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Interviewer: Hong Wei
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02：53-06:14

HW: So, we have interviewed you for twice and we've collected lots of stories… He will keep eye on the cameras… so, we have summarized some of the key events from last two interviews and Dr. Fang want to know more about the details of those stories. And would you please, you know, like share more of the details for…

HW: So in 1962, you attend the meeting held by the air force with Licklider.

LR: I don't know what this meeting is.

HW: So in Virginia…

LR: Yes, in Virginia, it was 1964, (Uh, sorry) it wasn't the air force it was a conference is just a technical conference.

HW: Okay. So would you please tell us more about that conference, like your interaction with Licklider?

LR: Well, in the conference, I don't actually remember the details of the conference, because it was just one of the technical conferences that we went to. But in between sessions, I sat down with Dr. Licklider and …He was the head of the MIT psychologic system and discussed the future of what near to happen. Where did we need to go over the problems? I have been doing research in many areas. First was artificial intelligence and I did pattern recognition with neural net, which was way in advance of today's activities.

LR: I did a lot of research into graphics, and I did the first 3D graphics work. And actually, also did virtual reality. And then I was looking for where to move next because I had realized the graphics was sort of twenty years in the future that they could use what I had done that people will be doing recognizing 3D objects from a photo or video. And that's what I had done. And that's a reference so often today that it's a major thing.

06:16-10:04

LR: So at that point I was looking for where I would go into the future. And Dr. Licklider talked about his view that we needed a network between all the computers. He had written about this is the galactic network, the problem was that he was a behavioral scientist and he didn't know how to do it. So he, had just talked about the potential advantage of being able to get access to various different computers and share their knowledge. I basically, had already had this problem that with moving data between computers. The AI lab at MIT,

Dr. Minsky wanted a set of photographs that I had taken and digitized for the TX2 computer, and moving those was extremely difficult job to him.

LR: It took me months and the problem whether I did buy an IBM tape drive building on interface to the computer, a new physical interface and write him a tape, drivers and then write him a tape with the data. It was a ridiculous amount of work, months of work, an expense, too, to be able to move some data to a different computer. And is a problem was going to get worse as more and more computers appeared in the world. We were in the hundreds.

LR: Then we were very quickly move into the millions. So, it was clear that we had to do something to get data move between them. And so that was the discussion. I decided at that point that, shortly thereafter as a result of that, that it would be a good direction to start work on, because nobody was doing it. And I wanted to be first in something, as I was in the graphics already, and probably on AI as well. So I'm basically, talk to Ivan Sutherland, who was Lick's replacement in the government after that, Lick had been the head of the ARPA office, but then, went back to MIT and he basically was replaced by Ivan Sutherland at the ARPA office.

LR: And when I say ARPA, but that's what it was then, it was now DARPA. But in any case, Ivan was my classmate, and my office mate at MIT for a while in grad school. And I knew each other. And so I suggested that I wanted to do a research task for networking on computer networks and do an experiment between two computers like across the world. I mean across the US to see what the problems were and what was needed to be done.

10:05-13:19

HW: No, I mean this is great. So, you mentioned that you are classmates with Ivan Sutherland as well as Leonard Kleinrock. So, could you…?

LR: Yes, well, actually, Ivan and I wasn't office mate. He just was in like class area and worked with me at Lincoln labs. But we work together on various projects, including the first virtual reality experiment where you put your headset on and looked around with my 3D graphics work.

LR: So, and then, Leonard Kleinrock was also an office mate for a while. And he also worked with me at Lincoln labs. No, he did for a while.

HW: Yeah. What kind of projects were you working on?

LR: Well, when I worked in Lincoln, I was asked to do software for this new computer they had built, the TX2. There was no software. There was only a plug board. So you the only thing you could do is programming the plug board, a little one.

LR: It wasn't, it would only do a load of a . And so that the entire plug board was to load the paper tape. And then, once the paper tape was in, nothing was there, there was no software. So I had to write the operating system and write the drivers, write everything to load the information into the computer. And I had to write the operating system which was

tuned. I did a time tuning system so we can have multiple users. And I did the assembler and the compilers, and all of the software for the drivers and all of the things that we put on the computer. Like, we put the tape of our own on after a while, not just the IBM tape, but our own tape.

LR: And so, all of these things were software that I did just to get the computer up and running. And then I did my master's thesis, which was the work on the reduction of bandwidth for video transmission or picture transmission. And that was the first bandwidth reduction that was implementable on hardware in that day, because the floppy disks were then built out of compliers. And so you couldn't do a quick job of a computing variety. They were going to send the stuff to the moon to take and read and send pictures back. And they needed something that was feasible to build in that day and age. That would compress the videos, I mean they're not videos but all still pictures.

13:20-15:24

LR: So, my algorithm was one that actually got patented was free to the government and there with the government. So, they didn't pay. And the technique was to add pseudo random noise to the image, to scan, more gray scale than you could normally, and then can compress it to just the top three bits, our four bits, or whatever you wanted. But in this case, typically three bits of intensity information for each dot. And the problem was, if you did that normally in just three bits, you'd have all sorts of strikes in the issues. I mean, as this is a great shifted, you have lines, and it's very disturbing, and people hate it.

LR: And so that's pseudo random noise wiped out those lines because they were sampling all the dots in an area with different levels. And so, the level was incorrect, but then compress the three bits. But then at the receiver, I had the same pseudo random stream. So, I could reconstruct and eliminate the noise that was added. And the result was I got a much better picture then. And for the eye, it was vastly better, because everything was smooth in the local area. So, we had the pictures from the moon, we're done that way. After that, other albums got much better. There was at that time seriously use.

HW: So, were you very close with Leonard Kleinrock and Ivan back in the school ?

LR: I was close with Kleinrock. I actually spent a lot of time working with him.

HW: So， when did you first meet with each other?

15:25-17:24

LR: I can't precisely say… it was between 1960 and 1964 that all the school things happen or 1963. I was only working at Lincoln after 1963. But a lot of the interactions happen at Lincoln because all three of us work there.

HW: Okay. Were you three all in the 6B class? Right?

LR: No, I was the only one in sixty. I see undergraduate, they weren't involved. I see. So, this was all in grad school.

HW: So, would you please share some of the stories of, you know, you three working together.

LR: Well, there weren't a lot of, there were some stories, but not many. With Leonard Kleinrock, I understood his work and because he actually was working on the theory of packet networks.

LR: And he wrote a book which was published in 1964, which certainly help me with his back, his thesis in work, and that was just something that happened over time with him because he was we talked in the office and so I knew what he was doing. And I knew that, his queuing theory proved that it was feasible to do packet switching and not lose the data. So that was the big issue. Uh, and as I said on one, uh, interview that basically without that, I wouldn't dare do the experiments and go into it, because I wouldn't have proof that it was, it would work, because the packets might fall on the floor like everybody was saying.

17：25-18：11

LR: I mean, all of the people and communications that I knew and AT&T and SDC and other places thought the packet switching was hopeless because it would all fall floor. So, the packets were just a symbol and fall on the floor. So that's what happened there with Kleinrock. One story was that he, came to work after me, and I was still in the lab in the TX2. It was a basement that's larger than this house. So I mean, it was a huge area and mostly filled with racks of equipment. And so I walked around behind the racks and while he started to work.

18：12-19:11

LR: And then I whispered to him through one of the little cracks, you know, in the rack, and it scared him to pieces. But he's reports that story over and over. That I had this looking at him through the back of the computer. And then we get together and more. Ivan, I had not as much technical interaction with in some cases. But there was one thing we did together. And that was the virtual reality. He wanted to do that. And he built this a suspension thing from the ceiling that held the head mounted thing, which is now the computer museum, uh, this big, uh, sort of Damocles that call that came down and held the camera because it was heavy.

19:11-20:03

LR: So I had the 3D vision then on display there. And my program, I developed the link and one which was an ultrasonic one. That would sense a beep so that we could detect location. And so there were four on either edges of the display screen. And they all listened. And then the one that you held beat one other side of the, or however many you wanted. And the four sensors gave me for more than three dimensions, four dimensions of information. So I can filter it and make sure that I had the exact place that one was pointing.

20:03-21:00

LR: So I could tell it was pointing over here, which might have been just a poster on the wall, which was different commands that I wanted to use to the computer. So instead of just the display screen, I can use a whole room for pointing at things too. So one of the things we did was amount those sensors on your head so that we can tell the decision, the place of where the head was looking. And then the computer mentioned uh, the computer um, monitor to the head position and change the display. And luckily, the computer was fast enough to do that in 3d line drawings. It wasn't gray scale at that time. But it was certainly a good virtual reality experiment.

21:00-21:21

LR: That was the main thing I did with him. He was working on sketch pad all the time on the computer. That's what he was doing. And that was a two dimensional drawing program. And I was working on my graphic programs, which was my PhD thesis. And so that was that those are the two significant interactions there.

21:21-21:50

HW: Were there any personal interactions, aside from the technical interactions?

LR: Did we get together? No, I mean, we knew each other personally, but we didn't get together afterwards to do things. I mean, it was all in the lab generally.

HW: How about you and Ivan?

LR: Samely, it was mainly in the laboratory or at school.

21:54-23:05

HW: So, in 1964 had the conference. So before that, did you know about Licklider?

LR: Yes, I knew about him. He was running a program, and he funded lab at MIT that I was in. So I certainly knew him. And Licklider reported back to their office as far as the I worked there.

HW: When was the first encounter with him?

LR: Physical meetings, probably when I met at the conference. I mean, I knew him and I knew of them, but I haven't spent time with him.

HW: So after that, after the meeting…

LR: I didn't talk to Licklider again. Ok, it was when he went back to MIT as a professor, oh I did talk to him again.

23:05-23:43

LR: When I was leaving the ARPA office in 1963, I'll say it was seven and seventy three. When I left, I wanted to leave ARPA, after being there six years, I figured I'd been there

long enough. And I try to find somebody to replace me. And the only one I could find that was willing to come was Licklider. So he was willing to come a second time. And he did, he came and helped me leave, so I can get out of here and start telling it.

23:44-24:35

LR: I tell him that I was working on getting started all the time. I needed to get out of there because FCC was approving our license. We became a license carrier.

HW: So what was Licklider like after work? Do you know his personality? His character?

LR: He was just a grand old master, start at that time sharing business, basically at MIT in other places, pushed it very hard. And that's what his main personality.

24:36-25:20

LR: But I didn't… I knew about his work, but I didn't spend time on it.

HW: So, in 1965, that was when you first connected TX2 to thirty two in California, right? (Yes.) And, so you were working with Thomas Merrill, right?

LR: Yes. One of the things that I've been suggested is Thomas Merrill wanted to work on networks as well. So I hired his group to help me program the stuff.

25:21-26:07

HW: What was Thomas like?

LR: Well, Thomas had a computer corporation of America, I think he called it. And he um, I actually spent time with anyone, stayed his house and knew his family, wife. He was a very personal person and I spent time with him. But I didn't work with him because it was his people who he said to help in the lab and program for me. So basically, he said some hired help to do the project because I didn't have extra staff in the lab.

26:10-26:41

HW: So I think at the same time in 1965…okay, so what was the situation in Lincoln lab back then in MIT like, what was it like?

LR: What was it like? Yeah, well, one of the things that happened when I went there was that I was still a grad student and doing my thesis when I started work on the computer.

26:41-27:18

LR: And I did the software before I could even do my thesis work. So I had to do a lot of software first. But in any case, the lab, effectively, when I got there, I started working on the software on the TX2. So I was managing the TX2 effectively, because no one else could use it yet. The director of Microbe, Wesley Clark, and the BB&N, and they decided to

leave because the Lincoln wouldn't support them working on cat brains. And they wanted to compare brains with intelligence.

27:20-27:59

LR: So they wanted to measure the cat brain and see what the intelligence was. I don't think it would have doesn't much good back then. But people still work on that thing. But anyway, Lincoln wouldn't allow them, the animals. And so they left and they went to Washington University and they left in a vacuum for me because there was no leadership. And I was a staff member, actually, just done, uh, just the standard staff member. And so I just took over managing all the people who needed to work on TX2.

28:00-28:46

LR: And I've written all the software. So they are effectively reported to me for their work in helping with TX2, were doing speech research like, Frank Heart was who actually worked with BB&N later on the program; he wanted to do speech research. He was in a different group. I already saw him. But I had to approve the work on the computer and so on. But in any case, the people in the laboratory hierarchy told me that not to worry about the fact that wasn't, it didn't have a supervisor job. I just managed them anyway.

28:48-29:36

LR: And I knew how to do that. So that wasn't a problem. And that was the situation that Lincoln was doing very well at that time. And the research funded on the TX2 was very advanced. And, of course this was founded by Licklider. And then I went. But Dr. Ford Benny, who was an amazing person from Washington, who did help them. He was once in the defense director, you know, the head of DDRNE or something like that in the defense department. But he came and interviewed me and about the projects. And some of those things were very exciting because we had great research.

29:38-30:23

LR: And it went over, but so I ran the program basically that at Lincoln for the TX2. And there were lots of other things going on. I didn't pay much attention to.

HW: What was the difference between Lincoln lab and the other labs in the normal universities?

LR: Well, Lincoln had, was where they did SAGE and sage had a huge amount of computing activity. So there was a lot of computing expertise, including the people who built the TX 0, which became its PV1, and the TX2, which became a PDP10, are six, and then ten.

30:25-31:30

LR: So basically, Lincoln had a great history there on own computing. And that was as a big difference. The other labs didn’t computing, except for the…

HW: Who gave you all the… impression back then? Were you impressed by anybody in the Lincoln lab?

LR: Well, Wesley Clark was very impressive, and that's who I started working with. And the other impressions I got were primarily like Dr. Beanie from Washington. Not a lot, people were good. But they went Stella stars. In my area, I mean they were in other areas I'm sure. I just didn't interact with people doing other kinds of things. I worked in my area.

31:30-32:20

LR: So I didn't, can't identify, you know, especially impressive people. When I eventually had the lab's call, the director of the lab to get me to move to ARPA. I met with the director and he was extremely impressive in telling me to go and they support me and take me back if there was a problem and so on, because I didn't want to get into management. But I turned out it really wasn't management and it was venture capital activity, which is actually more interesting in a way.

32:28-33:16

HW: Okay, so would you share some stories with Wesley Clark?

LR: With Wes?

HW: Yes.

LR: Well, I did just then talk about his cat problem. Later on, originally, he just got me started and then left. So I didn't have a lot of interaction. But then he went to Washington University. And that was one of the projects which I heard funding from ARPA. And when we had the PI Meeting in 1967, where I brought all the principal investigators together, which happens every year for that office of ARPA, we get all of the leaders of the different projects.

33:17-34:07

LR: It was at his site at Washington University that we did it. He was developing small personal computers. They were not small (in) their size. But they were, that was his goal is to get the computer down to where it was a personal computer. And of course that happened. One of the things that he recommended to me as we went back in a taxi to the airport was that he took me back, was that the instead of connecting the computers directly to the network, which is how I did Lincoln to SDC Q32, how I did my experiment.

34:10-34:51

LR: Instead of doing all that sort of work inside everybody's computer, which would be lots of different projects to do it on a mini computer that could be put next to the computer and then just have a standard computer interface to the mini. Well, that standard interface will still work, because it had to be built into every computer. But it became a much better way to approach it. Because all the routing software and network software wound up in the,

what we called IMPS. The mini computers were just becoming on available. I mean, this was one of the first mini computers that, five sixteen.

34:52-36:05

LR: And there was also the mini computers, but there weren't many.

HW: So when you took the ride with Wes to the airport on a taxi, you were talking about the idea of IMP, who came up with the idea first?

LR: He did.

HW: So he sent you off to the airport, right?

LR: He took me, I don't know exactly what the Caspian was about because why we were going to airport? It was his city, but he did. That's what happened. Wesley was together, and we were talking, and he was explaining that. Now in many cases, Bob Kahn has tried to say that happened at the meeting and maybe Wes mentioned at the meeting, or maybe he didn't.

36:05-37:06

LR: That story was created much later, and I'm not sure, whether Wes mentioned at the meeting or not. I was presenting the fact that everybody was going to have at the meeting got on the network. And this was his idea how to simplify that process.

HW: How many people attended that meeting in Michigan?

LR: It was at Washington DC. It was basically, thirty or so contractors were at projects at MIT and Carnegie and Stanford and everywhere.

HW: Were there any significant names, like famous…? I mean, they're all major names back then. So can you name some of them?

37:08-38:03

LR: I see Dr. Douglas C. Engelbart. Yeah, he was there, right? Yes. I'd have to go through every project and try and remember them, but it was probably Carpito from MIT and probably Minsky as well, Marvin Minsky. And then from Stanford Franganma and John McCarthy, most likely and maybe, maybe not. I don't know whether John came but like upon came and lots of other people, Newell from Carnegie. And it would be hard to remember everybody.

38:04-38:59

HW: So when all of the principal people at that time in history, in the computer field, basically.

HW: when did you first interact with Engelbart?

LR: Well, I had to manage his project as far as funding goes on. So I went out and visited him every year and his lab, and we worked on where he was going and what he needed for funding and what I was approving. And in particular, he was doing, the work with, what I thought was probably the best thing that was never used in the world. And that was the five-finger keyboard; because with one hand, you could type extremely fast as soon as you learned how to do it, which took time. But once you learned it, it was faster than the keyboard. And one hand, so you could use a mouse in the other hand. And he also did them out.

39:00-39:49

LR: Wow, so he was doing those too and editing online with what we I think of as, today a computer document who had parts, you know, much like a website, or what's the right comparison? Any case, very advanced editing capabilities to jump to other sections of the document and move around in the document. And I wanted people to be able to use that for their documents and produce reports. So one of the things I was funding him for was to get that ready for the online use over the network.

39:50-40:31

LR: And he did, and we all used it as the document center. He also, I think lots of the primary things he was doing that I remember about it.

HW: Yeah. So, apart from that, you know, professional interaction, did you have, you know, personal interaction with him? What was he like?

LR: Well, he was certainly very advanced in his thinking, but I didn't spend a lot of time personally, with management interactions about their project.

40:32-41:05

LR: I didn't have time for other things, actually. I mean, I know he was very good to work with. But it almost all of these interactions are professional mainly. Well, I spent some time on Kleinrock in places like in Las Vegas, because we both gambled with their counting system that I develop. But, outside of that, I didn't give too much to that.

41:10-41:51

HW: Okay. So Dr. Fung read from books that, he found out the fact you can read really fast back in MIT right?

LR: No, not back in MIT broadly, but probably good. But when I was there, I took a speed reading course. And, I learned that you could read much faster as a result. And what they said was that could be increased dramatically, more potentially, but they didn't talk much about it. They just were getting people up to hundreds of words for a minute. I got to thousands of words per minute.

41:52-42:29

LR: Uh, and the reason was I kept on using the techniques that, looking at the page and being able to see that whole thing, and register whole sections at once in my mind, and see all the keywords, and then put together the meeting without having to go through it, word by word. And that concept let me get to two thousand words in a minute. And I was doing a lot of read. Then at that speed, I found that reading novels like that was no fun. But reading technical material was good.

HW: So do you read lots of books?

LR: Today I read them online always. I don't like handling the physical book very much, although I do read when I'm sitting at the dining room table, but outside of, when I'm away from my computer, I read on the computer, but I read a lot. Not a lot of books today because I'm too busy. But, of course, then I have to read a lot of technical things.

43:17-43:52

HW: So you spent lots of time in front of the computer. What was the life like in MIT?

LR: Well, MIT, it was normally just the standard classes until my junior and senior year. And in my junior year, it was fifty eight. I did a number of projects for one of the advisers who wanted big projects done with a group of three or four people, students.

43:53-44:40

LR: And so I did a number of those, including building the highest, magnetic field post, had been done yet. And build all the equipment in a steel drum, because it was…we charged the capacitors to ten thousand volts or something, and then discharged it through a single loop of copper who had, but and so it created a huge magnetic power. That was one of also did a spinning ball in free air. Well, because it was magnetically supported. I did a lot of things like that.

44:41-45:15

LR: But then in my senior year, the TX zero appeared on the market. And at MIT, Lincoln had built. It is that at MIT and what was had built, it was building the TX2. So the TX zero, which was prototype of the PDP, as I said that, because that was people from like… and so they built pretty much a copy of the TX zero and the TX2 as their PDP three and six.

45:16-46:07

LR: But in any case, I worked on the… I guess we got sidetracked there. I got lost. Say something again. But what you're asking?

HW: I mean, what? Because you spent lots of time in front of the computer. Right? So, basically work on computer?

LR: Oh, yeah, at MIT on the TX zero, I found that not many people knew about it, and so I can spend a lot of time on it. So that year I spent seven hundred hours online on the

computer, which was probably more than anybody. It's been online in any computer in history at that point.

46:08-46:46

LR: And I did this pattern recognition program which did handwriting, recognition extremely well based on a neural network, now today's fad, but at that time, MIT and Minsky and McCarthy believe that what was stupid that you should to all algorithms rather than learning. But net learning was something that, one person had proposed, and I decided to try it out and wrote a program to do that. And TX zero and it worked extremely well.

46:47-47:20

LR: And I published that alone. Virtually nobody pays attention to it. But anyway, I spent a lot of time on the computer. And then on the TX2, I spent a huge amount of time, because when I went to Lincoln, in sixty three, well, even earlier, I did my master's thesis thing. So after sixty nine, fifty nine, I went to Lincoln and I was working on the TX2 and programming it or doing my thesis work. And actually my master's thesis was in sixty. So I got that done and the software as well.

47:21-48:19

LR: By then, and I spent a huge amount of time on the computer because that was my job, to make it program.

HW: So beside you work on computer, what's your personal life like?

LR: Well, it was not very exciting back then, because I had married somebody I shouldn't have. And, we spent fifteen years together unfortunately and we had two children. But she was, she had a problem that I hadn't realized that... Well, so I don't want to get more into it, because she's still alive. But, in any case, I did I worked pretty hard at home as well.

48:20-48:40

LR: And I didn't have a lot of external activities until I finished it off and went to work at telling it where I was running the entire company, hundreds of people. And it was I had to interact with a lot of people and I did and outside work in software work.

49:00-49:31

HW: So we know that you've already shared lots of stories about how you we're recruited by Robert Taylor and your interaction with him.

LR: Actually it was hurts who recruited me, he just talked to her, failed to make it happen. Actually, I even tried to hire me twice. And then, as his deputy, who he then turned in director Taylor, try it again once or twice, and then gave up and talk to her as well.

49:31-50:10

LR: But the story really starts way back because a tiger Bob eventually told me that they group of PI is choose the next director. So that group were pulled to see who should be running the office after Ivan left. And they selected me. And so I was predesignated for a long time. Then I haven't tried to bring in and Bob did. And so Bob didn't choose me. It was the PI's have chosen me. He was following through on his job to try and get somebody because he's, well, he's a favor behavioral scientist and couldn't run the computing part very well.

50:11-51:09

HW: When did you first meet Bob Taylor？

LR: Probably when I went to urban, I didn't know much about him. And he was, we work together in the office for several years before he left. But he was, and I helped him out socially in his and his family. But I didn't spend a lot of time with him. It was my job. And as I took over all the computing work, he started working with the military and their deployments.

51:10-52:05

HW: Were you in the same office?

LR: Yeah, during that couple year period from sixty seven, when I started till he was sixty nine, he left.

HW: And, according to some of our reference, and you spend the Christmas with him in 1966，right?

LR: Yeah, I don't remember anything about Christmas and I doubt it. I spent Christmas well with my family. I moved down in around Christmas in sixty six to Washington. And, bought a house and move down there.

52:05-52:43

HW: So what was the life like when you first moved to Washington from Boston?

LR: I was working at the pentagon, I mean, and living in McLean, Virginia, near the CIA. But I mean, its normal. I mean, there was nothing changed about my personal life particular. I see. And Washington was very much like they want a metropolitan city. So it was no big difference in it.

HW: What was the working environment like?

52:47-53:26

LR: Well it depends on was the first place, for several years. And then eventually we moved to Arlington to in a commercial building. But initially it was the pentagon and the office actually had five sides, like the pentagon, it was a strange office, and what was the story

that people like to tell is that I measured the distance to every other place by whether to walk inwards to it. There were five circular corridors and I would go in one, I should get a shorter path in and out or whatever to wherever I was going.

53:27-54:14

LR: And I could do that and get somewhere particularly fast. Because they main executives are in the outer ring, but you wouldn't want to walk around. The outer ring is the biggest one. And, so I would do that. The pentagon otherwise was irrelevant. I mean, the director's office was nearby. And I could go there. And in my office, I talked a little with Steve Lukasik in the seismic office because he became a director later. But he was running the seismic program of and we he had the computer circuits.

LR: And the teletype for that was in our office. So, we managed some of the computer work.

HW: So you share the same office with Robert Taylor. Were there any stories between you two?

LR: Not really. I mean, as I say, I visit him from time to time and his family. Um, I visited, but he was gone lot of the time overseas to the government side after I took over.

LR: So, there wasn't a lot of interaction. I mean, we've all read the things he's written. I don't always agree with that because basically one of the things he said is that there were lots of different printouts from their computers, and he didn't like having to do it. But there was only one teletype. There was no other printouts. It was all done by teletype back then. I put one small computer in the office eventually and we use that some, but we had no network yet. So was that not until we had tips that we could dial into that that became useful on the network.

LR: We all could use our personal portables to light dial into the network. So, we have we have a small personal printer typewriter, that's how most of the work I've done on their computers then. So I mean, although he knew that he might have had to have all these sources of printout, there was only one and half.

HW: So, when you worked in IPTO, you are… you know, you recruited Paul Baron as the consultant, right ?

LR: No, I never did anything with Paul Barron. And in terms of, well, I mean, the Rand contact technically came to me. And I worked with Willis Ware primarily who was running the program. Paul Barron worked under that somewhere, and I never met him back then. I didn't even know about him until 1967. When I went to, I'd already proposed the networked to everybody and was and I've written a paper about it. I presented it DARPA conference. And at that conference, I met Donald Davis people from the UK, the national physical laboratory. And he mentioned Willis' work which turned out was mainly classified, was in the office safe.

LR: So, I went read some of it, but it was not very useful. It was it was he had no technical design. Really, he has a concept that you should be able to do this and do a voice network. And it was only voice that he talked about. So it wasn't any change to what I was doing, because it didn't give me any new ideas or pieces of information. I didn't even hear about it beforehand, although he had published back in sixty four, I haven't seen that.

HW: So he was not really involved in this program, right?

LR: Not at all. Never and not in anyway. He had written all this stuff earlier and gave up when the when the air force rejected it. And at that point of time, it was almost certain to be rejected by DCA, which is where it went effectively, because the communications agency. They rejected everything I said to me, also, it wasn't until many a decade later, maybe they accepted the network. Because just like AT&T that everybody rejected packet switching, if they were in communications doing wire line circuit switching, they just thought it was hopeless.

HW: So, have you met with Donald Davis before that in London?

LR: It is not in London. At MIT he evidently came for a visit in… The date is not absolute. I don't remember perfectly, although it's in the literature, he came for a visit and talk to Kleinrock and I and he says… I don't remember much and I just was talking about my network plans at that time. He… that was already I had the plan was doing an experiment in and, he was working on the concept the from some point in time. It may have been from that point in time or it could have been earlier.

59:54-1h01:24

LR: I just don't have any way to find out of, but he couldn't get anybody to fund it in the National Physical Laboratory the government you mean. So he built an in-house switch. And that was what he was doing, that finally became live well after the Arpanet. It was later. So actually, although he's written a lot and is one of the first people to work on the concept of packet switching besides me and Paul Barren. But it was later he actually did the work. And it wasn't it didn't succeed in affecting anything, because except for giving me the word packet.

HW: So, according to one book, Dr. Fang had had read that is in that book you met with Donald Davies in London in 1965. Was that right?

LR: I didn't do that. I didn't go to London in sixty five, he came to MIT I think. But no, I don't know…I had no reason to go to London at that point. I mean, until I went to APAR, I didn't travel that much.

1h01:24-1h12:30

HW: Can you talk about the debate on the dispute on the claim of, you know, the invention of the internet in 2001, right? After you were uh, I mean, four of you were awarded with the Draper Award by…

LR: Well, I mean, the question really is what's…In my mind, what's the significant invention here? And that in my mind is packet switching, the fact that you can save all the money from circuit switching to use share and network with packets. The first implementation goes with MPP/NCP, which was a protocol that the group under Steve Crocker of graduate students develop for me as a project. And they came up the protocol between computers, basically. NCP and the IMPS at that time didn't quite have the capacity to do what I had requested, where the messages were saved…um…well, it did do it. They saved in this computer, and subjected it to send it on. But the computers didn't have enough memory to do that extensively. So that… But that allowed you to operate without any TCP type operation, any end-to-end protocol, all you have to do is send the file and the network took care of it largely.

LR: Steve Crocker tells me that there is an overload case which could happen, which was one deficient event technically, but Cerf was part of that graduate student group. And after I hired Bob Kahn in the office, he hired Vint. And Vint, I mean, Vint primarily and Bob, but basically Vint, worked on TCP to try and do an end-to-end thing, so that they could have absolutely clear file transfer without any potential mistakes. Meanwhile, I started telling it, and I built X25, which was a new protocol. I designed that. And X25 did all the checking on the network and had enough memory to do this and do it smoothly and reserve space ahead of time so that there was no conflict. You always got absolutely correct transmission through the network. It didn't need TCP. It's still used for a lot of financial transactions because it's more reliable and secure than the current network. But it's slow, because I designed it back in the fifty kilobit days. And nobody ever upgraded it to T1 or T5. So X25 stated in as the primary activity between sixty five, no, seventy five. When I when I put it in service, 1975 until about 1995. And then the Arpanet grew changed to use TCP in 1983. So the argument that Vint and Bob use who took over the office and deserved credit for a lot of things. Um, and that's why they were included in the draper award, because, uh, in my mind, you had to have a standard and to have uh, the Arpanet, where the TCP/IP as a standard was particularly important worldwide. We have a standard, and bob really did that because bob basically got it to be approved by the government as the only thing that accept and that forced other vendors to do it. And now it's all free to everybody. So they didn't have to go build a new standard or do anything. Vint primarily did the TCP design, and they mandated that all of the NCP operation convert to DCP in 1983.

They also talked about… well, I was running the office in seventy three. They talked about using the word internet to talk about uh, a network connecting other networks. Now we were connecting the other networks. We had a network in the UK that connected. We had a network in in Hawaii that connected the packet radio on. We were building other ones, and in each university would see a small network of computers like in MIT, various computers that were all tied in together. And they talk to each other all the time over… basically over the network. But, the concept that they've been arguing, and Vint in particular because he said most of the press because of his work at MTI(此处应为口误) and Google, um, Vint, because of the press relations primarily, uh, that basically TCP was the primary invention, and the packet switching was irrelevant. Uh, wasn't important. Of course, they both are uh, and TCP help the Arpanet avoid any growth problems, which you probably wouldn't have had been redesigned, like telling to have the right um, buffer space

allocation. Because buffer allocations, um, we're quite straightforward to work out. I mean in ATM forum, we worked out lots of them and argued about which one was best. Um, but in any case, the TCP was a strange application on top of all of that, that just helped get move files and the end. And it worked extremely well. And it was good for uh, well, from eighty three to eighty five, and the network collapsed because of there wasn't any way to control the load, really. Uh, and as the load built up to be using the network fully, then uh, the network crashed.

So it basic basically, um, that was fixed by changing TCP rules. But and that was done by the IETF people primarily, other people not been, uh, to fix it, so that its allocation was done correctly so that you couldn't mess up things, and have it collapsed at the midst of a transmission. So that got fixed in eighty five. And it continued to operate very well, of course. Uh, now IPD6 is having to replace it slowly. It should have had variable length addressing. And so it didn't need to go to V6. But they…none of us thought and variable length at that time, because it was harder to do in hardware. Now it's trivial. And so it was it was a difficult process. Fixes length was easier. And they settled on an address space, which is much smaller than that, actually telling it in with the uh, ITU standard that I created. Um, that standard had a big address space. Um, it was already in ITU standard, uh, so basically, there was this argument going on in the background with the press, largely not with… not between us about what was more important, TCP or packet switching. And Bob and Vint put down packet switching and pushed TCP and claimed that was the internet of the network of networks. But basically the all network was a network of networks as well. Everything was a network of networks. That's not a big problem. That's no problem. In fact, as soon as you receive one thing, you can convert it to the other protocol. And they did that in London. And they did that in Hawaii. They did that any place they needed to. Those are the two places that I can't remember that actually did the convergence to another protocol on another network.

Um, but that was something which has sort of small in law over time, because that's what they argue to get their press. And I don't have much more to say about it, except that I don't try to argue the case in public. It's not worth it. I mean, the packet switching is clearly the technical change. And the protocol was one of three in succession and was or four, it had a useful period. Today it's too slow in the network, today TCP is a real problem. I don't think it's a protocol, so much as the fact that the way it operates on the network pretending the network is dumb, it doesn't let it work very well, because the network throws away back. That's because it doesn't have any memory allocation. It doesn't have any way to manage the traffic speed. So you manage it from your computer. And that's a disaster and it locked us into distance dependent, delays that are impossible to overcome with TCP, so you can't send it higher than about twenty to hundred megabits. And today's networks are running at a hundred gigabytes and you can send a file higher faster than a hundred megabits.

1h12:30-1h15:07

HW: So how about the dispute over the packet switching? I mean, um…

LR: There's never much of it really, a dispute between who?

HW: Between Kleinrock and Davies.

LR: Kleinrock did the theory before anybody else, it is absolutely clear in their literature. I mean he published thesis before anything Paul Barron did, and anything that Donald Davies tried to think about, even the publish and did his book before anything that was done by Davies or anybody else. The argument, after Davies's death, Davies was too good a person to argue it. But after his death, his son published the story that packets weren't invented by Kleinrock, they were invented by Davies. Well the word is English postal services word. So that's where the word came from. And I picked up the word at the conference from them. The word isn't important, we were thinking of message pieces alone. And Kleinrock's book lays that out clearly. I mean that's the whole queuing theory is based on small pieces rather than huge messages. The auto tape and old paper tape forwarding systems used to hold messages, that delays any other message behind it hugely, that's a very bad protocol. So we never even talked about that. It was always in small pieces. When I did the first experiment. Well before Davies got involved, uh, in sixty five, that experiment was using small pieces. And I designed the piece to be optimal for the for the error rate on the telephone lines. And there were huge first noises because of relays in the background. So that you lose a bunch of data all at once, not just a single bit here.

Today we might lose better on lines, but then we lost bursts of traffic. So I had to repeat the whole packet if it was lost, and the packet would be the corrupted, you know, the subject would be hurt. So I can't get I could replace it was not be proud. And so it's I designed the subject to go around the error rate of the telephone lines, uh, in the packet length, which is about a thousand bit.

1h15:07-1h16:05

HW: So when was that when you choose packet…

LR: About sixty seven. That was at the conference in Cambridge. Um, and when I met with Paul's associate, she mentioned that they were using the word packet. And I thought that was a good idea because it was a different word message part or you know, some complicated phrase. It was not a good way to talk about it, so a packet was a much better handle for the for the concept. Um, but that paper was looking for the word packet in Kleinrock's early work, which of course they couldn't find because he didn't use it back then, he uses message pieces.

It was a mistake to publish, total mistake. I mean, it shouldn't have been published because it was wrong.

1h16:05- 1h21:55

HW: When did you coin the phrase Aparnet? (什么时候起这个名字)

LR: Right away. I was in APAR and we were building a network. So the Aparnet. I think even before I started doing anything, I started the name.

HW: That easy. I see. Who coined the word Apartnet?

LR: I named it. No one else use it as well.

HW: When was that?

LR: Back in sixtieth. Six seven? I guess. When I started. I mean, I needed a name. It was a trivial.

HW: So in 1965, uh, you issued by, oh, sorry, 1968. So, uh, there was a I-M-P,imp, bidding document, right? (LR: Bidding document? What's bidding mean?) I mean, uh, you have to uh, choose the right, I mean, there were many institute. Uh, we're trying to get the project right. It was a bidding. Was it a bidding?

LR: Oh, I see what you mean. Bid, the, in 1967, I planned the network and Sara help me, right? A RFP which was to request bit companies to do the imp, to build the imp, including choosing the manufacturer of the many. Yes. But they had to choose a mini computer and they had to design the software and build it rapidly. And, the winner of that bid was BB&N and they did it in nine months, which is amazingly fast schedule.

HW: What was the process and how did you evaluate?

LR: Well, a lot of the bits were not comply, I mean we had a bunch of criteria as to what was going happen, but the big one, at the end is how well as this group might be able to do it. And how fast are they and will they do it well and how fast and at what cost? And my final two bidders were Racion and BB&N. Racion had a hierarchy that had a bunch of people at the second level and more at the third level. It was much too steep a hierarchy for media like, as far as a structure to do this task, because you know it was like doing a big project with lots of different groups and they wouldn't be talking together enough. It had to be. So BB&N proposed one person, frank Heart, in charge of all the other people and I like that structure a lot better. People argue that I knew frank but that wasn't the important issue at all. I barely met him at Lincoln, uh, because he was doing speech on my computer. But um, it was basically that the project was a bid far better than the others. And that was partly due to Bob Kahn, uh, who did a lot of the work for frank on that. Um, it was all the other people. I mean there are a bunch of great people there, all I'm saying whatever.

HW: Who made the call?

LR: I did… choosing BB&N? I have to, I mean, I was a head of APAR.

HW: So did you, I mean…

LR: One, I wanted to make sure they agree with my plan and two, I want to make sure we done effectively and fast. Uh, those are the criteria.

HW: So did you know frank hard before that?

LR: As I said, I had met him at Lincoln briefly because he ran the speech project, but he wasn't on my floor, he wasn't near me. I didn't spend any time with them at all. I knew about him and I had met him much, but that had nothing to do with the decision. The

decision was based on the structure. And frank was a good manager that way. He was actually a bad manager in some respects because he was a father fixture, and had father fixture to everybody, and had had to work on and review every minor decision in allocate very well. But it worked. The group was broad and it was attractive, and it did it fast. And he was great at that kind of project. It turned out I didn't know how we'd be, but I had met him that really had nothing to do with it.

1h21:55-1h25:21

HW: So in 1967, there was… the deputy director of APAR was Steve Lucas, right?

LR: I can't give you the exact date. He became deputy or director. So you can look it up. I can't.

HW: Okay. So what was his influence on the project?

LR: The project was already planned and approved. But since he was the computer knowledgeable person coming from a seismic group, he, uh, as deputy probably was involved with the decisions. I usually met with the director, um, and that he became director and was very involved because he found it tremendously valuable to him in his office.

So as soon as we started, soon as I wrote the first email program, so that we could send messages across the network, and save them and retrieve them and file them. Steve asked me to make sure that was done. Actually, he actually said, I want to use this, but I can't use the stupid teletype version, which was all that BB&N had turned out. So I basically wrote the program, which was like outlook today or something. And in fact, nothing is changed, does the same thing. And he then demanded that everybody in APAR use it. And of course he had to improve and present to congress, some of those as he was director. And so his memos say that he used the nuclear issue at one time with congress. But even he didn't believe that was the reason he was doing it or I was doing it, I have no intention of worrying about nuclear, it had to be redundant just because it was a network, didn't want it to fail. And we had the capability to make it redundant. So we did, I mean, I always had two connected or three connected, but not ten connected like he might if you are worried about a nuclear blast, wiping out a section of the country or something or several cities. I had no intention of a major disaster being involved. It was just computer field here, so largely or line failures more likely. So in any case, he was the only one who's ever mentioned that he used that concept. And of course it was one to use with congress, not because it was a military issue. But we all have our issues anyway, and I don't think anything would have failed to pass congress otherwise. I mean, this was a major, major change to the world.

1h25:21-1h27:55

HW: Since you mentioned you wrote the first email application. Could you talk about more on that?

LR: Well, the one of the tasks that BB&N had was to allow people to send files and messages to other computers. And basically attention of some person. And so, what's his name? BB&N choose the outside between the person's name and computer as a way of

designating this message. But that was essentially intelligent message. It was just printed on their computer, and then they would look through big long list of messages, was fine for early data center activity to coordinate people at website at the data center. But it wouldn't work for everybody. I mean, it was not a user friendly thing at all. And it was teletype out. So I wrote this email handler. As soon as I started to try and use it, I saw the problem. And I use TECO, which is available software to writer, a message handler that would look at the incoming message, file it, store the address in the title of the thing. So you don't have to look at the titles. And if you wanted to read it, fine, and if you wanted to save, it was saved automatically. If you want to send a copy to somebody, all those things that you do today forward and so on. And that allowed it to be user friendly. And we could send group messages and do other things that were important. That was then copied by everybody cause TECO. Everybody had, and then other people rewrote versions in their own style and groom from there. It changed email from being between the data center operators in the first few weeks, actually didn't last long because I changed this almost instantly, to where it became the biggest traffic on the network, and in the world for a long time.

1h27:55-1h33:48

HW: I mean in previous interviews, you mentioned that you, you know, created your TV set in home and also the facts machine in MIT right?

LR: Well, I did the TV set as you know, and that was from a kit that I put together all the parts. At MIT when I started my thesis, my master's thesis, where I need to use photographs as an input, I needed to input photographs. Nobody had put photographs in ever. This this was a new thing to get photos into the computer. Let see, TX2 was way ahead of its time in terms of being able to work online and do these things. That's programming didn't lead to much in that respect. So to do that, I sorted through MIT and found in one of the attics, an old fax machine, that would scan, a roll scanner. So you can put a photo on a roller and scanned. It was intended to send effect. I then converted it to a computer input device and used it to read photos in the computer. And that's why Minsky later on one of the copies of photos because I had lots of them, so that was the experiment.

HW: I mean, it seems that you are very fond of, you know, creative things from scratch or building out things like the machines. And was that the trait which you know help you to build the Arpanet from scratch.

LR: Yeah, I mean, I was a total, I had done, as I said, the whole operating system and everything under computer. So I knew a computer from head to ground. Like most people didn't, I mean users maybe knew when IBM take that I mean, punch card group. In IBM, somebody probably knew how to build a computer, but I don't know there was one person or a hundred, but very few people knew all stuff from scratch, because you know, even the early OS is that, I mean I had were a team group. I know everything, I know what a computer could do and what I could do with it. So it wasn't a problem to me to understand how we could do the amplification, or do they change to the computer to do it or whatever, and do packet switching. It wasn't a big problem. And with background in the theory, I knew I could make it work. I'd already done their experiments, so I knew what would work.

So I was the only person in the country at that time who knew how to do it and make it happen. And that's one of the reasons the PI selected me.

LR: It was…There was another activity on the TX2 that I might mentioned that was Armour Bows wanted to develop his speakers, his speakers are unique and Bows' speakers, that his company now built back then are unique. And they do a frequency filter of the data to convert it from your home to a concert hall. Well, how was he going to make it sound like take away his home, which has all sorts of reflections. I mean wall to wall, there's all sorts of reflections. And so there's certain frequencies that are accentuated and de-accentuated at home. He wanted to find out what that was. So he, a concert hall you could figure out almost by theory. But home was difficult. So he asked if I could put, me and Thomas Stark could... For transform was Thomas did. I wasn't good at forward transforms when he did it on the computer. I did the programming of a physical interface to an ATT converter, to connect to a phone line, to our both house. And he had a spark in his living room and microphone at the other edge. And he recorded, he did set off a spark, and the information from the microphone would go over the telephone line to the TX2. We would process it into the TX2. And, do the forehead transform and then accumulate thousands of our air transforms for each part. So we can accumulate a valid noise free pattern of the acoustics they were living room. That's however you what he used to build the speakers. So he could remove that, the accentuate those frequencies and accentuate concert hall frequencies. It was a major step in quality as a result. And that familiarized me with telephone lines and working with them into a computer.

1h33:48-1h41:28

HW: So in October of 1972, I mean the demonstration of Aparnet on ICCC conference was a huge success. How long did you prepare for that? I mean, there were thirty eight those, right?

LR: Well, you probably are right. I don't remember the number. Well, we asked them all to prepare activity, but it really, I hired Bob Kahn, and he did most of the work on their conference. The coordination work was a lot to do. And I didn't have time for all of that. But basically it was working with all the sites to make sure they had a program, that they could demonstrate that would use the network and demonstrate remote access and maybe to computers. And it was and put it on the floor at the conference center. And then we had to put in the telephone lines to the conference center, which I did, arranged. And he then got everybody organized to do it. So it was a joint effort, but he did most of the work.

HW: In 1973, you left IPTO right? (LR: Yes.) For Telenet, right? So what was the occasion and what was the reason?

LR: Well, first of all, after I have that the network up and operating and looking at general APAR issues as far as what APAR was intended to do. It was to bring technology to that state, then somebody in the military could do something with it. Actually military haven't done much with it that we had a number of military sites on the network, uh, like the air force base would take her others so that they could do they could start working with sending tapes from sec to say and do other things that they did. Um, they did it securely, but it was

uh, they encrypted, but basically it was operated over the network. But there wasn't tremendous amount of that activity. But I brought it to the point where Steve and I both uh, located can I must believe it was reasonable to transition into industry or get out of APAR, to be running the network day today, because the feedback then in those days was, well, it was proven because I paid for it, but it's not a commercial success. It wouldn't be. And so AT&T and everybody else totally rejected it. I actually then decided, okay, I can turn it over to industry and asked AT&T and they developed a huge committee to look at it. And they said, no, they wouldn't take it over, even free. They went and they could sell it and sell it to us or other people. But no, they wouldn't do it, because it was totally incompatible with this way of thinking. And it was for many years, they rejected it until they finally bought it.

So then I went to University of Strasbourg and FCC and I said I got this problem. AT&T rejected it. There aren't many carriers out there. They could do it. And I want to get it to be commercial. And he said, well, start your own, because we started MCI and we have this open policy, so start your own network, we'll make it a carrier. Because you had to be a carrier, that it wasn't this open concept that other people managed to do later under modified FCC rules. So, I took that as a potential and start approaching it from that perspective. BB&N who I worked with all the time on the project, wanted to get involved in that and do it. And so they started working on as a concept with Phil Walker and Steward Medicine, the lawyer and marketing person. And they want to start a company with me as CEO and do this and get it approved by the FCC, and BB&N would put up some money. We had very venture company. So that got underway with BB&N and funding it. But I couldn't leave APAR, I was too busy trying to get a replacement to do that. Secondly, I thought the term is up, it should be like six years. That is that was the turnover of the people who really did the entire intellectual work. There were support people, but the leaders are basically came and went, because six years is about as long as they should stay away from their own jobs and do APAR. In general, that was what I got from Lincoln and other people in their history.

Because I noticed if they move from place to place every six years, they progressed in job. And if they didn't move, they didn't. So I saw that as a sort of historical issue as well. So I wanted to leave and do this. And I search for person and Lic finally agreed. Then we have just finished the FCC document to propose this for a carrier. And so I left in time to send that to the FCC and it got approved, by the way. And we started telling it, and got venture funding. I worked with several venture firms and we've owned BBN's money. They got the firm going on. It was great success. I but I took it public. And then, still have problems with big customers. Like, General Motors wouldn't buy, even though they had tested it, they wouldn't buy it for all their officers. Because what if we went away, they would have no communication with their officers anymore. And that was too big a threat. So they need a bigger company behind it. So GT eventually offered to buy it. And they nice, that will make things work better, because then we can get the big customers. And they did, they bought it, let your people made money. And I made money. And we got it to be larger. Eventually, GTE combined it with the voice project that had bought and turned it into sprint.

1h41:28-1h45:16

HW: What was the income level in APAR back then? I mean, was it low according to some of the references? We think that was.

LR: The income of, the budget that I had to work with was like fifteen million when I went there. And that was based on Lic and on the number of places that he had started with these high quality centers, like MIT so on. And then, that didn't allow any big projects that are allowed him to have time during started at the various universities. However, when I went, I haven't concept consoled me to learn the budget real well. So I met with the director, I would know every project on what it was. And I did. And that worked very well with the director, because I could get things approved. But I also saw that big projects got big money, and officers change the amount of money they had all the time from time to time, depending on what they needed. We need to just a fifty million. In fact, it's a lot of these projects were funded three years in the future. So what I realized was that I didn't need to fund them three years in the future. We had money every year. So that wasn't an issue. So I didn't fund MIT and some of the other places for year to me. I kept the project going, but it had was funded. And so I went and started new projects like the network, speech understanding, the OL for parallel processing activity, and other things like that, big projects that congress could see that. They could understand and fund, and I then asked for large money for that.

And that got, those got approved, because they could be approved by congress. And the result was, when I left, the budget was fifty million in the office. And I had a lot more activity and people working for the office and that shrunk and grew over time. But it was that's what it was. When I requested the Aparnet funding, I had projected it at fifteen million as that's the program plan you have to turn in to get anything approved. So that was the first funding of the Aparnet project was my program plan and it was fifty million. Bob Taylor says he got a million improved, but it hurts for a long time back. But that that's a verbal contact. It doesn't work on paper in the long run. I mean office fellow would have approved it probably, but it had to be a program plan. And I wrote that for fifteen and that was my estimate the time. Actually, when I later on wrote a paper about the effect on my computing budget, it was that I had saved much more than the network cost by reducing the number of computers we had to buy for all the projects. It was a huge, three to one in the cost of the office on computers and communication. So I saved a lot of money we have building the network because then they could use somebody else's computer. And we had a lot of that going on.

1h45:16-1h50:22

HW: What was the income change from MIT to… (LR: personally?) personally, personal income.

LR: Um, I don't know that, it was a lot. Um, I was actually well paid in in the government. It's probably the system. So I'm not quite sure at all. But uh, I wasn't really thinking about that at the time it worked. So I was fine. But I was one of the highest paid and on the civil service roster. In other words, PL3-13 could be paid a lot more than standard to G16 or whatever. And so my income was good. It was higher than the average employee in the government by a reasonable amount. But it was, it was not, but that was normal. But it wasn't unreasonable. It wasn't unusual. But it was, but it kept growing from there. So I

don't remember the numbers too well anymore. That wasn't the issue. Anyway. That wasn't the big issue. I just had to afford Washington.

HW: So back in MIT, you're in class 6b right? Because there were many talents there. I guess.

LR: Well, no, I mean, MIT decided the year I was there that they would start a new course, 6B. Six was electrical engineering, 6A was working with industry. 6B was to be this preferential course where they had all the instructors, be the heads of their departments. And so we have the key person in every case, as a class of thirty, they selected from the freshman class. I had all As, and I guess probably everybody did in the group, but that was the top thirty people at MIT at that time.

HW: Were there any significant names?

LR: I don't remember anybody in that class… I was then credited with class of fifty nine. When I concluded it, it was directive, not masters, actually. So I actually didn't graduate till sixty with both degrees, but it was always credited as fifty nine for the MIT roster. There were huge number of people.

HW: Okay, were there any memorable courses or professors you liked?

LR: Well, the professors were all memorable. Not sure I can remember them all now, but Bob Piano was one of them. And one of my advisors on my thesis, one of my advisors and my thesis with Claude Shannon, and what the other one was professor Dr. Elias.The people who ran the classes were the key person in each field. But Hoffman was brought in to Huffman code. I'd have to research my memory to remember all them all. But they were all great professors. And they all got to know me, which made my graduate at work. Well, when I actually, after the freshman year, I didn't know I didn't have to work quite that hard. So I didn't do homework anymore. MIT doesn't require homework, which is nice. They just base it on the test. And so I didn't have to do that anymore. I didn't need to. And then they could advise me when I started my graduate work on the regular committee that I should, I have to pay more attention to some of the courses and work. They made me do a lot of read work in the field theory area which field theory was never my interest, of many magnetic and electric fields in space, because you had to do all transforms like, it wasn't this interesting to me as computers which were directly digital.

1h50:22-1h53:49

HW: Nowadays, what's your daily routine? And what's your hobby?

LR: Hobbies, missing. Because it's too much work. In my company, I'm the CEO, the CFO and the CTO. Oh, and all of them take significant time. Unfortunately, the investment is not that great yet, but we can't afford enough people. So there is mainly, five of us altogether. And most of the work is done by one programmer and myself. And so I do all of the theory of what we're doing and how to take the next step, and every single facet of what's happening, which is complex. So it takes a kind of intellectual work I've done all my life and like and then I'm gonna technically, I run companies most of my life, I've been

CEO of five companies. This is a sixth. In one case, a transition to the CTO, but that got ruined by the CEOs who came in. So that didn't work out very well. But in any case, the work is basically, I get up at six and start working seven. Work until 7pm then relax and go to bed. And I don't have much time for meals or anything else. Basically a twelve-hour day of sitting at the computer. A lot of it is email for the CEO, a lot of it is administrative work for the CFO and filing, filing and doing the budget in doing the accounts and doing everything else, filing taxes and doing everything else is needed. And then the technical work is the majority of the time probably. But has to take second place sometimes to the rest.

HW: I thought on the shelf, you got lots of games. Are you a big fan of games?

LR: That's Max's stuff. Max's and Teddy's son. He has all these games, and that's his attachment.

HW: I thought that was your stuff.

LR: No, I don't do that. Never have. When I was at APAR, we had online games like text games on the computer. But back then it was in the sixties, but seventy's. But I did some of those, but nothing since this.

1h53:49-2h00:25

HW: So Dr. Fang want to write an autobiography of you. And do you have any suggestions based on…based on all this…

LR: An autobiography means that I did it.

HW: Oh, no, no. I mean not autobiography, just a biography of you, sorry.

LR: I'd like to be able to review it. And I would like to, if it does get done, have it get published in the states, please have been published in the United States reasonably soon if it gets done. I mean, I heard that it would be in China first for a long time. Yeah. And I'd rather have somehow big translated available, or I wouldn't be able to read it even.

HW: Do you have any suggestions for this book?

LR: You're getting all the information. I can't do any more. I mean, I don't know what you mean. Do you want some sort of agreement or what?

HW: So Dr. Fang said that the materials are quite limited. All the information are quite limited on the Internet. So would you know…

LR: I mean, you've collected a lot more. I don't have a lot more, I can't I can't generate tons more. I mean, this is all of stuff. And I don't know where there's enough there for a book, but it's up to you to collect enough material.

HW: If you are to divide your life in different phases, how many phases would you divide into and what are they?

LR: Within each company was a phase. But the first was school, and then basically Lincoln labs and the softwares and a lot of projects. And then APAR which was a significant phase. And then Telenet was a great activity changing the world as a result. That was became a worldwide network very quickly because we were carrier, we could become an international carrier, we could operate with UK, we can provide them with equipment which we sold the UK and gather equipment, so we can get the network spread around the world relatively quickly. And we did. And that was a lot faster than the Aparnet spread. It wasn't until… the spread is through the universities, because the government was funding it. But and when a chef took it over, but it didn't move to commercial until 1990, and by then Telenet was in twenty years in the history. So I mean that was that phase Telenet. And then I started doing other companies, worked is the CEO of DHL for a year. And that moved me to the west coast. Then I, as a result of the agreement with them, I started the express, which was, I switched to after the first year. Running packages was not my strongest interest. And so I started the electronics part. And that express was another activity. Every company since then.

HW: If you have time, shall we talk about, you know, your forty five years of entrepreneurship. Yeah, later, I mean in the future, is that ok?

LR: Before or after now? No, I don't know what forty five years was walking about.

HW: I mean from nineteen sixty three, you know, after the academic work and you move to the business.

LR: Yeah. Well, I started Telenet, and until eighty two, when I moved out here to California to run DHL. So Telenet was a great experience. Um, we opened our office in Washington, DC. Um, I got space there in downtown and near the AT&T fifty kilobits data center, digital data center that have been created. So we could get a high speed trucks digital service and started the company, hired other people. And I knew a lot more people back then and from the APAR experience. And so I built a great team and we built a network originally using the software which under government law was available from the APAR project.

02h00:00 – 2h01:59

LB: And we use that software to start the company and build our own hardware to take over the Telenet TV and it was sold worldwide. It was very successful. A much smaller device, but very fast. And well, it was fifty kilobits back then. But it was fast for multiple fifty kilobits speed.

LB: And the company did all the software and I did all the accounting software. I got tired of telling the software staff who were doing the system to do the accounting because we have bill for this. And they kept putting it off because that wasn't their interest. So finally, I took one labor day weekend and wrote all the accounting software to collect the records from the data from the packets coming in and create billing. It turns out that that was done

on a PDP10. And when the company was sold, it worked great and it was very fast and did the bills fine.

LB: But of course DDE thought, well, we can't run things on one of those who have to have an IBM machine. And we have to do our accounting on an IBM machine. So they hired Arthur Andersen and other people to redo this commercial machine, and found that they could duplicate it in reasonable time at all. It was much too efficient for what they can accomplish on our big machine because I knew how to do it pretty efficiently on the small machine. Well, I'll be that hands who were fast then. So that's just one story, but there's all sorts of stories for telling them.

2h02:00 - 2h06:50

LB: But you know, those I tell her were probably the most significant activity in some respects, because that was very successful. There are lots of other companies and each one has a story.

HW: Yes, that's why we want to schedule another interview with you.

LB: Well, it may take more than one. I don't know.

HW: So would you please comment on the fifty years of development of internet?

LB: Well, we started out with a network. What would you like?

HW: But I want to ask a question.

LB: But let me finish. We started out by building a network. What I expected would be an intelligent network that was watching weather and traffic, was maintaining buffer space and was correcting the traffic, checking it link by link, and making sure it was correct in delivering it.

That's what I did tell you. Eventually they operated that during the NCP period. However, then when TCP, the concept was the network, could be done, we could use fibers which didn't have a bigger rate so that they shouldn't have a problem compared to the least lines that we had before. So although it didn't start with fiber obviously back then in 1883, they didn't have much fiber at all T1, T3.

Eventually we had higher speed trucks. And that went on and made the network done. And that's one of my concerns with it today. Another concern was that we should have had a variable address space so that we didn't have to do IPV6. There's other concerns like that about the way the network is gone, but it's got mostly very effectively and very successfully. Security is the third problem. It's a massive problem which we're not going to solve with the network the way it is today.

One of the problems is we don't check who was sending. You can fake any address you want, so you can pretend you're me and send messages to somebody or something else to somebody. It gets lost in the shuffle. It doesn't know where it came from. That shouldn't

be. That's a huge security risk so that they can send all of the hacking from wherever they are, not get stopped. I have no responsibility. There's other issues too, but it's all due to the fact the network hasn't been done to help; in the process that end computers could not do it all to refine so many holes. In the end, computers are going to be the new ones, and you hack every day, and they won't be able to fix them fast enough.

I think it is possible to build a computer that is effectively secure if we did enough work on it. People might not be willing to pay for it, but it's not clear that that would stop it because the network is not secure.

2h06:50 – 2h08:23

HW: So can you give a prospect of the development of internet for the next fifty years?

LB: Well, I think we have to move to where it's intelligent and does a lot more for security. There's a lot more for speed of throughput, a lot more for managing the traffic. So it can run at a hundred percent load, not fifty percent. It's a running network. The way we deal with TCP is very inefficient and has a lot of problems, but it's going to take a lot of work to fix it.

But at last, over time as well as the security that's got to because we can't live with a security hole. These speeds when we started in 1990 on the internet, if I want to send a word file of any size that I could create, or I even thought about, I could send it by email because the files weren't that big. Today my daily traffic with the office is in files that are in gigabyte, not megabyte. And so that traffic just wouldn't exist on the network back then. I mean, with TCP we have to do different things to move it. We can't move with TCP at reasonable period of time. Actually, we will drive to move most of it.

2h08:24 - 2h13:33

HW: You mean we need a whole new protocol.

LB: You know what we need to do is to have the network being more intelligent and not to restrict the speed. Because basically, if you're going to do TCP, you got to get an approval for every packet from the other side of the world or the network. That takes a lot of time and therefore makes it slow.

HW: Dr. Fang would like to interview several people from BB&N. Do you have anyone in mind that you can recommend?

LB: Well, one person is about kind who worked there as they were doing it. And there's a whole bunch of other people who I have to send you email addresses for. They'll cross there, but I can't give you all the different moment except maybe if they send emails.

HW: So actually next week we are going to interview Bob Kahn, but we haven't fixed the date, probably around eleven or whatever.

LB: He can tell you about Libya and its operation while they did the original because he was there, then he came to the airport office and help move it into commercial man, I mean to world wide standard status.

HW: I'd like to know why you did those things?

LB: Well, in each case, I wanted to do something new that hasn't been done and do it first and good. In the United States, in my period that involved starting companies outside of what I did in Europe. I could start projects, but largely I had to find a group who was interested in that. I would find them and work with them and maybe give them direction.

Of course I had to adjust the course of their project in where like politically change, like what was happening with the Iraq for cause putting it at the University of Illinois. I would have had a student riot. So we moved it to that same things. Those are the kind of decisions I could make. But anyway, my drive is to do things first and make them happen in the world, not just look not in the left. That's why I didn't stay at looking. And definitely, I mean, what is it or go back to that kind of thing. I didn't want to disagree on the left because what I saw with my graphics, which were it was way ahead of time, twenty years before you could use it, anybody could use it and sell it.

And it was sort of useless back then, I mean, it's quoted. It's referenced all the time, but that' the only. And it helps other people perhaps with that facet of the issue. I mean, it's the original form how you do three dimensional perspective, geometry, because it's a four dimensional matrix transform. Then I created; I have to do the job. No, it drives as a drivers to it and it would make things happen first.

2h13:43 - 2h17:51

HW: The artificial intelligence. (LB: It's moving along tremendously fast.) I mean that you think it's a long way to go? Because twenty years ago, we have already had artificial intelligence. But for the twenty years later, we just...

LB: What would it require? It turns out, fast computing.

HW: Fast computing, you mean now it is unable to do it?

LB: Yes, I mean it's even with the hardware able, it needs fast computing. And the hardware enable made it faster because clearly there's money available to do that. But the problem with it is that that makes the neural network concept work, makes it work like a brain more than with algorithms. And the problem with that it's kind of limitations. Unless you build in a lot more, then we have a huge brain like we do, and we don't yet on computers. And the computers aren't big enough. So it's going to be limited to the things that can do. It's gonna to be very valuable in the short term for recognition of objects.

LB: Visual recognition and voice and other things and contextual response. Like my hope is that Microsoft will put all of the details of what goes on all the features of Windows or anything like that into a database that the AI program knows about. And I can ask a question about any part of it, whether it's by text or voice. I don't care. The thing is that I can say,

where is the feture to do this. I can't do this today. There is no way. Microsoft does not have enough people to answer the phone.

LB: And while they charge you a lot, if you want to. And the same is true of any these software out there, they can't give you the manual effectively, because manuals are really tough and don't work very well. And it takes me too much time to go through the manual, I even try. So we've got to solve that problem of learning about the object we created, being able to have the AI understood. That's straightforward and we can do that. When I call a company and I don't get an operator, I get a recording device. It should have an AI background that lets me find out everything I need to know or do things I need to know.

All of that feasible today, like driving cars, it is almost feasible. But we've got problems there of whether it's good enough. I mean, we have car crash because they didn't do something, right? That's gonna to be a problem, but it'll get done well enough, I suspect. But it's the thinking that isn't close. I mean we know no intelligent to the IQ is very low by so far, I mean, it's basically pattern recognition and against the database that works.

2h17:52 – 2h19:39

HW: So you know the blocking securities of the currency, something you have things like that.

LB: I expect it will get used, but I don't know where. If people want to keep track of a whole bunch of items and make sure that it's secure, that can't turn the way. They know the past. That's a good technology, but it's very expensive at the moment. I mean the cost to operate it is huge with their fast computers, even the current things will become more reasonable. But still electricity costs too much today.

I suspect that permission in block chains, like a bank might use, are more reasonable. They don't need thousands of sites. They just need five sites and they don't need quite the same permission security. They just need to make sure that is what encryption that they all know works or something like that. And then they can do it as a block chain so they can keep copies and save the record. But they don't take the permission in time as it takes today, and acceptance. That has to change, and change are gonna to be useful. People are doing that.

I don't know where will it be used first in in real practice. Currency's is currently not my interest because I don't want to invest in things that are likely to be a fan.

2h19:40 – 2h23:43

HW: What do you look for in employee?

LB: They know all of the program languages and content that I need them to know and understand. That might be that. They know all about TCP. It means they know all about programming or both, you know things like that, but they have the skills that I need.

They've been shown to be very good at that. And that's basically the issue. I don't really worry about their number of graduate degrees, although that may show on there that they're

brighter. But it's not always true. So mainly I look at is what their capability, is to do what I need done. And then if I can look into their past history of their personality and how that interacts with everybody else, that's great. But usually you can't find out a lot.

HW: Excuse me. One last question. So when you work in a IPTO do you recall any other projects that you supported or managed?

LB: Yes.

HW: Can you give a few examples...

LB: They all on computing. The law project that way, doing packet radio, the Alien4 project to grow a computer, speech understanding I did in Carnegie and Stanford and a whole bunch of universities.

It is a jet program to learn how to take voice and worry about the semantics as well as the syntax, so that we're trying to not only recognize the volumes, but we are trying to recognize it against the context like airline reservations or something, or baseball or some context. And that's why I say context-based AI is good. I mean it has a base that you can look at, then it can do very well. But a speech understanding proved that the program was very successful. There's lots of programs that I did, but those are the bigger ones. That other the network was part of slower, but when I did AI at Stanford, and AI Carnegie and I at MIT, I did a lot of graphics work at Utah where they did picture recognition and other competitive picture and compression. Thomas Stark, who worked with me back at Lincoln labs and then left and went there.

It was an expert in voice reconstruction from old recording. So they could take out all of the noise and the problems with the old recorders, spectrum limitations and so on to make it sound much more reasonable Crusoe things like that. But there's all sorts of projects.

2h23:44 – 2h27:05

HW: We want to reschedule another one. I should talk about those because you know you have so many project.

LB: Well, I don't think I can talk about most of the harmonic project. I can just mention them. I don't think I can give you more on each of them. I may be able to remember more, but it's not going to be a long activity. We discovered a lot of the best, but I can’t... because it wasn't my activity.

HW: The upper part has been supporting research in different colleges or universities, right? I think I still doing that. So what's the difference between back then and now?

LB: Originally it was mostly universities because that was what his interest was. And it was mainly academic and didn't change much for that because he wasn't there that long. He did start other projects like the Alien4 project, but there was that sidetracked. What was the question?

HW: I mean, what's the difference?

LB: Well, it moved to where we were finding corporations for things because they had a good proposal. Today that's very common to allow them to patent it and have their commercial success with it. Because there was once that commercial success, so it becomes available. Today, they would like to have something to go to production so they can use it. It used to be that they just passed the information over to the military and think they could implement it, but they can't in general. These are the army, air force and maybe groups and they got admission to do. They're not going to build things and they don't have the capabilities to do much, like turning it into a private product. They do have some research centers like rand on Lincoln and things like that, but that is not producing protects from them. Like today, opera has the grand challenge with the robot, but they're getting corporations to do that and build them and make it viable and saleable to them, so they can buy a robot and things like that.

2h27:06 – 2h30:00

HW: How do you describe your relationship with the other three founding fathers of the internet?

LB: Well, I was closely with Kleinrock, because we've always worked together. We acknowledge each other. And I work with Vayne and Bob whenever we get together and whenever we have reason to communicate. It's not all that common. Today, people are doing more research on the history. We all participate in that. But that's really the main changes of more recent times.

HW: How would you describe your contribution?

LB: We've already talked about that. I mean, as I say, they developed TCP and I developed packet switching and clean record basically, because they did the theory.

HW: Were there any disputations or debates among all of you?

LB: No, they may tell a crash rather than between us. We don't ever argue between us. I mean, we're very friendly. The only argument comes out when they're talking about their work, they don't mention at the dinner, you know.

HW: Thank you for your time.