

# A TEI Project

## Interview of William Naylor

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### 1. Transcript

#### 1.1. Session One (October 1, 2013)

FIDLER

This is an interview with William Edward Naylor for the UCLA Center for Oral History Research. It's being conducted in UCLA's Boelter Hall by me, Brad Fidler. It is the morning of October 1, 2013. Let's go back to your initial interests in computing. How did computers first become visible to you, and what sparked your interest in them?

NAYLOR

Okay. I have to say that my first introduction to computers was when I was an engineering student at UCLA, and I was signed up for a required course in programming, and I was given a three-inch manual and pointed at the computer. I don't even know what kind it was at this point or remember. And I said, "I can't do this." So I changed my major to mathematics and subsequently got my degree, and two years later, I was a programmer at the Boeing Company in Seattle.

FIDLER

We'll get to Boeing in a moment. In 1966, you got your M.S. in mathematics from UCLA.

NAYLOR

Right.

FIDLER

But you started that in engineering.

NAYLOR

Yes.

FIDLER

Before you switched out of engineering, did you know other people who had interest in programming? Were there people you knew that did it as a hobby?

NAYLOR

No, I didn't. I know some of the people that I met once I was in the ARPA group had been exposed to programming in high school, and I had not.

FIDLER

Now, you mentioned that you went to Boeing, and that was in 1966 you were there. You were also, after that, at the Wolf Research and Development Corporation and then

Systems Specialists Incorporated. This goes from '66 until '68, in this period where you're not at UCLA. Can you take me through these jobs and just kind of explain what you were doing?

NAYLOR

Sure. At Boeing, we were converting from FORTRAN II to FORTRAN IV, the programs that were used to make the drawings of the aircraft. During the time that I was there, which was less than a year, I got engaged to my former wife and decided to come back to L.A., so that's when I got the job at Wolf Research and Development. We were developing a set of tools that were used to make electronic drawings on—I don't remember the name of the machine that we were writing to, but it was an interface to this automatic system of drawing. And then that, actually, I think the company went out of business, or they had started this West Coast division and the West Coast division went south, and so that's when I got a job with, actually, a person who worked there, started a company called—what was it?

FIDLER

Systems Specialists Incorporated in Woodland Hills, California.

NAYLOR

Systems Specialists. Yes, a very distinctive name. So I was working for this woman and I was contracted out to Rocketdyne, and I was maintaining the rocket engine simulation software that they had there, and that lasted until I decided to go to the Institute of Geophysics and Planetary Physics at UCLA.

FIDLER

So in 1968, you're back at UCLA at the Institute of Geophysics and Planetary Sciences. Had you expected to get back to UCLA in '66 when you'd finished?

NAYLOR

Yes. I expected to go to graduate school. I didn't have the grades to go to UCLA, so in probably '67 or maybe the fall of '66, I don't remember, I started taking classes toward a master's in math at Cal State Northridge. I got the grades. So then I transferred to UCLA in math. Again, I don't know exactly the year. Probably '68. May have been subsequent or coincident with starting at IGPP. And so I was going along being a programmer. At IGPP, I was doing data reduction software for the OGO-5 satellite, particularly the magnetometer instrument on that satellite, and the thing that was most fun was looking for the signature of the heater and removing that from the magnetometer data. And then for some reason, I realized that there was computer science department being started up in the College of Engineering. I was already a programmer. Maybe I should try this route. So that's what I did. The summer of '69 is when I met Steve Crocker. I was taking a course in program verification and it was kind of a seminar course, and I was giving a presentation on a paper written by somebody at Stanford whose name escapes me right now, who was prominent in the field at that time. Steve Crocker came to my presentation, and since he was interested in program verification and later wrote his dissertation in that field, he said, "You should come to work for us." So that's when sometime in the fall or summer of '69 I changed from IGPP to the computer science department on the ARPA project.

FIDLER

Now, at that time, the summer of 1969, there had been, for example a press release by UCLA that had talked about the National Computer Network. There was also an

extremely small Daily Bruin student newspaper piece on how UCLA was going to be the first node of this national network. Was there much buzz in the circles that you ran in about the ARPA computer network?

NAYLOR

I wasn't aware of it until I met Steve and I became part of the group that included Jon Postel and Vint Cerf, Mark Kampe, Evelyn Walton, Charlie Kline.

FIDLER

When you heard of it, what were your expectations for what this network could potentially be?

NAYLOR

Well, it was advertised as a network, even to ARPA, to connect the various ARPA research facilities together so that they could communicate in hopefully an easier way and/or share resources that was more difficult to do previous to that, so there were no expectations at that time that it was going to grow into something that would be public and used by virtually everyone.

FIDLER

When you started at the Network Measurement Center in the summer of 1969 or maybe just in the fall—

NAYLOR

That's actually not quite accurate, because it may have existed as a name at that time, but there was nothing to back it up, except to say that there were the three types of measurements that were defined and implemented in the IMPs, and I think that was done by Jerry Cole and maybe Len, I don't know, but I'm pretty sure Jerry had something to do with it. But there was no software on the local computers to make it work. We had a SIGMA 7, which didn't have a time-sharing system, or if it did, we wanted to build our own—I don't know the politics behind that—so we did. We, as a group of grad students and even some undergraduate students, worked on building this time-sharing system so that we could hook it to the ARPANET and be able to, ourselves, share resources over the Net. And it wasn't until we completed the work on making that time-sharing system work that I was able to write the software that collected the data from the IMPs on the SIGMA host.

FIDLER

So before you started working at the Network Measurement Center, you said you saw its kind of earlier form where there was a time-shared system, the SIGMA 7, that was not yet ready to go, there was the name of the Center, but before the IMP arrived, the Interface Message Processor arrived on Labor Day weekend in 1969, you describe it more as a name. There were preparations in place, but not a lot was happening yet.

NAYLOR

Right.

FIDLER

So let's go back to the early work you did at the Network Measurement Center. You mentioned the Scientific Data System, SIGMA 7. It had arrived, I think a couple of years before at UCLA, and then you talked about rewriting the time-sharing system.

NAYLOR

I don't think it came with a time-sharing system. I think it was probably a batch system at that time, and in order to take advantage of the network, we kind of needed to have a

time-sharing system, an interactive kind of system rather than batch. So what I did as part of that project was to build the terminal handler, which took characters from Teletypes and buffered them and put them in a stream. And because I had done that, once we were connected to the network and we had the network control protocol, a precursor to TCP/IP, I built the server side of the Telnet protocol. I believe that it was after that that I built the software that sent message to the IMP to set the measurements to start and to stop and then collect the data in a file on the system.

FIDLER

And who did you work with on this initial work?

NAYLOR

I think I did the software all by myself. I, of course, had to understand the way the IMPs worked, and there may have been conversations with people at BBN about that, but I'm not sure who I would have talked to about that. Once it was up and running, Jerry Cole did some experiments. I don't remember anything about the details, but he was my first user.

FIDLER

One of the descriptions of how the Network Measurement Center and other elements of the ARPANET program, one of the ways they're described is very little supervision of graduate students by professors or ARPA. Does that line up with your experience?

NAYLOR

Yes, for sure.

FIDLER

So you were kind of given the task of setting up a time-shared system, getting it ready to work with these—

NAYLOR

It's not clear to me. I mean, I came in sort of after the time-share system was starting to be thought about, so I'm not sure whether that was an assignment or it was just a realization by the team that said, "Okay, we need to have this. A batch system is just not how we want to interact." As far as the Network Measurement Center, the software that I wrote, I was thinking about that yesterday, over the last couple of days, and it seems to me that I just saw a need that instead of typing commands into the IMP, that there ought to be a better way to do that, and that's why I think I came up with it and I just did it. I think that's kind of the mode that we were working in in those days.

FIDLER

That certainly lines up with other people's experiences at the time. You also worked on—

NAYLOR

The reason for the name RFC was that Steve and Vint, who were the leaders of the group at that point, said, "Well, we're just a bunch of graduate students. We don't know what we're doing. So we have to say, 'This is a request for comments because we have no idea if this is right or not. So let us know, people.'" So that's where the RFC name came from.

FIDLER

Additionally, you also worked on Telnet, I believe?

NAYLOR

Yeah. On the server side of Telnet, the one in the NCP timeframe, as I say, it was a natural fit because I was already accepting characters from local Teletypes and putting

those into a stream for a user. This just made sense to do the same thing for outside users coming in through the Net.

FIDLER

And about when was your work on Telnet? When did that span?

NAYLOR

I would guess it would be '69, '70, but I don't remember when we had defined NCP. It would certainly be after that, or it wouldn't have functioned until after the NCP had been implemented. So I don't know. I mean, it was first the terminal handler and then Telnet, I believe, and then the network measurement software.

FIDLER

Did you have a sense of other work that was going on at the Network Measurement Center at that time, what other people were working on?

NAYLOR

Well, I know a lot of the group were working on the aspects of the time-sharing system. I don't remember who was doing what, to tell you the truth. I remember that Evelyn Walton did the user side of Telnet. I know Charlie Kline and Mark Kampe were certainly writing software. That's all I remember.

FIDLER

With those people, what were the relations between people at the Network Measurement Center? Was there much of an active social scene outside of work hours?

NAYLOR

There was somewhat of a social scene. I was less involved with it than I probably would have liked, or, looking back, it would have been better to be more socially involved. I was married and most of the other people weren't at the time, and that may have had something to do with it. I was also a bit older, certainly, than Charlie Kline and Mark Kampe. They were undergraduate students at the time, and I was—how old was I in '69—twenty-three.

FIDLER

Did people from the Network Measurement Center interact much with other research groups on campus? I think, for example, the Brain Research Institute was next door. I don't know if there was any kind of awareness of what people down the hall were up to.

NAYLOR

I don't remember interacting with them. There was somebody who had an office in that side of the third floor, and I think he was a computer science professor, but he was interested in brain research. I don't remember his name. I remember him sometimes being in the computer room.

FIDLER

Was that the west side of the third floor?

NAYLOR

Northeast side was where his office was or maybe the—I don't know exactly where it was. North.

FIDLER

And while we're on the topic of relationship between people in the Network Measurement Center with other parts of campus, 1969 was a tumultuous year in the United States. Do you recall witnessing or having on your mind these events while you

were working at the Network Measurement Center, and do you think any of that impacted or was otherwise in the thoughts of the people who were working there?

NAYLOR

Yeah. I don't remember the year and I'm not sure it was '69, might have been earlier, but my wife was working for the chancellor in—I don't remember the name of the hall—the Administration Building, and there was a protest outside and she was working inside. That kind of worried me, and I think I went over to get her, and I'm not sure how it worked out exactly. I don't remember all the details, but it was a scary time.

FIDLER

So on Labor Day weekend in September of 1969, the Interface Message Processor arrives from BBN, and in late October there is host-host connection with the Stanford Research Institute. Do you recall being around for any of this?

NAYLOR

I wasn't around when the IMP arrived. I don't remember specifically being around for the host [unclear], but I think I was. You'd think I would, but—

FIDLER

These events, in retrospect, they seem very significant, but at the time they could have been much more business as usual. What kind of sense do you get in retrospect about how these would have been perceived?

NAYLOR

Well, it certainly would have been exciting to see that first message. The thing I remember more distinctly than that was that after a while—and I don't remember what year this was, but I remember Jerry Popek coming to campus as a new faculty member and he wanted to connect to the Net. So he came into the machine room, because at that time that's the only connection we had. We had Teletypes in the machine room. We got some new ones that were fifteen characters per second instead of ten. [laughs]

FIDLER

Excellent.

NAYLOR

And I got him connected, and that seemed like, "Oh, this is cool, right? This is different than business as usual." Because he'd been a graduate student at, I think, Harvard, maybe, and had access to the Net there as a grad student, and he wanted to connect, maybe read his email, or I don't remember exactly why he wanted to connect, but I thought that was kind of cool.

FIDLER

And were there other instances of that for you where people would come requesting network services from the ARPANET group?

NAYLOR

That's the only instance that I can recall. There was probably—I happened to be in the machine room at that time.

FIDLER

And the machine room, are you speaking of the Network Measurement Center room where the SIGMA 7 was?

NAYLOR

Yes.

FIDLER

Now, speaking of the machine room, there's reports that there was—  
NAYLOR

There might have been a room next door where one or more of the Teletypes were.  
Maybe that's where the museum is now. I don't know.

FIDLER

There's photos of graduate students and perhaps undergraduates that were working at the Network Measurement Center in a room that seems to have been just to the right of it if you're facing it, and they were playing some kind of European theater strategy game. So it looks like there would have been a second room, in fact.

NAYLOR

Yeah.

FIDLER

Back to that space, there's reports that there was a bit of a crowd when the IMP was delivered, and even though this wasn't a very specific event for you, in retrospect, do you think this is the kind of excitement that was reported? Different people from various parts of the engineering school were present. Was this due to it being a well-funded ARPA project, or was there something specific about the vision of this network that would have excited people at that time?

NAYLOR

I don't know, but my own feelings about it at that time were that it's a cool thing to be connecting computers together, but it's limited to ARPA researchers. The bandwidth of the interconnecting links was really low. Although pretty high for that time, by today's standard, it's crazy low. So it seemed like it was kind of limited, right, in its scope, and I at the time certainly didn't envision it growing to what it is today. I have to say when I got out of academia and went into the world, it wasn't until my kids went off to college and said—particularly my youngest son said, "Dad, you've got to check out this thing called the web." [laughs]

FIDLER

And you'd heard of it before.

NAYLOR

I had not heard of the web at that time. I don't remember what year this was, but he's thirty-eight in a couple of days, three days, so we're talking, you know, twenty years ago, and I think the web was fairly new twenty years ago. I don't remember the exact years on this. So he turned me on again to the Net, because I was off in the business world. Actually, at that time I was at Citibank, and Citibank had its own proprietary internal email system that didn't connect to the world. Maybe a year later they connected into the world, and then they took it away because it was too open and free, you know, no personal emails at work.

FIDLER

I'd like to return to the Citibank at a later time.

NAYLOR

That's fine.

FIDLER

So you finished your M.S. in 1970?

NAYLOR

Yes.

FIDLER

Before you began your Ph.D., you supervised the activities of the Network Measurement Center for a year in between that. Can you tell me what that would entail, supervising the Network Measurement Center?

NAYLOR

I have to guess that it was directing people doing measurement experiments, showing them how the software works, and then either speccing or getting specs from other people to do experiments. There wasn't any more software development on the measurement tools themselves. There may have been some software written to reduce data more, but I—you know, it's kind of fuzzy.

FIDLER

Do you recall any particular contact points, people you would have worked with?

NAYLOR

You mean offsite or—

FIDLER

On or off. I think, for example, Anita Coley had an administrative role with the Center at that time.

NAYLOR

Right. Well, she would have been in charge of making the machines were up and stuff like. It's possible that if I had a long-term measurement to do that, there would have been interaction with her to let her know that, you know, don't reboot the system unless you have to. I mean, don't do it for just administrative purposes. So, yeah, there's probably some of that. There's one outside user that I can recall, whose name is Dave Mills, and I think that he created the NTP, Network Time Protocol, and he was doing some experiments offsite. I do not remember what year that was, but I'm sure it was after the software was ported to the 360/91. So I interacted with him to get him up and running.

FIDLER

And at this time, and then for your subsequent years in the Network Measurement Center, did you participate in or discern any kind of general management philosophy, and how would it compare to other places that you'd worked before or afterward in terms of the level of kind of supervision, for example, the culture of the Center, that kind of thing?

NAYLOR

I don't remember being supervised very much. [laughs] But I think I've been lucky in the sense that the jobs that I've had have been like that, or I'm enough of a self-starter that it just happens that way.

FIDLER

And is there much that you recall about the organization of the work at this Center at this time? We've touched on this a bit, but, for example, the division of responsibilities into hardware or software or other areas, does any of that stand out?

NAYLOR

You mentioned Anita Coley, and there are other people who filled that role in the sense that they were—I can mention their names too.

FIDLER

That'd be great.

NAYLOR

Ari Ollikainen and Lou Nelson, they would have been the people responsible for keeping the hardware up, ordering new hardware, whatever needed to be done in the Center or in the offices, because at one point we had dumb terminals in offices. And software, let's see. It was the ARPANET team which—and I'm not sure whether Lou, Ari, and Anita were part of that team or not. I'm not sure how the management structure worked around that. I was always an individual contributor, and I kind of reported to Steve and Vint, but not really. [laughs] At that point, there was no professor. For the work that I was doing as a programmer and a network measurement manager, wow, I guess at that point, I must have been reporting to Len, but prior to that when I was a programmer, I was not reporting to any professor.

FIDLER

Was that largely how you operated then, through your time there, doing measurement work?

NAYLOR

Once I finished my Ph.D., I was here about another year after that. Then I was reporting to Professor Chu on the satellite project.

FIDLER

We'll return to the satellite, Packet Satellite and Packet Radio, in a little bit. So you're working at the Network Measurement Center. You're not reporting to too many people. [Naylor laughs.] There's different levels of organizations of which your work is a part or funded by. So you're at UCLA. This overall project, the ARPANET, is getting funded by the IPTO at ARPA. Then there's ARPA itself. Through yourself and the general feeling at the Network Measurement Center, who were you working for? Was this a UCLA project? Was this an ARPA project? Was this IPTO? What kind of sense did you get of organizational identity?

NAYLOR

Well, we knew it was an ARPA project. I'm not sure when I met Larry Roberts. It might have been during that time. He was the project manager for the network. But from my point of view, there was no interaction. There may have been between Larry and Len, but I didn't hear about it. Yeah, I felt like we were pretty autonomous, and it was this group of graduate students who knew nothing, creating this Network Control Protocol, and asking the rest of the group out in the outside world what they thought of it. But, yeah, it felt very autonomous, and I wouldn't call it a UCLA project. I guess you'd call it an ARPA project, but we weren't managed very closely.

FIDLER

And that suggests to me that there wasn't a lot of thought about how the ARPANET would relate to other research interests or missions of ARPA at the time.

NAYLOR

Yeah, except that it was being built so that we could interact, whatever that meant. Later on I had interaction with other researchers working on the network speech project. There were a bunch of people who knew about compressing speech and then some network people.

FIDLER

Then you began your Ph.D. in 1972?

NAYLOR

I think that sounds right.

FIDLER

And your fields were computer systems modeling and analysis and applied mathematics and programming languages in systems. Can you describe to me the process by which you arrived at those and then also how you got to network measurement through that?

NAYLOR

Sure. Programming and languages came from my master's. That's what I was trying to get my master's in. Prior to that, I mentioned, or maybe before we started recording, I started at Cal State Northridge as a graduate student in math and then transferred to UCLA as a graduate student in math, and eventually made my way to computer science. So I had all this math background and really none of it was applied, but that was what fit. So the computer systems modeling and analysis was what I was doing in working for and at the Network Management Center. I was trying to figure out how this network worked, and so that was how that happened. Actually, I think I audited Len Kleinrock's classes in queuing theory, but that's the major portion of that major.

FIDLER

Who else did you take classes with around that time?

NAYLOR

I think Dick Muntz taught one of those courses. As part of the master's program, I took courses from Cardenes. Martin, he was my master's advisor, Dave Martin. Wow. I don't remember. Obviously some others.

FIDLER

And then the other field was applied mathematics and programming languages and systems.

NAYLOR

Right. I said the programming languages came from the courses I took as a master's student, and the math came from my graduate work in math. So I had actually more math courses than I needed for that minor.

FIDLER

And this was kind of concurrent with your interest in network measurement then. That's what you're describing?

NAYLOR

Yeah. I think that my interest in measurement and pattern recognition, if you will, came from my experience at IGPP in looking for the signature of the onboard heater of the OGO-5 satellite in the magnetometer data and trying to remove as much as possible, either by just skipping that data or trying to subtract it out.

FIDLER

Back then, the field of network measurement was obviously comparatively new. Can you speak to in your mind, then, what the field looked like, perhaps the intellectual lineages or influential work for you that had been done by that time?

NAYLOR

Well, I came into a set of tools implemented on the IMPs that was defined by, I think, Jerry Cole, and maybe some others had input into it, which were designed to give, I think, a pretty good picture of what was going on. There were three types of messages that I recall. There were accumulated statistics which were basically a traffic matrix with roundtrip delays attached to them, if I remember correctly. So they were measuring both the amount of traffic and the time it took to get to all the destinations. There was Trace,

which you could turn on a bit in a packet, which would trace its route through the network, and each one of the IMPs that it hit would send back a message saying it got here at this time or whatever. And what's the other one? Snapshots. Now, I can't remember what Snapshot reported. Instantaneous look at the IMP, queue lengths and such, and its routing table.

FIDLER

Now, in 1972, you published a paper with Vint Cerf on measurement on the ARPANET, although that was focused more on buffering. For papers that you published, I think in 1975, one of them with Len Kleinrock, there was data that had been collected, I think, in 1973. Do you know how early measurement began using these, for example, accumulated statistics, Snapshots, Trace, like when that started?

NAYLOR

I'm not sure. Prior to '73, I guess. [laughs] I know that actually before I started doing any measurements, I believe Jerry Cole did some. So those were probably the first measurements that were done using these new tools and the net itself. I don't remember whether he published or what the result was. I'm not sure when he finished his Ph.D. It may have been part of his thesis. I don't know.

FIDLER

In your 1976 paper on Line Overhead, it mentions that the Packet Trace functionality was suggested by the Network Measurement Center and then implemented by BBN, and this was surprising to me and it almost suggests that measurement functionality of the Network Measurement Center might have been expanded over time and in cooperation with BBN rather than just all put there at the beginning.

NAYLOR

You know, I don't recall that in that same way. I recall there being these tools already implemented. Yes, I believe that the definition of the statistics being collected was done by people here at UCLA, primarily Jerry, but to suggest that it changed over time, I don't think that's the case. I think it came already done because the definition had been done before.

FIDLER

Speaking of measurement, there was an experiment you did with Len Kleinrock where you collected data. This was actually August 1973. This became On Measured Behavior of the ARPA Network, and this was written up in 1974. I'd like to bring up a few of those findings, if you don't mind.

NAYLOR

Sure.

FIDLER

So one of the findings was that network users tended to communicate with nodes that were geographically nearby, and this appeared to be surprising in the paper. It's a new finding. Did that line up with your experiences at the Network Measurement Center or kind of the sense you had at the time of how the network was being used?

NAYLOR

I guess I would have to say I don't know, because I don't think I had a preconception of how it was being used. I mean, I know how I used it. I don't know whether I did—I'm not sure what I did. I don't remember. And I think that the going-in position was that this network was so that remote sites could talk to one another. From that point of view, it

became a surprise. Thinking back on it, I think that because different computer manufacturers were not interested in connecting their machines together at the time, they really wanted to sell you all of their equipment and then they could talk. Maybe it's obvious that since this was a really handy way to connect local computers together at that time, that it just naturally happened that, "Oh, now, I can talk to that thing across campus," whereas before I couldn't do it.

FIDLER

Right. Because there was also that finding that I think it was about a fifth of network traffic just stayed on its own IMP, and it was just between machines at the same institution or even in the same building.

NAYLOR

Right.

FIDLER

You mentioned the way you used the ARPANET, and I think that's probably difficult to recall, but do you have much recollection of what you might have done on it besides the measurement experiments that we're talking about?

NAYLOR

Well, we had email. It wasn't exactly the same as it is now. I recall that after the SIGMA either went out of service, I'm not sure of the lineage of this, but we eventually were using computers at ISI, and so all of our email correspondence was through—it was probably called DECmail or whatever the terminology for the PDP series of machines was. It was manufactured or written or supplied by the manufacturer DEC.

FIDLER

So that was remote access to ISI through UCLA?

NAYLOR

That was remote access, and I couldn't tell you how that worked. I just don't remember.

FIDLER

Actually, that explains why all the UCLA email addresses at this time were through ISI.

NAYLOR

Right.

FIDLER

It's also mentioned in that paper that the experiment, the weeklong collection of data and its analysis, was repeated every two months. Is there anything else you can recall that was done with this data and how it was used in other ways?

NAYLOR

Sorry.

FIDLER

It's all right.

NAYLOR

I don't remember.

FIDLER

Even just that paper is really useful.

NAYLOR

I'm glad we wrote it down. [laughs]

FIDLER

So the last thing from that paper, there's a suggestion that the size of the packets might be reduced to increase network efficiency. In a later paper on Line Overhead, there's another suggestion for optimizing the network based on the allocate NCP control command. There's these suggestions for fine-tuning the ARPANET that come out of the Network Measurement Center. I suspect that these may have been communicated to BBN at some time, or were they simply published and put out there for people to see for themselves?

NAYLOR

Yeah. I would think that we would have communicated with BBN. I know there was a lot of interaction that I had with BBN during some of this stuff that I was doing, to try to understand what was going on. In particular I can think of another paper, but we can talk about it later, the one about loops, routing loops that I discovered. I had a lot of interaction with John McQuillan, who was the architect of the routing algorithms at that time.

FIDLER

So can you tell me more about your interaction with BBN over the course of your time, even, at the Network Measurement Center?

NAYLOR

Well, yeah. Very early on, I would find myself in the machine room or I would get a call in my office and go to the machine room and be instructed to use the switches and put some code in the IMP, which was kind of interesting, kind of fun. [laughs] And that would be to do something—I don't remember exactly what any one of the things was, but some patch that the IMP needed at the time to make it work better or to make it be able to download a new version or something. I don't remember. But that was an interesting interaction very early on that went away after a while. And later, it was more talking about the internals of the IMP and the routing algorithms and things like that that I would talk to people about.

FIDLER

Do you know if that was the Network Control Center that would call?

NAYLOR

Yeah, I believe so.

FIDLER

And when you're discussing routing with BBN, is that to do with your role as someone who's doing measurement and someone who's looking at these questions?

NAYLOR

It was, yeah.

FIDLER

Do you remember anyone else who you spoke with at BBN?

NAYLOR

Yes, and I can't remember his name.

FIDLER

There was Alex McKenzie, Dave Waldon.

NAYLOR

I certainly talked to those people, but there was one in particular I had a lot more interaction with, whose name I can't recall, and it was before I was talking to John McQuillan a lot on the routing stuff.

FIDLER

Now, Frank Hart [phonetic] was managing these people.

NAYLOR

Right. I knew the name and I know him, but, yeah, I didn't really talk to him.

FIDLER

You mentioned that there was that initial interaction about loading programs into the IMP and stuff like that. You said that went away, and then subsequent to that it was discussions about routing. Can you speak more to those latter discussions?

NAYLOR

Well, I was finding what I thought to be strange delay patterns and traffic patterns, and what I later determined was that there was a loop in the routing algorithm, and the routing algorithm had been modified by John McQuillan, or at his request, to have this thing called a hold-down, which to say, "Don't be flipping back and forth because the data suggests you should do it. Lock it for a while." And it was under that circumstance that I noticed these loops were happening, because you, in fact, could lock it in a position where you were sending packets out, and they were just coming back out in the network somehow. So I had a lot of discussions with him about that and wrote a paper about it.

FIDLER

Do you think that kind of interaction between you at the Network Measurement Center and then people at BBN was common? Were other people involved in discussions about the function and mechanics of the ARPANET?

NAYLOR

Other researchers? Other ARPA researchers? I kind of doubt it, because they had their focus. Like the network speech group was interested in compressing speech and transmitting it over a packet switched network. They wanted it to get from Point A to Point B, but I don't think they really cared much about how it got there as long as it didn't have too much variability and delay. That was the key for any kind of stream traffic, and you can imagine with a routing loop you might get high delay for a while.

FIDLER

Perhaps. [laughs] In your dissertation, you actually suggest something called an asynchronous loop-free routing scheme, and you're talking about ways to change the routing messages on the ARPANET so that it would create better network conditions; for example, speech. Do you think that there was much traction for this kind of idea with other researchers? Would other people have liked to see changes such as this implemented?

NAYLOR

I don't know. I don't know. As you mention that, I don't actually remember that, but I think I kind of get the idea. At the time, the routing messages were synchronous and I could see spikes in delay. I don't know if I have a chart of it in the dissertation or not, but I could certainly see them in the measurements that I was doing at the time, and it turned out that they were due to these routing messages that I guess must have been happening relatively synchronous at each node, otherwise it wouldn't show up the way it did in the delay.

FIDLER

Is there anything else from your dissertation that you'd want to point out, anything that stood out to you as being interesting?

NAYLOR

Well, I guess the main idea in the dissertation about transmitting stream traffic, which would be speech or television or things like that over a packet network, would be that you can somehow manage the variability and delay so that you can have either continuous speech or continuous streaming video, which we have today. I don't know whether anybody used the ideas. I know that, for example, Netflix, when it starts up, it's buffering. First it's measuring the bandwidth and then it's doing some kind of buffering. I don't know if it's adaptive to variable delay that it's getting, but I know also sometimes it stops.

FIDLER

So there's these moments when using the contemporary Internet where you'll think back to similar problems that you were looking at in the seventies?

NAYLOR

Yeah.

FIDLER

While at the Network Measurement Center, you consulted with members of Packet Satellite and Packet Radio groups, and I'd like to go through those and maybe start with PRNET, Packet Radio.

NAYLOR

Okay. That's the one I'm not going to remember, but I know there were a number of grad students here working on Packet Radio protocols and the performance analysis of the protocols. I don't remember doing Packet Radio experiments, so I just draw a blank there.

FIDLER

Well, we can talk about Packet Satellite. I understand that your involvement kind of grew over time. For example, by 1977, you were the primary person responsible for technical management of the Packet Satellite project at UCLA.

NAYLOR

Okay. That's true. [laughs]

FIDLER

Can you tell me a bit about what that entailed? There was, presumably—well, there were people at UCLA working on this project. It was dispersed throughout some other institutions.

NAYLOR

Right.

FIDLER

What were your communications like with those other people? Who did you work with at UCLA?

NAYLOR

I worked with Stan Lieberman. He worked for me. I think he was the only person working for me at that time. Oh, no, there was another guy, Katz. No, that's not right. Yeah, it is right. Mark Katz, K-a-t-z. I think they might both have been working for me during that time. The other groups involved were Linkabit in San Diego, if that was still their name. I think it was. And I believe there were some people from University College London involved in that project, and now I'm not sure who else, what other groups were involved. We had meetings. I remember one down in San Diego. It was during the summertime and it was raining, which is crazy for California.

FIDLER

I can mention the participating organizations if that might help.

NAYLOR

Oh, maybe. Sure.

FIDLER

So we've got BBN, of course. There's the Communication Satellite Corporation, COMSAT.

NAYLOR

Okay. Right.

FIDLER

Linkabit, as you said; Lincoln Lab; obviously UCLA and University College London; and then the Norwegian Defense Research Establishment.

NAYLOR

Oh, right. .

FIDLER

So your interactions, then, who were they primarily?

NAYLOR

They were primarily with Linkabit. I did have some interaction with University College London. I actually visited there. I can't remember if it was for a meeting or I went to Europe and London and decided to pop by. I was thinking about that just this morning. Yeah, so it was mostly with Linkabit, with Erwin Jacobs in particular. Oh, and Dick Binder.

FIDLER

On the ARPANET, there was the Network Measurement Center, and measurement was a significant part of the project, at least early on. With SATNET, was measurement given the same resources and status as on the ARPANET?

NAYLOR

The SATNET project was—there was a resource allocation protocol called CPODA, which I think I possibly simulated and/or analyzed. I don't remember whether it was implemented, and I think there were some measurements done. There was a satellite link to London, not using CPODA, and probably we measured delay over the satellite, but that would have been just using ARPANET measurement tools. I don't remember whether there were measurement tools even specified for CPODA or whether it was ever implemented. I know we wrote a paper about it, but I don't know—I can't remember.

FIDLER

Do you think that the Satellite IMPs, which were the SIMPs, very similar to Honeywell 316 IMP with some modifications, would those have had the same measurement abilities built into the IMP program?

NAYLOR

I would think so, yeah.

FIDLER

Actually in that paper you mentioned in '79, "Experimental Results on the Packet Satellite Network," there's mention of measurements being controlled through ISI.

NAYLOR

Oh, okay. That's odd. I don't remember.

FIDLER

More generally, with Packet Satellite, compared to the ARPANET, as you said, no one's expecting the Internet to come out of the ARPANET at that time, but there was still, from what I can tell, a bit of a vision attached to its beginnings, like this could be a large national network at the very least.

NAYLOR

I have to say that I didn't see that, but it's not clear to me that the visionaries in IPTO and perhaps even some of the PIs didn't see that or think that it was possible.

FIDLER

Or even just scaling up to nineteen nodes, for example, there was a plan to at least try to make this big. Now, mentioning that to compare it with SATNET, was there a sense of a future of Packet Satellite when people were doing these experiments?

NAYLOR

I don't know, and maybe it's because I left in '78. I think I left in '78. Maybe the project was still going on and I didn't get to the end of it.

FIDLER

In your CV, you talk about PRNET, Packet Radio, and SATNET, Packet Satellite, as being extensions of the ARPANET, and I'm curious what your thoughts are either from the time or in retrospect, about the relationship between these networks.

NAYLOR

Yeah, I guess I call them extensions in the sense that they were similar but separate kinds of projects, although I'm not sure that's true of SATNET, because I know that there was a satellite link to London, and I don't know if that was part of SATNET or whether it was a separate thing. But the Packet Radio net was definitely a separate entity from the ARPANET, and it was thought of, by ARPA, Defense ARPA, as a thing that could be deployed in the battlefield, so it was made to be really reliable. I mean, there were some aspects of the ARPANET that were like that, too, but the PRNET was more, I guess, hardened or resistant to failure than the original ARPANET. So I think of them as something in the same realm of ideas, but in a different kind of implementation for a different kind of environment. PRNET came out of what was going in Hawaii because you can't have wires between islands. Well, I guess you can if you put them under the sea, but it was just easier to use radio. So that's kind of what I remember.

FIDLER

It doesn't look like you were involved in the early TCP experiments that involved PRNET, SATNET, and the ARPANET, but from either at the time or in retrospect, did you or do you have any thoughts about those, impressions of their—

NAYLOR

Not really. Yeah, I wasn't involved. It certainly make sense to connect those separate networks together, but that's about it.

FIDLER

More generally, regarding the ARPANET and your use of it—just getting back to some bigger questions near the end of the interview here—do you have a sense of your use changing over time? There's your introduction to it, then you were on it for a number of years, and then you left. I was wondering if you can tell me about how you used it, and then I think I understand you stopped using it at a certain point as well.

NAYLOR

Yes, I did.

FIDLER

And then there was a period of time where you were not online. I wonder if you can take me through that.

NAYLOR

Yeah. I left in '78, and at that time there were no, or at least very few, companies on the net at that time. I mean, it started out as just ARPA researchers, and then it expanded to a few companies, like DEC was on probably pretty early. But anyway, so I went to work for Xerox, specifically XTEN, which was supposed to be a nationwide network which was capable of transmitting extremely high-quality fax, and that was the idea. In the end, it didn't get built, and even though Xerox PARC was on the net, we were not. So how did we communicate? I don't think we had email there. I'm not sure at this point. So it was, you know, memos. Somehow it doesn't sound right. But then I went to work at the other TTI, a part of Citibank.

FIDLER

Was that at Transaction Technology?

NAYLOR

Transaction Technology, Inc., yeah. And there I was involved in—well, it doesn't matter what I was doing, I guess, but there was—

FIDLER

Actually, if you want to talk about that now, that would be great.

NAYLOR

Sure. I became the head of a group which was responsible for having enough capacity to handle the transactions from branches. It was this homegrown system built on Quotron machines that had been modified by TTI, and they were providing the online interface to the branches to do banking transactions and to do some merchant transactions as well for their private-label cards. So I was in charge of a group whose responsibility was to make sure there was enough horsepower in place to handle the traffic.

FIDLER

And the branches you mentioned, that's Citibank?

NAYLOR

Citibank branches, yes. So there were tellers doing interaction, there were merchant terminals for the private-label cards, and there were ATMs. I think all those terminals were built by TTI at the time. So that's what I was doing there. We had an internal email system, but no connection to the outside world. At some point we moved the office and we did have connection to the outside world, but we still had this internal Citibank mail system.

FIDLER

And when you say "outside world," do you mean ARPANET?

NAYLOR

I mean Internet.

FIDLER

Okay. And this is from 1980 to 1982 that you're at Transaction Technology, Incorporated?

NAYLOR

Right. And then I went—because Steve Crocker was starting up a computer science lab at the Aerospace Corporation, and suddenly I was in charge of connecting Aerospace to the net. [laughs]

FIDLER

And that's in 1982 and 1983 you were there?

NAYLOR

Yeah.

FIDLER

And that's the Computer Science Research Group at the Aerospace Corporation.

NAYLOR

Right.

FIDLER

Can you speak a bit more about that?

NAYLOR

Other than I left. [laughs] I don't remember if the Internet interface got implemented before I left or not.

FIDLER

I know there was a selection in procurement of a LAN for resource-sharing within Aerospace Corporation.

NAYLOR

Right. Yeah, and instead of Ethernet, it was one of the other competing technologies at the time, and I can't remember its name, and it's probably no longer around. I left and went back to TTI.

FIDLER

So when you went back to TTI, on your CV it says Citicorp, so this is the same relationship with TTI and Citibank, I assume.

NAYLOR

Right.

FIDLER

Was this similar work to before?

NAYLOR

Well, I had managed a group when I left, which is partly why I was somewhat unhappy there. It was more fun to me to do technical work than to manage people's personalities and stuff. I don't like that. So I came back as an individual contributor, and at that point or—let's see. Yeah, I think it was at that time we were setting up a proprietary home banking system. So people would call in to our system through dial-up, because at that time the Internet at home was not—either you couldn't do it or it was very sparse. So we had this homegrown system, and it was my responsibility to manage the capacity, make sure we had enough phone lines and servers and stuff like that to handle whatever traffic we expected to have, and pretty much I continued to do that. Even though we transitioned to the Internet, I still managed the capacity of the servers.

FIDLER

You said it transitioned to the Internet. So when you left, there was an ARPANET/Internet connection.

NAYLOR

Right.

FIDLER

And you left in management and came back more as an engineer, I suppose.

NAYLOR

Yes.

FIDLER

So that made it much more like your time, for example, at the Network Management Center, where you were working on problems and not dealing with management overhead.

NAYLOR

Yeah.

FIDLER

And when did your time with TTI and Citicorp come to an end?

NAYLOR

It came to an end at the end of 2007 when they laid a bunch of people off. They said that we could go to either Singapore or Ohio, and I decided California was a lot nicer.

[laughs] So they actually paid me for another year, so my retirement is actually at the end of 2008.

FIDLER

So you were on the ARPANET from '69 to '78 through UCLA, and then at various times throughout TTI and Citicorp and Aerospace, you were kind of back on and off as the ARPANET became the Internet?

NAYLOR

Right. But it wasn't until my youngest son turned me on. He was at college at the UC San Diego, and he had access to the Internet, and he said, "Dad, you've got to check out the web. It's really cool." So that kind of got me more interested and—I'm not sure. Maybe along about that time I was able to get Internet connection at home. I live in Topanga, which is kind of behind the times, but at that point I was able to get it through the cable provider, because I was too far to get DSL from the central office, and now I have FiOs.

FIDLER

And that would have been like mid-nineties when you got the call or email from your son?

NAYLOR

Yeah, something like that, yeah. And now I maintain—well, I've made four websites, it's up to.

FIDLER

So you're doing HTML.

NAYLOR

I'm doing HTML, yeah, just maintaining. I'm not changing the look and feel that much.

FIDLER

Is that for yourself or for a firm?

NAYLOR

Well, the first two were just personal. The second one was for my wife, who is a writer, had submitting some things to a blog. She's a humor writer. Then one of her old friends from a previous work environment wanted to do a new idea for a book, which was called a roadmap, and the first one was about baby's first year. Okay. So he wrote it and it was very dry. He took facts from the Good Baby Book sources, but the way he wrote it was

very dry. So he took it to his friends, and his friends said, "You've got to soften this up." So he brought it to her and said, "Will you do this?" So she did, and so she has a book in her name with an ISBN and everything, so that's why she has her own website. So that's the second one. The third one was she belongs to the Sand and Sea Knitting Guild, and so even though she calls herself the web weaver, I'm the guy that actually does the work. And the fourth one is our neighborhood in Topanga has the Topanga Coalition for Emergency Preparedness, and they have a website, and I looked at it and found that there were inconsistencies and stuff that was out of date, and I said, "Somebody's got to fix this." Turns out the person that built it stopped doing anything at least two years ago, so I have made some changes to it.

FIDLER

So that's an interesting history with the Internet that almost nobody has. You go from, for example, the time-sharing system on an SDS SIGMA 7 to the Sand and Sea Knitting Guild. [Naylor laughs.] In between those two milestones of Internet use, was there a point where you thought, "Okay, this is going to get beyond this initial resource-sharing mission, and it's starting to look like this will become at least a social phenomenon, maybe a global one"?

NAYLOR

Well, I have to say that the big eye-opener was when my son called me or maybe sent me an email, probably sent me an email, that I kind of realized, "Oh, everybody's going to get on this at some point." It was pretty widespread at that time, but it wasn't even the way it is now twenty years later. So I think the fact that my kid grew up not knowing anything about what I did, right, because kids don't, and then he goes off to college and he has access to this great tool that we can communicate anytime we want, and he's exposed to that and then he finds out about stuff that's out there that I didn't even know about.

FIDLER

And do many of your friends or family members know about your extensive history with this? You had email for four decades, for example.

NAYLOR

Right.

FIDLER

This is not an incredibly common experience to have. [Naylor laughs.] When you think back about changes to the Internet, you can go back four decades if you include the ARPANET. Is this something that comes up much with family and friends?

NAYLOR

I would say not a lot. When I got on the cover of Wired, I bought a bunch of them and I gave them to my family. Yeah, it's up there. But, no, we don't talk about it that much.

FIDLER

Do you think the length and, I guess, depth of your experience with computer networks gives you a particular perspective or informs your opinions on the future direction of the Internet, what's going on today?

NAYLOR

No. I have to say that I'm not a visionary like some of the people that I grew up with, so I don't know.

FIDLER

In closing, I'll ask if there's any particular points or observations that I missed that you want to go back to and bring up.

NAYLOR

I can't think of any.

FIDLER

Okay. Thank you for your time.

NAYLOR

Thank you. [End of October 1, 2013 interview]

## **1.2. Session Two (November 26, 2013)**

FIDLER

I am here with William Naylor. It is November 26, 2013. We are doing a second interview. This is going to be about your time after UCLA.

NAYLOR

Okay.

FIDLER

Why don't we start with Xerox. You were there between '78 and '80, I think.

NAYLOR

Something like that. Yes, that's right.

FIDLER

Great. And how did you find yourself there?

NAYLOR

I found myself there by it was time for me to leave UCLA. I'd been here roughly a year after my Ph.D. was done, working on the satellite project, and it was time for me to move on, so I went out and interviewed. I don't remember specifically how I got to Xerox, XTEN, but I went there for an interview and they gave me an offer, so I decided to go work there. It was to be a nationwide telecommunications network that would support high-resolution fax between two sites or multiple sites.

FIDLER

And when you say XTEN, do you mean, rather, this is the Xerox Telecommunications Network.

NAYLOR

Yes.

FIDLER

Was that the main project you worked on while you were there?

NAYLOR

Yes, it was the only project.

FIDLER

Is there anything else you can say about that network?

NAYLOR

It didn't get built. I left the Friday before it was announced that they were moving some of the group to New York, and so I didn't get a layoff package that some other people got, but it just wasn't going to go anywhere, it seemed like. I was actually in charge of the work being done by NAC, Network Analysis Corporation, and a spinoff from that as well, whose name I can't remember. They were also a contractor.

FIDLER

So there were a number of ARPANET clones that were being built, had been built and were being built around this time by BBN in particular. Would this network look like—was it similar to the ARPANET in any way or was it a significant departure?

NAYLOR

It was a significant departure. I mean, it didn't really get built, but it really wasn't conceived of as being a packet switched network at all.

FIDLER

And how far did that project get?

NAYLOR

Just into the analysis phase. I mean, it really didn't get very far. I don't know exactly what happened after I left and they moved to New York, but I know it didn't get off the ground.

FIDLER

And in that early analysis phase, was that part of the work you were doing with Network Analysis Corporation?

NAYLOR

Yes.

FIDLER

And what were the kinds of dealings you had with them?

NAYLOR

They did some simulations of the design or of the—yeah, I guess it was the design of the network, or they were postulating some traffic matrices, I think, probably based on population or something we got from higher-ups in Xerox. I don't remember exactly how that went down.

FIDLER

And were you working with a broader team?

NAYLOR

The team at XTEN was pretty small. There was one other guy who was sort of in my area, whose name I don't remember, but we all fit on one floor of a building in Woodland Hills, so maybe thirty to fifty people, maybe even less than that. It was small. So the idea was that we were basically a bunch of people who were monitoring contractors doing the actual work, which wasn't the best for me because I like to do actual work.

FIDLER

Right. Earlier you'd said that when you were at UCLA, just being able to work on a project and not deal with managerial tasks was better for you, and so that experience carried through to here.

NAYLOR

Right.

FIDLER

Did you get a sense of the educational or work backgrounds of the people you were working with? Was it similar to yours?

NAYLOR

The fellow I was working with was similar, as I recall, but the higher-level managers were primarily from the phone company business, I think. They were more interested in

doing a circuit-switched kind of architecture than packet-switched, and that was the direction we were headed in.

FIDLER

So is it accurate to say that phone companies or the representatives had something of a say of the overall design of the network? Is that what you mean?

NAYLOR

Well, the employees of XTEN who were formerly with phone companies or synchronous-type networks had the upper hand in where we were going.

FIDLER

Can you speak in general about how your work at UCLA translated to the kinds of things you did at Xerox?

NAYLOR

Well, I was monitoring the work of NAC, so there was some queuing theory involved in the mathematical models that they were working up, and they did some simulations as well. So it's kind of the same kind of thing that I was doing when I was here. I mean, I did simulations for my thesis and models for the SATNET and other things that I was doing and for my dissertation too.

FIDLER

Was the main difference working at Xerox versus working at UCLA largely due to having a managerial role versus actual engineering work, or were there other things as well?

NAYLOR

Yeah, it was different. I guess that there were deadlines, not self-imposed, but externally imposed, and it wasn't—well, I said that already. It wasn't me doing the work, so I had to wait for the products from NAC or from the other company to come and review them. So, yeah, I think that was the main difference.

FIDLER

You've described managers being above you and also that you were managing people. So this is kind of a middle-management position?

NAYLOR

Well, I didn't have anybody inside XTEN reporting to me. It was only external contractors reporting to me. So I don't know what to call that. [laughs]

FIDLER

And regarding the background of the people you worked with, did you happen to come across anyone with a similar background with ARPA funding or get a sense that—

NAYLOR

I don't remember anybody at XTEN that came from that arena.

FIDLER

And finally, what was the network connectivity like at Xerox? Were you on the ARPANET? Were you on other networks?

NAYLOR

We weren't on the ARPANET. We did have a Xerox email system, which was proprietary. I don't think it was connected to the net, but we certainly could talk to contractors that way, so there must have been—well, yeah, I guess that they were actually users on the Xerox internal email net, now that I recall.

FIDLER

And when you left, you described as being in part, at least, due to your unhappiness with having this managerial role. Were there any other reasons why you decided to—because you said it was before that they moved to the East Coast.

NAYLOR

Right. The writing was on the wall, I think, that it either wasn't going to go the way I wanted to go, or it wasn't going to be built at all. So, yeah, I decided to start looking.

FIDLER

And when you say the way that you wanted it to go—

NAYLOR

Well, I guess I wanted it to go as to be a packet switched network.

FIDLER

And when you signed up—

NAYLOR

It wasn't clear.

FIDLER

It wasn't clear. So there was a hope of it going that way, and by the time you left, it was going to be a circuit switch network or nothing at all, is the idea.

NAYLOR

I think so, yeah.

FIDLER

And you left, and then you began at Transaction Technology, Inc.

NAYLOR

Right.

FIDLER

And this is in 1980.

NAYLOR

Yes.

FIDLER

What was the process by which you found work there?

NAYLOR

I just looked—in those days, it was look in a newspaper for want ads and noticed that they were hiring. I went for an interview and maybe a second interview. They gave me a job, and it was to manage a group that was in charge of the performance of an existing network of in-house-built terminals that were in the branches and ATMs which were also located with the branches and some at other places, but mostly in the branches, actually, mostly external to the branch. There's an interesting story about that which is that as long as the ATMs were working, the branch manager didn't know about them and didn't care about them, because they were outside the branch and the line of people was out there, and the manager didn't care. But when they stopped working, then they were upset because they had this flood of people in their branch.

FIDLER

Right. So the ATMs suddenly became visible if they weren't working.

NAYLOR

Right.

FIDLER

And then was it your job to find out what the defaults were and manage the repair, for example?

NAYLOR

Not my job, no. My job was to make sure that there was enough system capacity in place to service the load that was being produced by the ATMs and the other terminals.

FIDLER

And those other terminals, just to clarify, those were branch terminals used by employees?

NAYLOR

There were two kinds of terminals. There were branch terminals, which were actually used by the customer. They still have something like that at Citibank, where you walk in, you go to a teller, you swipe your card and enter your pin, and then they know who you are.

FIDLER

Right. It's that authentication system.

NAYLOR

Right.

FIDLER

I've used that as well.

NAYLOR

Those were called Type 1 at the time. They've been replaced since, but there were those types, and there were also a merchant terminal, which were in various merchants that Citibank had a relationship with. And actually, the load on those was very much more dependent on the time of year. So around this time of year, the load on the merchant terminals was already going way up.

FIDLER

Are those merchant terminals the point-of-sale electronic fund transfer?

NAYLOR

Yes, actually, they were. I guess that Citibank at the time had several private-label cards that could be used in those, and then the others were the ATMs.

FIDLER

So is there anything you can tell me about the structure of those different networks?

NAYLOR

They were—wow. The branches were all basically hardwired to the two datacenters. Each datacenter had what we called a hub, which is where the transactions came in, and the hub would route those transactions to the appropriate processor. If it were a savings-account transaction, then it would route the transaction to the savings processor, and there was a checking processor and a merchant processor, and I can't remember what else. So that's kind of how it worked. Each one of those, including the hub, could be multiprocessor systems, and it was my job to make sure that there was enough there to handle the load.

FIDLER

And was that each of these networks that you've described working in that same way? Did they have the same hub?

NAYLOR

That was all one network, basically.

FIDLER

And was that kind of a star structure, then?

NAYLOR

Yeah, it was a star structure, and even within the branch I think it may have been star, because there was something in the branch, and I can't remember what it was called.

Yeah, I think it was star inside the branch, even.

FIDLER

So it doesn't sound like this took much inspiration from the ARPANET.

NAYLOR

No. It was—when was it built? It was built in 1974, so it was really pre. I mean, ARPANET was there, but—

FIDLER

Still an experiment.

NAYLOR

Right.

FIDLER

Do you recall what kinds of technologies you used to measure capacity?

NAYLOR

The machines were configured with counters, so they would count the CPU utilization, for example, and probably memory usage, but I don't remember that specifically. It was primarily a CPU-bound kind of operation. The other thing that was measured, of course, was the transaction rate. So that's what I did. I created graphs that plotted one against the other, basically, and kept a historical record of the peak transaction rate, typically the peak hour of the month. And that grew—also the number of terminals that were out there, so that you could figure out if you were going to deploy twenty new ATMs, that would add approximately so much to the peak load.

FIDLER

And that load was largely or entirely in these central computers.

NAYLOR

Right.

FIDLER

And that's where you tested and that's where load was measured?

NAYLOR

Right. The load was measured in the active datacenters, and there were always two. Citibank had this notion—or maybe TTI fostered that, I don't know, of no single point of failure, so that if one datacenter went down, we still had enough capacity in the single datacenter to handle the load.

FIDLER

So it was very clear that you were working with these fault-tolerant systems.

NAYLOR

Uh-huh.

FIDLER

What were your dealings with departments or sections inside TTI, and how much did you interact with Citicorp itself or the actual Citibank branches?

NAYLOR

Right. I interacted primarily only with the datacenter folks, who, at the time, were actually part of TTI for this particular datacenter, but they were housed in New York in Long Island somewhere. I can't remember what city, but, anyway, yeah, they were in New York. So externally, I talked to those people. Internally, I had a manager, and I had, I think, five or six people working for me. One of the first things I wanted to do was to revamp the reports that we were creating, and I was told basically BCR, which was the name of this network, is going away soon, so, "No, don't bother." And I persisted and said, "I can't really do my job with the way things are." So I wanted to change it, and I got my way.

FIDLER

So what kind of changes were they trying to enforce? What was the structure that you were presenting?

NAYLOR

Well, the reports at the time that I arrived were very ad hoc and had been written by cowboys. That's my term.

FIDLER

And by cowboys, do you mean—

NAYLOR

I mean just seat-of-the-pants. They didn't really totally understand what the job was, to make sure that there was enough capacity. So I proceeded on the path to just have a set of standard reports that were published probably every month, and it used a similar process for each of the components of the network. The other thing that I did was create more standard measurement tools so that in our lab we could simulate what we wanted to see out in the world.

FIDLER

And those standard measurement tools, those would have been working on those main systems?

NAYLOR

Right, but in the lab.

FIDLER

So it sounds like you're describing this as, at least initially before you got your way, less systematic than the kind of work you were doing on the ARPANET at UCLA, the nature of the reports.

NAYLOR

Yeah, I think so.

FIDLER

And compared to Xerox, it sounds like there was a bit more engineering and a little less management?

NAYLOR

There was a lot more engineering, yeah.

FIDLER

And to the extent that you were exposed to managerial authority over you, what was that like compared to your time at UCLA?

NAYLOR

I think over the time—and I'm not sure about the initial period at TTI. I was there a long time. But eventually, it was certainly I got left alone to do my job. I certainly wasn't micromanaged.

FIDLER

Just a couple more things about TTI and then we'll move on. When you say you were there for a long time, actually, you were at Transaction Technology, Inc., from '80 to '82, and then you were back at Citicorp in '83.

NAYLOR

Right.

FIDLER

And was that also at Transaction Technology?

NAYLOR

At the time, yeah, it was. It didn't morph into a—TTI was a wholly-owned subsidiary of Citicorp when I joined, and I don't remember when the transition actually happened, but eventually it became just part of Citicorp.

FIDLER

But there was an interlude in '82, '83, when you were at the Aerospace Corporation.

NAYLOR

Right.

FIDLER

And what inspired you to go there? What did you do?

NAYLOR

Steve Crocker inspired me to go there. He was setting up a computer science lab at the Aerospace Corporation. They had several other labs, which was some kind of special designation, and I can't describe exactly what that means, but this was a new lab being set up, and it sounded like fun, so I went off to do that.

FIDLER

And with this Computer Science Research Group, it sounds like it was more experimental work than, for example, what you were doing from '80 to '82 at TTI.

NAYLOR

Yeah, I thought it was going to be. Initially, I was tasked to set up a LAN. The lab itself had a computer, and we were trying to connect the rest of the facility into it and connect to the net. I think that we were connected to the net, but without a LAN for a while. I don't remember exactly the chronology, but I know that eventually Aerospace got on the net. But then it was clear that I was going to be working for the air force, and I didn't really think that was a great idea for me.

FIDLER

And that stuck in your mind as being different than working for ARPA, air force versus ARPA?

NAYLOR

Yeah, it did. I'm not sure why. I mean, yeah, they both have defense in their name, but—

FIDLER

Do you think that was a rather common sentiment amongst people that were also ARPA-funded that you worked with in the past?

NAYLOR

Yeah, I think so.

FIDLER

Because ARPA was seen as pretty benign, right?

NAYLOR

It was the late sixties, the early seventies, and we were working with a bunch of bearded people. [laughs] They looked the type, right, that were kind of antiwar and—

FIDLER

And ARPA did have that interesting mix of counterculture engineers, but then when you get up into the DARPA offices, it's much more formal, and you don't find bearded counterculture types anymore, but that's different—

NAYLOR

Right, although I know a few who did, like Vint and Steve both went to work for ARPA.

FIDLER

Right. They were both program managers at the time, at least.

NAYLOR

Yeah.

FIDLER

But with the air force, you sense that that kind of relationship wouldn't be the same?

NAYLOR

Yeah. I didn't really get into it that far. And at the time, my marriage was falling apart, so I think that had something to do with just feeling altogether uncomfortable.

FIDLER

So the air force was one more thing.

NAYLOR

The air force was one more thing.

FIDLER

And with the Computer Science Research Group that was setting up a LAN, that was your main task.

NAYLOR

Right.

FIDLER

And that was going to be used by that research group?

NAYLOR

Right, and other people at Aerospace. Other people at Aerospace would then be able to get access to the net and have email addresses and whatnot.

FIDLER

And is that the particular task that Crocker approached you with, or was it more general?

NAYLOR

No, it was just something that needed to be done, and I didn't really know that much about it in terms of acquiring hardware and stuff like that, but—

FIDLER

So now you were connecting to a packet switched network unlike the last couple of positions.

NAYLOR

Right.

FIDLER

Can you say anything about the nature of that connection or the kind of a LAN that you were working with?

NAYLOR

Yeah. It wasn't Ethernet. For some reason I thought—and I don't remember the name of it now. For some reason I thought that it was going to be—it had some aspects that were better than Ethernet. I believe it might have been collisionless, and I liked that idea. But as it turned out, it's gone now. Nobody uses that technology.

FIDLER

And this LAN was implemented. Was it implemented during your time?

NAYLOR

It started to be implemented. What happened is that in order to get across the street, we had to put in some cable, so that would be ordered, and that was like a long-term thing that had to be put into the works. I don't remember before I left whether it was implemented or not.

FIDLER

And any network connection that you had, like, personal access to even email [unclear] the ARPANET, would that have been through Aerospace, if it existed at all?

NAYLOR

Yes.

FIDLER

And was there any personal use that was going on at this time or even before, or was it work-related that you largely used it for?

NAYLOR

Let's see. We're talking about—

FIDLER

Like '82, '83.

NAYLOR

Eighty-two, '83. Could have been some personal, I should think, but I don't know. Yeah, I don't remember, but I guess it would have been mostly business.

FIDLER

And mostly business within Aerospace or were you communicating with, for example, the people that are putting the lines or—

NAYLOR

I was communicating a little bit with ARPA. I don't think that I had any contact with outside contractors. I think that was done through the bureaucracy at Aerospace, but I certainly could have interaction with that group. I don't know if it was via email. It probably wasn't. It probably was paper.

FIDLER

And you said ARPA. Does that mean, for example, old colleagues, people with whom you had connections during PRNET, SATNET work, Network Measurement Center?

NAYLOR

Yeah.

FIDLER

And is that something that was happening at TTI before that, or Xerox?

NAYLOR

Probably not at Xerox. It's possible it could have happened at TTI, although at that time, Citi had its own internal proprietary like Xerox email net or a system, and I don't remember if there were at that time any outside connections. It was probably similar to the way Xerox worked, where the vendor had to be signed up as a user within that proprietary email system. I think that's the way it worked.

FIDLER

So insofar as you could, you talked to your former colleagues. Was that something that you thought other people were doing? Were you connecting to an old cohort, for example, where other people were in touch?

NAYLOR

I'm not sure what you mean by that.

FIDLER

Well, if you, for example, got in touch with someone that you'd worked with before, do you think they were also in touch with others that they had worked with with you, for example?

NAYLOR

Yeah, I guess I assumed that they were in touch.

FIDLER

So kind of, at least, connected-via-a-network group had kind of survived over the years, by the sounds of it.

NAYLOR

Yeah.

FIDLER

But then you left.

NAYLOR

Then I left.

FIDLER

Then you left, and you were back at Transaction Technology, Inc., for Citicorp, which eventually became a part of Citicorp rather than a subsidiary.

NAYLOR

Right. And I came back as a non-manager, which was fine.

FIDLER

So was it former connections that got you back in, or did you just apply for—

NAYLOR

Yeah. My boss' boss really wanted me back. [laughs]

FIDLER

And what was your new job or new jobs when you were back?

NAYLOR

We were, I think, at that time planning a new kind of network, which was for home banking. But again, the model was we would build the terminals and people would put them in their homes. They were actually a huge phone with a tiny little screen, keypad. I don't remember if it was just—there must have been a full keypad rather than just a number pad so that you could type text. So we actually implemented these things. The system was built for a hundred users, and so we built a hundred phones, and by the time we were done with the system, it was twelve hundred. So those were our proprietary—

oh, I guess maybe some of those were not, because somewhere along the line we started implementing software for ATARIs and TRS-80, and I assume PCs. I don't remember.

FIDLER

Banking software, you mean.

NAYLOR

Banking software, yeah. So it was proprietary software that we had written for these other devices that weren't our terminal but could connect in.

FIDLER

And all these used modems?

NAYLOR

They all used modems at that time, and so they dialed—we had a bank of rotary numbers that they would call. And I had to figure out how many we needed, right? With twelve hundred users, it wasn't so bad, but actually part of the twelve-hundred-user-system, it was written in, I think, FORTRAN for a—there was datacenter software, too, to talk to these guys and then talk to the various transaction hosts within the bank to do the actual functions that the people wanted. So as part of trying to get that system to go from a hundred users to twelve hundred users, I created some software that looked for, basically, a subroutine call in the code, changed that to JMP to me, and do some counting and timing, and then go back. So we were able to use that to isolate where the time was being spent in the code, so we could actually optimize the code, and we got it from a hundred up to twelve hundred by doing that.

FIDLER

So it was software that let you scale.

NAYLOR

Yeah, in that, but then we moved on beyond that. Any more questions about that, I guess?

FIDLER

Well, yeah. If there's anything you can say about that particular project, that'd be great, or we can move to—because presumably you were there until, I think—was it 2007?

NAYLOR

Yes, 2007.

FIDLER

It sounds like it was the kind of job where your work at ARPA gave you kind of a broad expertise in networks, but then this was, again, not an ARPA-like network.

NAYLOR

Right. This was not an ARPA-like network, but I did use Erlang's formulas to figure out how many phone lines I needed and things like that.

FIDLER

Oh, so you were still going right back to these early thinkers that were relevant to, for example, work on the ARPANET.

NAYLOR

Uh-huh.

FIDLER

So after these home-banking terminals and the network that you worked on, what was the next job?

NAYLOR

The next job was actually doing—well, it was a follow-on to the first home-banking system, which was called Homebase, and that was the small set of users, to something bigger, and I think we called it HS10K. So from 1,000 to 10,000 was the next step. We actually for some reason decided—the time was—when was the time? Eighty-two, '84. I can't remember exactly when we came out with HS10K. We built UNIX, we rebuilt UNIX by ourselves for a processor that was—what was it? I think it was a 68000 Motorola. I don't know why I'm going down this path. [laughs] But at that time then we were moving to PCs, right, instead of these—I think we could still support these terminals, but we were moving to PCs as well.

FIDLER

So there were still these servers, but then you were working on software for people's PCs.

NAYLOR

Right. And I think we supported Macs as well at that time. But still it was in the mode of dial-up, so we had the same problems. They're just bigger, right? And the next step was, of course, "Oh, there's this great thing called the Internet now." So we, of course, changed everything, and it became a website.

FIDLER

Right. So everything just switched over to using the TCP/IP Internet.

NAYLOR

Right.

FIDLER

Before and after that, were your measurement tasks similar to what you'd done before where you were looking mostly at the capabilities of the servers?

NAYLOR

Yes, mainly, and there was that added task of sizing the modem pool, but that went away with the Internet, but it continued to be, you know, what is the server capacity.

FIDLER

And was that what you worked on until the end of your time there, or were there other tasks?

NAYLOR

Yeah. There were some other tasks. Well, there were various different systems. There was this in-house-built system. Then we moved to a PC-server-based system that presented the website. Then they moved again to what was called a portal architecture, where the bank began to have a little more control over content than they did by having a request come to TTI and say, "Do this thing on the webpage." They would have a contact management system as part of that portal infrastructure. Each time there was a new system, and I had to make sure the capacity was sufficient for that. And they were at different stages in different parts of the world, so we were still on the PC version in Asia and were on the portal version in New York or U.S.

FIDLER

Were you aware of similar work being done by other firms? Did that show up on your radar at the time?

NAYLOR

Yes, we were. Yeah. I mean, we were pretty early into it, but I believe that Wells Fargo in California got to be bigger, more users than we had pretty quickly, so we weren't the biggest. I think they've got over a million users right now, but still that's not enormous.

FIDLER

And why did you leave in 2007?

NAYLOR

I got retired.

FIDLER

Congratulations.

NAYLOR

As it turned out, there were a bunch of technology islands within Citibank, and Mitchell Habib, who came from RCA and was a cost-cutter, decided that that was a bad idea, so they were going to move us to either Ohio or Singapore. And I'm happy in California, so I decided it was time to retire.

FIDLER

Can you say what your particular island was vis-à-vis those others? And by island, do you kind of mean like a silo?

NAYLOR

Yeah. Well, we grew up as this technology company that the bank bought back in the seventies, and in the beginning were very much our own thing. We had our own vacation policy, our own health benefits, and all that stuff, and our own offices. We had really nice offices compared to other people at the bank, and people commented on that all the time. [laughs] And part of being integrated into the bank meant we moved—I think it happened, actually, when we made this move from Santa Monica, where we had offices, to Marina del Rey or along Jefferson—I think it's actually L.A.; I forget the zip code—where we had cubicles. At the time I moved, I had an office, but eventually we got smaller and we had to move, and eventually got a large cubicle. [laughs] So for the last, I don't know, three or four years, I was in a cubicle, which was a big change for me, because I, even at UCLA, had an office even as a student. Well, I guess maybe you'd call it a cubicle, but it was floor-to-ceiling temporary walls with no window. But ever since I was a postdoc, I had a window office, right?

FIDLER

Right.

NAYLOR

And now I was in a cubicle. It was a weird feeling. Why did I get off on that tangent?

FIDLER

We were talking about the inspirations behind retirement.

NAYLOR

Oh, okay. That was one. [laughs] And actually, I had partially retired a few years earlier, and that was because, well, I wanted to work part-time, and because of the retirement policy at Citibank, I wasn't going to make very much more money the more years I worked. I was sixty-one at the time. So I cut down to 60 percent time, took my retirement benefit, and I made about the same amount of money working 60 percent time. And after the next, I guess, four or five years, I was ready to retire.

FIDLER

Before we move on to some more general questions, is there anything else you'd want to say about Citicorp and your time there?

NAYLOR

You mentioned the personal email. That actually started happening when my kids went off to college and I was working at TTI at the time. And they discovered this cool thing called the Internet because they went to college, and every college student in America had Internet access at that time. My first—'85. I was trying to think of when that was, but it's okay. So that's mostly when my personal email started happening, is with my sons. And then at some point in time, like all corporations, TTI or Citibank decided that that was a bad idea. So how did they fix that? Well, they told everybody not to do it, and they started barring certain websites so that you couldn't use Yahoo mail or something like that with a network interface.

FIDLER

So that would have been in the 2000s—

NAYLOR

Yeah, I think so.

FIDLER

—when that kicked in.

NAYLOR

Yeah.

FIDLER

And you talk about emailing with your sons. You mentioned that before that, people that weren't in your immediate offices that you would have had contact with would have been old colleagues, like UCLA colleagues.

NAYLOR

Right.

FIDLER

Were there any other groups besides family and former colleagues?

NAYLOR

Yeah. Family was starting to get email addresses. I don't remember exactly when the transition that TTI made to be on the net as opposed to the proprietary internal. In fact, it was a transition, right? They still had their proprietary, and you could have an external address as well, and then eventually it all went to external addresses.

FIDLER

We talked about this a bit last time, but I'd like to return to it because you're one of the few people that can speak to this. You had this experience of getting online and probably having an email address in the very early seventies.

NAYLOR

Right.

FIDLER

And then you kind of watched as the rest of the world got online around you. Can you say anything about what that would be like?

NAYLOR

Well, it was frustrating to have to go off to somewhere and become an email island, right, where no one else could talk to you except people inside the corporation or people who could be signed up, right? I'm trying to think of when the transition happened where it

was free again to be able to talk to anybody, but, again, I know it was my sons who kind of kicked that off.

FIDLER

But it sounds like the process of going from email in the early seventies wasn't one of just naturally progressing connectivity with everyone around you. There was ups and downs based on the access provided by—

NAYLOR

Wherever you were.

FIDLER

Wherever you were.

NAYLOR

Right.

FIDLER

And I mean, nowadays, if you have to go off the Internet, it's a problem and a source of great anxiety. It sounds like it was still annoying then when this happened.

NAYLOR

It was, but it didn't feel like there was an alternative, right?

FIDLER

Right.

NAYLOR

And there really wasn't an alternative until either you could get it at home—and I don't remember which happened first, whether I got it at home—although being in Topanga, I had to wait. It really made me mad. [laughs] Because I'm sure that at least one of my sons was off at college when I was living there, and I couldn't get Internet access at home. Yeah, it's a hardship. I remember just recently my oldest son was out of contact for a couple of weeks, and he remarked about it when he came back, that, you know, it's a strange feeling not to have it everywhere.

FIDLER

But then back in the early eighties, you'd still take the job—so nowadays, if you got a job, and they said, "But you can't have personal access to the Internet anywhere," people would just not take those jobs. This was just something of a negative side effect of a bit of a still—

NAYLOR

I didn't think of it as a conscious—I mean, it wasn't a big deal because nobody offered, right?

FIDLER

Right.

NAYLOR

And there was no access personally. Now, since I have personal access, I don't care whether they would allow me to have personal email at work or not. I would expect to have an email address that I could talk to anybody in the company or even outside for business purposes. That's fine. Since I have own personal one at home, I'm good with that.

FIDLER

And are there any other observations that you've had when—again, going from even, say, '69, having interactions with the ARPANET, to the present and watching the rest of the

world get online, are there any other observations that you've made during this time about the changing nature of the Internet, for example, something like that?

NAYLOR

Well, I have to say—well, that picture up there shows it. Fifty-kilobit-per-second lines, you know, having that the speed limit would be really difficult to have the kinds of services that we have today on the net. I don't know how much that clouded my thinking about what the possibilities might be in the early days.

FIDLER

When you were doing measurement work at the Network Measurement Center, can you recall how you thought about the ARPANET as an infrastructure? Was it largely something to be measured and experimented on, or did you also see it as this tool you were using to stay in touch with other people, even if it was just a few other graduate students?

NAYLOR

Yeah, I guess from my point of view, it was something to be measured. Though I did have some interaction with people via email, I was mainly interested in how it worked and—

FIDLER

And did that continue until, say, I believe, 1978 when you left UCLA, or did that change a bit?

NAYLOR

Well, I wasn't doing any measurement experiments on the ARPANET itself, but on new features of it like the SATNET.

FIDLER

Did that lead you to leaving the ARPANET in a sense when you went over to the PRNET and SAT Network?

NAYLOR

No. I just thought of it as just an extension of the same kinds of ideas, so I didn't think it was different in that way.

FIDLER

You mentioned still drawing on, in a sense, Erlang, I think, when you were at—

NAYLOR

TTI.

FIDLER

When you were at TTI. Were there any other broad themes that ran through all this work? So, obviously you were working on networks, and I think from what you said there was definitely a theme of measurement in the work that you were doing.

NAYLOR

Yes.

FIDLER

Are there any other ways that you think of these jobs and the things you did as having a kind of continuity with your work at UCLA?

NAYLOR

Yeah. I guess from the point of view of understanding the capacity of a server as opposed to a bunch of network links or an IMP or something like that, I found it similar. And I

certainly used queuing systems modeling in my work all the time to try to understand what I was looking at.

FIDLER

And in that sense, did you feel that you had a different background than these other people you'd be working with overall, like coming out of work on a different kind of network you'd be on? You'd been using networks for quite a long time. Did this give you a sense of having a different background than your colleagues throughout the eighties?

NAYLOR

Yeah, it did. I remember trying to explain what an Erlang is to some managers, and I had a fun time with that, actually.

FIDLER

Is there anything else you'd like to bring up about your work that you did for these firms or your experiences on the ARPANET or Internet?

NAYLOR

I can't think of anything.

FIDLER

Okay. Thank you again for your time.

NAYLOR

Thank you. [End of November 26, 2013 interview]

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