of work for the Navy, and now they were gonna try to decide what the technology was that was chosen. And BBN and Bell Labs were chosen, I think it was Bell Labs, were chosen to do a competitive fly-off, design a system, make the thing work and the government, as I

remember, the admiral or whatever it was, the captain maybe at that time, had the two groups set up their system in the same room, side by side, so they could see what each other were doing and then feel greater pressure to deliver. So they were really trying to outdo each other and ultimately, the BBN method was chosen, that's a pretty clever procurement method. If you gonna get a lot of work off a couple of really great group, the next step that happens is the contractor. Now a big contract was gonna be left for this system and all the big aerospace contractors, several of them, used IBM systems. Others came courting us to be a technical group on their team while they put together some big system, but shortly the IBM guys were saying, okay, IBM will be the project leader, BBN could be the deputy project leader, IBM would be the technical leader, BBN would be the deputy project leader. Well, we knew a lot more about this than IBM did, and so somehow the word got to the admiral and we called the captain up and he called up the IBM guys, basically, somehow in an appropriate way, no doubt, and told them BBN will be the technical leader, IBM will be the assistant technical leader, IBM will be the project manager, BBN will be the deputy project manager. BBN was gonna be the technical leader, exercising contract power to make sure that the smartest guy there was on the particular subject and his set of people were going to lead the technical design. The last thing I think of that contract was, they then came to us, we were supposed to sign a contract to be sub-contractor, and they were reserving for them the right to replace us. The big guys always ride the little guys, because government may not want you. There is always a good reason why we should be replaceable and I wouldn't sign a contract then unless we would be guaranteed a certain percentage of this for the life of the contract. He won't take your team and have new management of IBM two years from now...

BF: So did BBN job changed with the 1975 transfer to DCA operation of the ARPANET?

DW: Yes, I'm trying to remember how that worked. ARPA still was kind of the boss in terms of R&D and DCA was the boss in terms of operations. So we kind of had two bosses as my memory... I don't see that being particularly hard. Anyway, Alex McKenzie is the best person to ask about this than me.

BF: Was there anything you observed about DCA/ARPA relationship?

DW: No I wasn't close to it, my impression is it worked fine. ARPA needed somebody to operate the network and they withheld the authority they wanted, that's my memory. So we had two bosses.

BF: The transition from experimental to operational status, I understand ARPA started much later before BBN

DW: I don't see it ever having transitioned from the point of view of what we did, we were always continuing to develop stuff early on. I don't know when anybody might have declared it operational, but if it was declared operational at some point. That seems to me... we more or less did the same thing, we have been operating it, operationally, as a prototype network for some time, and now we operated it. It was bigger, I suppose,

more important, more people to deal with, but I don't remember any big difference in what we were doing.

BF: So all the development work and whatnot that you were doing was still through ARPA?

DW: That's what I kind of think, I can't be sure, I don't really remember at all. Yes, I remember the money might have been coming from DCA, but we were getting direction from ARPA. When did it go to ARPA?

BF: 1975.

DW: '75. So the new routing hasn't gone in then, certainly that was collaboration in some dimension with ARPA. I don't know how we interacted with DCA for that, John is the right one to ask, John McQuillan or Alex.

BF: I think you have answered this for me, they were not Arpanet sponsors, they were DCA. My suspicion is that you don't have any deals with that?

DW: I wouldn't know, I wasn't close enough to it by that time, Paul Santos would know. My guess is there were sponsor meetings and Paul, somebody like that had to deal with them a little bit. So I would be surprised if there was no connection with so-called sponsors, but I would also be surprised if they were very big part of it as it was being managed.

BF: Another big shift for the ARPANET was the creation of the Defense Data Network, did that change BBN's job with regards to the ARPANET at least?

DW: I think the answer is: I don't know. The Defense Data Network was as a result of Autodin II not happening, right? And so BBN basically got the contract to...well, as I said before. I think I mentioned there was kind of a competitive propose-off between Western Union and BBN with the government person leading each team. And Heidi (inaudible) was leading our team and Ed Starr, Peter Savchik, people like that were doing our stuff. And by the way, that whole thing was being promoted, that that was happening they had to go the way that the ARPANET technology would be used. That competitive fly-off was probably DCA trying to be fair with Western Union to give them a chance to participate after they have dumped them but Keith Uncpahr, I believe it was a big deal in getting that to happen. Keith Uncpahr was on various advisory committees, certainly in contact with ARPA, certainly in contact with DCA, I believe, and he was one of the people, I am sure, who was saying: "Come on guys, use the ARPANET technology rather than continue to fail with Autodin II" And of course, BBN didn't win the Autodin II proposal because of poor proposal management by us. We put in a good system bid and that was a mistake. It was correct in the case of the ARPANET, it was a mistake in the case of DDN...because the DDN procurement was broken into pieces, we were supposed to address them independently, and it was evaluated by different people, different sub-groups of people. So we were saying things like, "You can't do some of this", but Western Union was saying "Yes, we can do it all", and not checking off all the boxes and writing it more as a consistent thing. John McQuillan was leading our proposal effort and he was having great difficulty because Frank wanted to have it be a system proposal

and it shouldn't have been. And so they only who had such technology running, they didn't beat the people who didn't have it running, because we did the proposal in a way that disqualified us. That got us the second ranking. And then when theirs didn't work, because they promised to do stuff that was too hard, but they weren't that good, or they didn't have it running already, then eventually Carlucci cancelled them, the deputy secretary Carlucci cancelled the terminal. Paid them penalty payment for cancellation, I think the number I remember is 84 million dollars, to cancel their contract and then had this competitive procure-off and we won that. When that came to BBN that was a kind of a big change for BBN, because now ARPANET was out there in some places, but basically we were running this new network for DCA. I don't really know a lot about it, I wasn't close to that at all.

BF: Lets discuss BBN's relationship with other networking groups and also some of the other networks, the first is Cyclades. And you mentioned earlier that you have meetings and in fact a piece by (inaudible) said that Cyclades went out of its way to find out what you were doing, so that they could do it differently.

DW: You're talking about their paper in the BBN special issue of the Annals of the History of Computing. Yes, they said that and I wrote those sentences. I pulled that whole special issue together, but that paper I pulled together and then we had to withdraw a bunch of our papers because there wasn't room. So I took my name off of that paper because they were withdrawing my co-editors' papers as well and I didn't want to have that one and them not to have one. And this is the same paper that the two of them and McKenzie and I had in the BBN 'Culture of Innovation' book, slightly revised. So, yes Cyclades, we went and visited them quarterly in Paris. Mostly they had people who came to see us. For instance, Gerard Lelann came and spend couple of weeks with us studying the IMP, looking at the IMP and so on. I remember those trips very fondly, dinner in restaurants with Hubert Zimmerman, things like this, wine for lunch in the IRIA cafeteria, it was terrific. My program for those visits was...first, when we first took the contract from them, the consulting contract, BBN's contracts guys tried to have a rate uplift in it for foreign duty and Louis wrote back and said no, being in Paris is not hardship, a hardship assignment. Then we said ok, we accept that, I will fly Wednesday night, sleep on Thursday and consult on Friday, spend all the weekend in Paris, consult on Monday and I fly on Tuesday. This was my approach to consulting at Cyclades and it was great and Louis will find wonderful restaurants for us to go to, like the restaurant on the west bank where you get the chocolate mousse, but instead of bringing you a little cup with a tea spoon, they bring you a big bowl and a scoop and a cup and a tea spoon. Fantastic.

BF: Was there any influence from that, besides the restaurants, was there anything influence on you or BBN from that group?

DW: Well I certainly think that Louis was promoting datagrams pretty heavily, and when I was writing to Vint and Bob, or to Vint probably... which I send my memo which I mentioned earlier, I probably had datagrams in mind as well. But I'd had something other than the ARPANET host to host protocols in mind ever since RFCs 61 & 62. I think

they influenced us a little bit, certainly it influenced the world a good bit, for which Louis has been honored often.

BF: Later, we will go back on RFC 61 & 62. I read that you had Peter Kirstein on retainer, can you explain why?

DW: Sure. BBN, Frank Heart in particular, wanted to somehow exploit this technology. We invented it for ARPA, developed it for ARPA, we were selling it to the government, we were operating for the government. We wanted to have another networks. I don't know how Peter and Frank got in touch with each other, possibly through ARPA, possibly some other way, but Peter was in Europe and got around Europe, met new people in Europe, he'd also spent time in the US earlier in his life and consulted for some company in upstate New York or something. I don't remember the story. So we had him on retainer to kind of look for opportunities for us. I don't remember, it was between Frank and Peter. We saw him when he came. We were all very friendly and we will visit with him when we'd go to London to see him. We particularly saw him in London in the early days of the Internet era, when Kahn and Licklider and Rettberg and I and others went to London to meet with Peter and people from UCLA, maybe from the post office maybe Derek and Barbro I am not sure. Viterbi was probably there. Maybe. I am not sure, he got involved pretty early as Linkabit's person thinking about satellite reservation systems. Not good restaurants in London! So we had him on retainer. That resulted in... I don't know exactly if that directly resulted in or indirectly resolved in or was independent... We did contracts with Logica, we did contract with SESA for them to represent BBN selling networks in Europe. And we trained the people at Logica, Phil Hughes was the guy at Logica, we trained the people at SESA and I don't remember the name of the person there. Alex might. I remember John McQuillan and I probably went to France at some point trying to sell networks, I don't know if Peter Kirstein had any involvement with our networks with Olivetti. We had a very big arrangement with Olivetti, them selling our networks. We staffed up in Italy. Alex was in Italy for a year, Tony Michel was in Italy for a year. McQuillan and I made a lot of visits to Italy. I can barely remember the names of the two of the people that was there. Mrs. Belsario was a key person, and the guy above her...Mercurio. was the guy above her. I am not sure we developed them so much as we trained other people to do it themselves or to sell our networks...

BF: So there were some cases where...

DW: ...to represent us in Europe. We were not well positioned in Europe at all. We didn't know any of the issues in France or Italy, so in the case of all of Olivetti, we became an OEM, basically. I think we were delivering networks to them, they were selling the networks and delivering them

BF: And were this very similar to the ARPANET?

DW: Yeah, Yeah. Yes.

BF: Is this an example of where the IMP code gets used ?

DW: Yes, as the IMP code evolved, probably the last machines that we sold all were MBB based machines.

BF: How much were you involved in some of those other networks that BBN just built and managed, like in the case of for example the NSF regional networks in your in your net bought and managed?

DW: I was very involved at the beginning. Frank and I were involved shortly. Alex took over from me and other people were involved like Bernie Cosell and others. In the Logica and SESA, I was around during the selling of those. I wasn't involved in anything that actually happened. My guess is McQuillan was more involved there, In the Olivetti case, I was actually involved early on...I would say later, when I went back to BBN Communications, because it was in trouble, I did a good bit of work for Olivetti trying to calm things down. I'd almost been the project leader day by day for a few months, to stop making promises we couldn't keep, and promise what we could do, things like that. There was a period I was pretty involved with Olivetti. I made a few trips, had some fantastic meals in the hills of Italy, the Olivetti guys took you to some wonderful meals. Wow! I forgot about those. Piemonte wine's really good.

BF: So there's Citibank, was that just a subnet you put in...

DW: That's all I know, I don't know what else happened, I helped get the contract, get it started, went to meetings with Cy Ratner for a while and then drifted away. Alex took over, I think it was Alex.

BF: One of the things that comes up with the Defense Data Network by that the time, the Communications Corporation you were producing your hardware at this point, there was not just Honeywell, there was the c30's and the c70's, can you explain how that came about?

DW: We used the Honeywell hardware, we modified it substantially and made it work, even on the hardware Honeywell engineers weren't very good at implementing it, but Barker and Ornstein made it go. Then we got into studying the Pluribus. The whole idea that we should have a non-stop computer that should be a packet switch. So all the 516 algorithm were re-implemented for the Pluribus but for running in parallel processing environment on a different processor, plus a whole bunch of codes, which was also called the reliability code, which kept the machine running when you pull parts out of it. You could pull parts out of the Pluribus and it would keep running. That was a pretty interesting project on a theoretical sort of way. For that, we bought the Lockheed SUE factory in Hong Kong, to use the Lockheed SUE processor board, board on the processor, I don't think we had micro-computers yet - as the thing we plug into racks with other equipment that we implemented. So by that time, we were doing our own manufacturing in some sense, and Honeywell was still being delivered as well. Then Rettberg and (inaudible) got interested in micro programmable computers and...I don't know if they were in the IR&D project or not, I don't remember...they certainly were thinking about micro-programmable computers and they came up with a proposal. I guess there must have been an IR&D and they made the MBB. And on that we

immediately implemented the Honeywell 316 instruction set and micro code in that machine, plus a little bit of changes to make it a better machine than the 316, such as the bigger memory space. So that machine was basically running the 316 software as it had evolved at the time. By the way, the Pluribus the 316/516 software had to evolve in parallel at all times. They were completely compatible one machine to the next, through all the routing changes and everything, so implementing the new routing algorithm that McQuillan was doing on the 316 code, John Robinson was busy doing it in the Pluribus code in with parallel with him. And then we got the idea of starting the BBN Computer Corporation and making the MBB into a Unix machine. The machine that just ran Unix as its somehow native language, if I remember correctly, that works so well. Then it became BBN Communication Corporation and somewhere in the...they redid the 316 micro code to be what was called NMSS, maybe? Native Mode Software System... some letters like that. You can find this in my paper on the second issue of the Annals of the History of computing this year. And what that did was put a whole bunch of more stuff in the hardware that used to be in the 316 software. It had queuing instructions, it had program flow instructions, it made a better machine than the 316 and then later it was changed later, once again to be even more compatible... incompatible with the 316 so then it disappeared . But I think it's a pretty interesting case study of software originally written in 1969 evolving into the 90s, I think, through emulation in some sense. By the way, the argument always is, it's always easier to start from scratch. It's almost never easier to start from scratch, and if it is easier from scratch, then it's less reliable to start from scratch, they actually went to get done sometime. It's a lot better to modify what you have than starting over. That's my theory of software development.

BF: Looking back on everything we discuss I will like you to come in on the elements you see in BBN's culture/structure/organization that helped it become such a successful piece in the ARPNAET story, its development, its operation.

DW: Well, I think there was certainly a component of BBN to hire a person you think might be good when they come by you... figure the rest out later. Without being being too immodest, that happened in the case of both Kahn and me, and we were part of that team. I think the selection of Frank and the availability of Bob gave us a powerful combination. When they then added Severo and me and Will and Bernie and Ben, that caused Bob a lot of heartburn, as he perhaps talked to you about when you interviewed him. He thought he should be running the group. Maybe not the first year, but after that he thought he should be. But I think that Frank, who was an experienced system builder was probably better...we wouldn't have got this much done as we did. The whole way BBN operated with their clients for the most part got technical people talking to... talking with technical people. Sure, we had to get through the competitive procurement originally, but the people doing the selecting were from the world that we were from, doing procurement another way. And there is debate... I don't know, I have heard different stories. Bob Taylor takes credit for choosing BBN. He said that Larry was gonna chose Raytheon. But he made... I don't know, they don't always agree on their memories. Bob clearly claims that he was the one that made sure BBN was chosen. We certainly had a bid that was competitive. Therefore... and my guess is it was the right choice that

choosing Raytheon for that wouldn't be as good as choosing BBN. We fit in better with the other parties, we fit in better with the universities and SRI and ARPA. That's opposed to being a big aerospace contractor. And we performed over and over and over. Stuff kept working, so we kept getting hired back, you probably couldn't have heard that some of our friends went there, when Vint or Steve went from UCLA or Stanford, I guess, in the case of Vint, then we had known from the first days of ARPANET, to ARPA... that probably didn't hurt us any. When Bob... however bitter he might have been about Frank, when he went to ARPA, he knew us all, we knew him, he respected us, he was certainly willing to send work to Frank's department and group - that surely didn't hurt. I think BBN was just a good match for ARPA. It was the kind of place like third major research universities. I mean if you look at MIT, UCLA, Stanford, Carnegie-Mellon, BBN played in that league. We were more like them than were like Martin Marietta. Historically, it's all part of coming out of MIT and SAGE and Licklider and Lincoln Lab, that whole set of people who were in the Boston area.

BF: I'd like to ask you about RFC61 which became RFC62 which is 'A System for Inter-process Communication and Resource Sharing Computer Network', I hope you can tell me what it was, what you were arguing and also how you see that more broadly in the history of the ARPANET, its protocol, the way it was envisioned and even going forward to the history of the Internet.

DW: Well first, I don't remember much about it, so I can't tell you too much, but you can work it out. The definitive version was published in the Communications for the ACM. What was striking me at the time, I remember typing it again, I was gonna write something, you think of something and you decide how to write it down. I was struck by the fact that NCP was this connection based protocol and we were building the network and I didn't quite understand why we had to mimic the telephone system by having in essence, dial-up connections. And so I started thinking about it, and also, I had been studying computer architecture and inter-process communication was a thing that was on my mind, and why didn't the processes just talk to each other? Why did we need all these connections? So that's what was motivating me. So I wrote something and I kind of mailed it up. How to solve the manual logic? It typically happens when you write it down. When you kind of raise your hand and speak about it, it often doesn't have enough logic. But if you write it down and it has some more logic and then quite quickly, I understood that I wanted to change something, so I changed it. That's the second RFC. Then I thought, why don't I send this to the CACM? I have done a lot of publications there. So I started off with them and got reviews, got very strong reviews. One of the reviews, I remember to this day. Of course, I have no idea who said it, but "This paper will be remembered as long as there is networking". So maybe it was a person who didn't like the way NCP was being invented. Now, in fact, of course, it's been completely forgotten. What happened was, there were a couple of people who implementing things, versions of it. Bob Bressler did his master's thesis on it at MIT. I think Dan Murphy might have is there an RFC by Bob and Dan and me... Bob and me and one third person... I think there's another RFC where the three of us report about some prototype representation. Bob had one in his master's thesis and somebody else with whom

Bob and I... and there were some person around BBN, if I remember right...talked about some kind of prototype implementation. And that's the last we ever heard of it, because TCP came along and got split into TCP and IP and I view it as somehow the first person to publish on thinking about in at least this context of the ARPANET/ Internet...kind of like datagrams, but of course they never built a network based on it that went somewhere. So like so many things about ideas... they have been heard before, but they don't go anywhere. I think that's where RFC 61 or 62 are. But as I said before, it was my first peer-reviewed paper in CACM. First time I got to ever experience sending something, waiting forever and then it comes back saying here are the reviews, fix it in almost no time, and have it sent back to us.

BF: So overall is there anything you will like to talk through or is there a topic that we didn't cover you will like to address?

DW: I don't think so, there's probably lots of other topics I will like to address but I don't remember what they are. But I thank you for coming to see me

BF: Well, thank you for your time.