

Lawrence G. Roberts
Oral History
Interviewer: Leonard Kleinrock
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You talk to fill out. History. I started getting interested when I talk to look lighter. Homestead at a conference. And so I then propose to. Ivan who was then running the office. And Ivan and I would work together with you in Lincoln. So we knew each other well. And I haven't. Funded. The experiment. So I contracted with Merrill and we did their experiment. And in that experiment. I designed the packet length. Based on the error rate I was seeing on telephone lines and. This is important because later people forget that we had such limitations. Noisy telephone lines that why we had short packet which are only a thousand bits. Those early network. They were very short messages. And so basically we had to do that and they were to keep the memory short in the amp and we had to keep the. Noise from hurting us too much on the line. So I did their experiments. I set up the packets were there some checks and everything and that all worked fine for the computers but showed it was much too slow and so and so I and much too unreliable. With dial up telephone lines. So I switched that strategy. And I knew what the strategy probably was after working with Len. But I switched to using a packet switching network rather than just packets on a line and that's of course why I had started that way. In any case. That was in sixty six that finally got the paper written. And then I've been left. And Bob Taylor who was his deputy took over. And he tried. I haven't tried to get me a couple times and. Bob try to get me a couple times and I said No I'm busy doing research and eventually went to Hertzfeld and asked him to talk to the director of ARPA Lincoln Labs and Lincoln Lab director. Talk to me and said it would be good for me and they will back me up and take me back if anything happens and. I don't like it. So they sent me down to Washington. And the end of a sixty six. No it was basically they wanted me and they wanted me to. Come back if I didn't like it but he thought it would be good for me. And good for my career and a story convinced me that that had some potential because I really didn't want to get totally into management. But. But I think that in talking with the director I was convinced that it would probably be a good move. This was in sixty six. Late sixty six at this point. And Hertzfeld was the director of ARPA and. Now and then I forget the name of the director of Lincoln. So I'll have to dig it up. Yes. OK. OK so. So Lincoln. He convinced me that it was worthwhile. Well yeah. Hertzfeld understood that I was that was not qualified to be my superior. Really. Because he was a behavioral scientists in his computer science office. In fact he was the wrong person. Theoretically for it to begin with but as a deputy to to have and that was fine. But anyway so. He may need chief scientist. To begin with and later. And I sort of acted as a program manager managing everything of the computer science and worked out of that office. Even though Bob and I had a good relationship but he wasn't trying to affect what I was doing and office. Everything worked. Well pretty soon it changed and wrecked and then Steve look a sick joke. Run run the computer science program as well as to start the network program. Now as Bob has written. Taylor. He had talked to her child wants to see if there was potentially some money available. And I know how that works in our But basically he talked about a million dollars being quoted. That was never in the budget it was just that hurts

Phil said that he could do that. You have to write a program plan and put it in the budget and that's a long process which I did. And eventually. That was like fifteen million that we needed. Over the course of the first time years or something I mean it was only two and a half million for the first. I can look up the exact number but it was a smaller number for the initial year. To get made and get the four no is set up. You know. Back. Years. Back. You. It was quite well I have a lot of those numbers. I don't remember putting them into years. It was pretty much. Cost per packet. That I was figuring. But that depends on the film filled and so the net. Obviously it was relatively low liked. Tended a minus a sense or something like that. OK. So getting back to the packets were small. So like. You. You know. OK Well let's talk about the whole computer science program to begin with because that was the main thing I had to manage. As far as this money went. And one of the items the thoughts that I haven't left me. Was memorize the budget. Know it backwards and forwards. Because the director will. Will want you to be able to quote what you're paying for anything any time he talks to you and you better know what in your head. Not on paper. Because otherwise. He's not going to be comfortable and so I did. And what I realized pretty quickly was that. Look letter had been funding these programs two or three years in advance. So they had two or three few years funding already. Like MIT project mac. So that when I started doing was funding them. Year by year if they needed it. But not into the two years they did I took that money and start a new programs. And so as a result. I moved the budget from fifteen million to fifty million over the first two three years. Because I kept starting big programs like the speech understanding and parallel processing. And the network. All of these programs were big enough that Congress could hear about them and see something serious rather than just a bunch of university planning. Now of course still we had all those universities doing what they were trying to do and they were getting paid to do these things. But the. But the effect on the budget was much more effective with getting more money out of our put in Congress. By having big projects. Which. For. You know well let that all started changing with Mansfield and various things that were starting to happen and Congress where they really started. Bearing down on. Six point one and pushing it to much lower so I had to take my programs in Cape some six one in each university but I had to counsel them as to programs that had something something I saw as a future for example. I went to MIT they should be what they thought they would want to do for the next year. And I said well we've done lots of compilers and compilers and compilers are making five percent advances. I think you had a you know. Not do that but undertake. Another program. You know that we can see a different kind of come like this because you're standing or the. The network or any of the other programs or anything they proposed it looked like a had a good strong output. And so it. Yes there started to become after a couple years. Serious. Restrictions on what they could do in terms of cutting down the six one and making it more six two. That's what I had to undertake during that period. But at the beginning that wasn't so necessary. You just chose the best performers. How. Well first of all. Look at gotten all these universities started. So I got to know those people. During the process of M P I meetings and so on and. And I understood. You know how good that people. Carnegie and MIT and various places are. I knew what they were doing and I knew. You know what their strengths were so that wasn't very difficult to do I also looked at new

proposals from everything. And started normally Brisson at the University of Hawaii quo and things like that where they were just proposing new proposals to see if they could get funding. You. My Yeah. I mean that's what I was saying as I was looking at the different projects they were talking about selecting those that I thought fit the six to plan and leaving him six one money but not. Nowhere near as much as originally. Because there just wasn't that in the budget. So that I was directing. Which things they were out of the things they thought they could do that were interesting things that they could be undertaking. On how you interact much interaction with the universities for example. Was typically meetings every year or twice a year. I forget exactly how often. And the P.R.I. meetings. I didn't spend a lot of time at each one but I went around to all of them over time. So I was I was interviewing them. But it wasn't done a daily basis their weekly basis that they had any feedback it was mainly on the program they were undertaking. Well to begin with. No because Bob and I would anyone is there and he was more involved with the military and their plans. He went to Vietnam and did other things like that to help them move their computing. Plans. But later I heard very Wessler and he did some of the work. Outside of that I didn't have any other program managers. And I didn't need them it wasn't that big a program fifty million as is a reasonable amount to manage and in fact. Companies. Now you mention. So much. Or. Well it depended on the program. It was a speech understanding as all of the universities involved or the sites involved it wasn't necessarily all universities I mean it could have been render. Lincoln over. Or even I.B.M. is involved in some things but the programs were usually local. And they gave their results it T.-I meeting so other people knew what they were talking about. But for the speech understanding and parallel computing and things like that bigger programs they had dinner at work with all of the groups. Because speech understanding. Required. Some medics and sent tactics and all of the other things that we now do to understand speech. Much less. Well there was a lot more after the network. Because then they could communicate. And I did it. I did a research. I originally said I could reduce the cost of computing by doing the network. Because you can use somebody else's computer. Some of the time in fact. With I.S.I. building up a number of computers which I built up as a computing center for other people. I didn't have to buy everybody happy D.P. Ted. I could let them use half time record time on somewhere else. So in reality. When I look back at the program and how much I want to computers I would have had to buy. Save a factor of three in my computing budget. Much more than I spent on the network. And so that in fact people were using other people's computers and working mostly for their own business. No Miskin McCarthy found that they could communicate papers across the network and and work together. Because they were now it Stanford and MIT and things like that work very well but the communication. Increased as time went on with a network of your sleep. In. Well if anything of that sort of decision was between the director of our Congress and me the ways I put together a program play out in a dissertation and gave the military background to the need as well as the civilian need. Like with a network. And the director presented that to Congress and they were fine with that. To begin with. Later on. You know they did reject several programs that are proposed not me but other people like building fast tunnels because they needed them for the military but they said no Department of Transportation should do that. So don't do it. And there was very good

ideas about how to increase the speed of drilling equipment. You know of using plasma Jets water jets other things that. But that was squashed by Congress. And that never happened of course with anybody else because apartment advancement isn't didn't have any budget for that. So in fact there were things that weren't being done. But I didn't have much trouble because I saw those things ahead of time and plan the programs appropriately and had the right. Presentation you like for this role in fact no I didn't have much to do with the military. I knew what the military needed. But I didn't have a lot of meetings with them of any kind. Now is that the problem that ARPA has always had DARPA is that they don't have good transfer to the military. They've improved it over time. I mean they. They've been building planes and other things which of course do have a reasonable transfer. But a lot of the stuff that was done back then didn't ever transfer and. And it was a problem that I saw because it. There was no past the real use. Even when I was doing contracts for TARP or later. Gosh. What was it typical meeting in many respects. With each one of them presenting their plans and talking about it. I presented the network plan and told them that this was going to be happening and they were going to be involved and generally they reaction was negative. Because they didn't want to lose their computer time. They thought everybody would take their computer. Minsky and McCarthy both were concerned that somebody would steal their time on the other hand they found it very valuable as they started trading papers. And so they changed their mind within a year or so. But in reality the. The and put was reasonably negative but they can say no so they didn't. Wes Clark did propose that a small computer rather than doing what we originally been doing. And putting it in the mainframe and the. And that was a good idea. Wes knew about little computers. Like no one else at that time. Because he was building personal computers at that point. But we clearly had many computers around it would do the job. So it took that approach. That was largely a discussion in the car going back to the airport with us. I can't say whether anything happened about that at the meeting. Because I can't remember whether he mentioned it during the meeting. But he certainly talked about it in the right to the airport. And in many of the reports I've seen of the meeting. Taylor has reported it differently than. Then I'm reporting it. And I don't know exactly why. Right I wrote a contract to help me write the details are of P.. And I don't lie and what I thought it should have for is routing and and so on and running approach was not of course the directly what was used but it was a possible. Reasonable approach. Find your neighbours and find the ones next to those. And in fact they did that very well and later. Improved a lot. But it was there was. We gave exactly the size of the package in a some check and everything out. So it was. It was well defined. It was mainly writing all of that. That US or I helped with home ownership eroded a lot of the work. Well I put most of the requirements as my original thoughts and I swear I worked with those and. We may have discussed it in immediately I don't know how much but other people weren't involved really. I mean it was pretty clear to me what the lines were do. And what speed they'd be and I had worked out all the economics and the rest of the issues so I knew what we needed and what kind of response time we would get. That was not a major saying. The measurement stuff was largely up to you to manage to put together with the U.C.L.A. program. Although we did put in there are features actually what they needed to be reporting here. That you talk. Sure. I don't remember what

he was involved with. We had a requirement that it had to be. Fraction of a have a second. OK. So many want you. One last. Well I have I have a strong feeling that the real change. The major change is going to pack a touching. From circuits which it. That is no matter what's happened since then in terms of protocol issues and in terms of everything else. The biggest single change was to going to packet switching because that say fifteen to one in terms of compression. You know. Space wasted on the telephone lines. And so that. That was what you and I developed basically with your theory and me putting into practice and working out the detailed numbers for the activity and laying out all the network lines was another thing to get the right to policy that. I did all of the calculations until we brought her or Frank in later. And using cuts at the rate it worked out pretty straightforward like. But. So I knew I knew what we were doing. Fifty kilobit lines. I've seen reports. Christan has a paper version he says that the pic got that from Donald Davies group and I did. But I didn't know they existed I would have gone to the I.O.C. lines I could get. But I didn't know they actually existed. And that modem was wild I mean it was took nine hellhole lines and was very expensive. But with help AK I could afford it and it was the best way to go. And I could get the response time that we needed. So soon and I knew that happened and I went to tell PAC people and got the prices. Everything was straightforward and. We had fifty kilobits that turns out that that's still using telephone lines with all the noise. So the regional network. Had to use smaller packets. Because of that because of the noise in the probability of loss of a packet. I don't know why nobody has talked a lot about that issue. Because you know. Later on people and protocols have kept on increasing the size of packets and they don't know why we did it so small for some reason. But of course you couldn't with this memory we had the size. The number of burst noise on the telephone line. Which had measured very carefully at Lincoln. So the result was. It was a major change to the thing about it we went to digital in we got better. Digital circuits when we got better and I did that when I went to started telling it. We went to digital circuits and we could get much better performance. What Byron. Yeah in fact one hundred seventy one. You know. We published. Tons of papers on new ways to manage packets in Aloha. And everything else. And it was. You came up with a number of theoretical reductions I did. And so did. Norm and quot and other people. Another thing that happened was that it was well. It's a different subject so we'll get to with the culture that somehow. It was OK. Go. Oh sure because now they could experiment with networks and network. Related issues. And they could use computers which may be more powerful or more capable than what they had but. The reason. One of the reasons why it was so productive in that early period was so it had all the papers. And so we could publish and be available to everybody instantly. In the network community. So. That publication capability of putting everything online and getting it up and available to everybody. Quickly. Was a major factor in terms of letting people quickly. Do their new work without waiting for a conference in the writing a paper. Years later. So we got tremendous amount of new activity happening with online publication. Capability and. You can you can tell what effect that had but it basically meant that there was a huge surge of network activity. Network theory. During the seventy one period. In that era. And the researchers around the country. All had the capability to work on that as well as their project which they could now know use the network for. Thank you Eric. Bob described

the belief that leave. Well I mean in a project or in the home or all budget. Well in fact they were giving a budget in so I didn't have to worry about them going over budget because they couldn't. When they could ask for more. Well they were basically generous in the earlier years it got to where there was a lot of six point two. The budgets were bigger because I had more money. But the budgets were more directed in the sense of what kind of things they could be working on and in fact that generated a lot of output. Because we didn't need five new compilers that you're. You know we needed. We needed network technology we needed. Speech. Understanding we need other things. And we needed to learn more about parallel processing. I don't think we ever did well enough but to how to program it. Mind yet. You know. Well and in fact in the program plan that I presented to begin with. I help line that their exit strategy. And then actually strategy basically was to turn it over to a carrier and make it a service. In the seventy three time frame. As soon as we had done their experiment. Proven it and made it work. I have no question that it would work because with your work and my study of it just wasn't any question about whether it would work. Question was whether we did it. But it would work. So the real question was now how do you get out of it because it was a research project. Well it turned out that when I talked to a T.N.T. about that and presented it to them is a proposal they were the only carrier big enough at that point though anyone who could have done it. They involved. Half the people in Bell Labs and half of the management of T.N.T. and they said no they didn't want any touch it. And partly the reason was probably because I'm a trust agreement with Western Union. They didn't want to be in messages. It could have been totally just because they were all in the circuits and couldn't think any other way. And that's what it seemed like but in the back of my mind I think they also had messaging. Issue. Because they didn't want to fall on their own sword there. In any case. As you know they kept trying after networks started building up and after telling it was formed and so and they kept on trying to get in and do it again. But they failed multiple times until they finally but were. Well. The CIA in the beginning. When I presented the idea to meeting government groups before I built a network. The CIA was basically throwing rotten apples. You know that basically they said this is ridiculous it will never work and shouldn't be trying but it didn't affect our pedal. Nobody was concerned about the fact that they were written back in the black ages. So in fact he and others. Propose an eight M. and and C.D.C. would propose on the be all saying it was impossible because the computers would be too expensive. Their computers anyway. But. Many people bit there are of peace and that was proof that it was straight for and you could do it. I gotta get back to your question so I had no roll up until Bob Kahn later after I left. Started trying to figure out how to do the transfer issue. And he and. And then serve waited a long time it was eighty three before he even started T.C.P. and it was ladies before they actually transferred it were whatever to N.S.F. I forget the exact year. But in any case. They transferred it to DCA and N.S.F. got up out of it so. Match. It could be. I don't know. I can't remember. No No in fact. D.C. area was a meeting encouraged to consider the technology. And in fact they went out on bed. At one point for the network. But they they didn't. They didn't do very well with that. Seventy five. I don't know exactly what happened in seventy five. Myself I was gone and seventy three. But as I say I got split. Now. How in fact. You know. Well as

been. Very wrong. Reports that it might have had something to do with the fact that I knew Frank hurt from Lincoln. But that had nothing to do with it except the fact that the proposal. Had very good sounding. And so did the one from Raytheon. But the. But the problem with the rating on one is there were four levels are free levels of hierarchy. You know directors. You know manager director and workers. And it was much too steep. In my mind and I knew that doesn't work very well and be the answer pozole was frank it. Running it and everybody else working for him. One level. Basically. That was much more attractive. And given their proposal which was also saying all the right things I thought that was the best strategy to go with somebody who could work it quickly and not have all of the up and management issues. And it wasn't that big a team you need. People have looked at that but I don't know where it is. I mean I didn't do anything based on that except I did know some of the people sleeping. They weren't. They weren't I didn't owe them anything. I had no reason to help them. But in fact there was an awful lot of MIT's involvement of the whole program I mean you and I are the only originators of the program in a sense. You know. Separate lick who we were needed. But to do it. MIT was the main source of the activity and then. B.B.N. was very close to them. Were no big problems. Bob Kahn who is working for Frank at that time. Came to me quite often. Complaining about the relationship with Frank. Because he didn't like working for a dictator. And Frank was a dictator which runs a good program. And gets it done quickly but he also wanted to answer every little question him self which was probably a little bit over for Bob. But anyway I venture Larry Bob into the office to get him out. After they built the system. Because well because Bob couldn't stand Frank. Venture they hired him. In the our prophet. But basically the interaction was heavily with with Bob because of those issues and not technical issues. Technically everything was going smoothly I reviewed it periodically and I knew they were going well and they were doing it extremely rapidly and nine months anybody's built anything lately. I mean. It was a very fast program. So I mean they did a tremendous job and they did it. Well and of course there were a few bugs that you found but not many. Straight. Most of the interaction was with rectenna and Steve look a sick. Was a more remote. Senior person. Just had a standard meetings when I had a budget review. And we didn't have a lot of other interactions. I mean he liked the program everything was fine I didn't ever have a problem with him and the programs. But it was just those meetings. As we had new programs and budget reviews. Steve look a sick. Who had worked with in the office already for years because he ran the seismic program. And we interacted in in fact I used the line to Norway to connect England into the network. Basically our relationship was closer and in fact once. Once I wrote the first email program. Well of B.B.N. the start of the first email program. And it was just send receive. And so you are like a teletype Prater. That was very uncomfortable but he realized that if it was done better. It would be tremendous value to DARPA for managing its own people. Because they were all over the world. And they needed. Time Zone fixing. Communicate So in fact I one weekend I wrote to go to do the message handling and get the e-mail straightened out so you could respond and you could build lists and so on and as soon as he had that he had everybody in our But the required to use e-mail. And it was. It was a big change for ARPA actually in terms of proving the relationship and communication. And I couldn't communicate easier with him as well because we could just send messages.

And it wouldn't have to set up meetings. And that helped everybody in course it helped the older people in the field. In the contractors to but. So the relationship was actually not terribly close with any of them because I did my job and they did theirs. I didn't have any problems with them over. But I kept on increasing the budget so I did all right in that respect. How much you. Well. I would say it was like ten percent. Not huge effect I didn't mean we had to fund the network itself. And B.B.N.. And I had to allow each contractor to spend some money and of course the U.C.L.A. program. Was more directed towards it but in large part. As I said it was like fifteen million overall while I was there. And the original proposal was you know when the two million it wasn't a lot. I mean in terms of what I needed to start with. But the program was only fifteen million then. And it was fifty million later so I imagine ten percent are reasonable number but I don't know exactly right. For that act. Only on the network and. You may be able to help me on exactly what. Stablished. Because I needed to protocol. Designed but I don't know exactly how we got the people together. That may be there right. Yes. Well me. We always talk. Oh I was. I was always comfortable with things that might not work but I had pretty good companies that the network would work. I wasn't so sure about speech understanding. You know. Because in fact. It never got into the real world until recently. But in fact. Prove that it was possible. If you knew the context. But in the network. World I knew what we were doing and. It was important that we do have participation from the various groups. So that they would all be involved and get the protocol so it worked between all of them. And so it was important. Remember that the network and address space of eight bit. So it wasn't a very strong network in terms of growth in terms of the protocol. Protocol was very constrained by the amount of memory available in the hand size of the packet and the like. So in fact it was. It was a continuous change that had to take place. To larger address spaces over time and change due to the fact that. As we went from analog lines to digital and fiber. The noise kept going down and we could have longer and longer packets. And we could in fact start. What then did in that. To go without any or checking throughout the whole net. Couldn't do that to begin with when the made any useful throughput. But as time as time proceeded it disappeared as a problem and so the normal evolution took place. I think you know the evolution is really. Threefold. It was and C.P.. And then telling it. With X. twenty five. That was the next. From seventy five to ninety that was the primary network in the world. And all the other countries supported it and it was an international standard. That all a carriers to have this work worldwide had to have a standard. They couldn't just do something else. The fact that. T.C.P. IP eventually became required for D.O.D. pushed ever. Element of factors to start supporting it. And the other thing that happened was either net. Was done and it required T.C.P. so you had to have it. To interact and the. We made the code free for interface. Through the Berkeley. Code. So there was there was a way to get T.C.P. to be a nationwide. Worldwide standard even though it wasn't even though there was no standard committee involved until the. Except for the new newly formed. Internet Committee. He way. So I think that the protocol became. And now volution airy process which had to take place. And of course now we're going to P.V. six and. I believe we have to move to Cuba. Three three one three which now standardized with the I to you and reduces the delay. Dramatically to pay her people can stream continuously. And not have any delay at all and

never have a packet thrown away. It's a something that hasn't happened but I'm now talking to organizations where they see that as critical like in the stock market where they need to get there to lay down your. Find. Which the leak. You. The experiment was basically to see what was the problems and issues with building a real package which network like you had laid out in the in your book. Which was the basis of my thinking. Related that it would be it would be a switch network. But in order to do that up front as an experiment. My thinking was we needed to test the computer and how it. Communicated and whether you could talk to it. OK. And interface to it. And the communications and what was needed there. And I started with only thing available economically was early. Dial up two point four kilobit. Fastest it was available. Very slow dial very very slow moving and I was only sending one fifteen to the time in their experiments because that's what computers do. So in any case. I laid it out and worked out the packet structure very carefully and her checking all of those things so that I knew that I get the highest throughput. But outside of that it was really. I knew that switching could take place in that same thing. But I. The test was to see what kind of communication. Trunks we should be using and how well they would work and work so poorly on dial up. That I couldn't even think of going that way. I didn't really believe it was going work very well but at least I saw bad what. And the result was. I knew how to proceed with leased line. Now ninety six is the. And I leased line modem not a dial up modem and fifty kilobit was was a novel. Capability that he and he had sort of hidden. We're Yeah that was only thing I could get right. Although once they mentioned the fifty. I could. When found out about that it was easy. You know because he goes nine telephone lines and. If you buy. Under Telapak that's much cheaper than least lines. Without me for that many lease lines. Anybody could use Telapak if they were to have enough business and have enough lines. But very few did besides the government. And so we had a special tariff that was particularly good. But in fact a lot of my time was spent up demise in the communications trunks. And that apology and in the speed in looking at the cost and look. Looking at the delay in the response and all that well before we built it. Right. That's what he. About didn't spend have any time on any of the programs. At that point. I did all of the computer science in the network. Bob got involved in other things we talk from time to time but there was no contribution that I can remember at all so in fact. You know that said most is have an office managing contracts and. Because you know here in the people looking at proposals in the like most of the work I did at home every night. Because I was working out all of that apology and working out how to build it and what the response in the delay and everything else. And the cost in particular and a lot of my graphs from the period show how how I was trying different approaches to see what the cost per bit would be. Course. Well I I had the tariffs for least lines. And then the Telapak. And I had originally laid out what it would take with ninety six which is extremely complex and slow. But it would work I mean it but it just mean the response time was much less. How to use a lot of lines and their expense was higher than using the bigger lines. But basically as soon as I knew the other was available than concentrated on that. And the cost was generally fifteen times less. Then if you did circuit switching. Except for the fact that search. Circuit switching. Also raise the price because it was on demand. And so it was well above that. But just the raw cost. If you do still leased line versus the network. It was fifteen to one. So

it was a tremendous gain and that was primarily from my link in experiments of what the actual usage ratio was. You had no data data. Not voice data to S S D C in back. Looking at those transactions and watching the actual utilization. I found. Actual theoretical average. Utilization was fifteen. If I was working. Right now or it course. You know the machines work very well because they were all time share their book times or a machine so they could interact. Jerry. Right. And at that point. We mentioned there somewhere before. Timesharing became much less of an issue because a manufacturer is very picking it up. And so we weren't pushing that new office anymore by that time look did most of it. You could. Well that speech in a standing program. I put together. I think it was five different universities but positive on the number of this point but they were all sharing a challenge to with the project to develop the best feature understanding system they could using semantics and tactics whatever they could to try and put together something that truly understood speech. I knew from from conversations with then I say that you can even tell what it any or it is if you don't have the sound effects of the room. In hand. Because the sound the same depending on. If you just do them in isolation. There's no way to tell. So if the bells are a real problem in just finding them out from listening you have to see what word fits and then what's a medically. Thanks and most of the benefit came from semantics. Where they said if you're talking about baseball I got it close and I know the words you'll probably use and. I can I can handle this and I said just find it kind of he did that just will. But without the context nobody did extremely well. But they all did reasonably well and had. You know ninety some odd percent but ninety percent is not the right number. We have to have much closer to one hundred get the editing down to where it's reason. So in fact the context was about the only one that worked in that environment. The way I'd like to see it work. And after. I think it was five years or three years or something that Herminator. But we did that program and that was that was important because it gave us a focus with Congress and could solve a bigger problem. The same was mainly just with the University of Illinois doing the parallel computing but paying for the high tech for which I haven't started a massive undertaking. But it was important to get that straightened out and of course I had to then respond to the student up welling it. Uprising it Illinois and move the potential destination to NASA Ames. So that they could use it over the network. Rather than have it Los close by to rip apart. Yes. Well I was there. Yeah well I'm trying to think of any of the other big programs but those are the Network of Those two with the larger programs. There's a lot of network I. Well I was it was an ongoing activity from look. But it actually was getting less and less interest in Congress over time and I hit it more and more. I didn't make it into a big for him because of that. They were seeing that is pie in the sky and it's now. Doing good things but it took a long time. Well the fact is what programs I thought I could even put through. And Cells of the government I could mostly hide it so that wasn't a big problem with the university were had lots of things happening. But with respect to starting a new initiative I did have to worry about whether that was going go over with Congress and the same was true after Mansfield. I mean it was even more. But I had but as you asked before. Could I just hide it and change the numbers well no you can't totally do that because they can see through that. But I did in fact. Change their approach with the schools somewhat and still basically nobody got hurt

tremendously. Because I just guided them to things I could talk about. And could and could explain as major improvements rather than minor improvements. Well actually Congress. Is there one who. Alone who changes it. Director. There are protector and. As long as I have big programs that are that he can sell the Congress the good. Then he has a much easier time. Raising more money for the I.P.T. office. So. But there's a lot of things that take place. So when I did was found that Likud funded these programs three years in advance so I didn't like an MIT I didn't fund them for two years. I kept reviewing them and seeing what they were doing and working with them. You know what might happen in the future but. But I funded other programs in the meantime like the lower net. Militias and. Now I had all these programs going like the ones that wrecked in and look a sick could sell. And therefore gave me the money to do. But I was actually using that same fifteen million but I tripled it effectively. Because I used the money that we're going to all the schools that were overhead to start new programs and then. If you have a program going. It's much more likely to stay. And so now. I needed. Thirty million and then forty five and then to fifty and within a few years I got I got the program to fifty. And that that was my intent and I did it on purpose because I know you couldn't do enough with regional budget. And I felt. You know it was very important for a program manager. To have enough business. That he acted like a business owner of some reasonable size organization rather than funding one person like what was happening in the Navy in the army and their little contracts. They might fund. One in one researcher. And that would take so much work for the manager. To get it done. And that's all the budget he had so basically running. One or two people managing practically nothing. Well the basic one that would be used with Congress was the benefit for the military and proved capability. But the fact that it also helped. The country was OK until later and as I said. The drilling program for drilling tunnels. Didn't sell because they thought the other agencies like the O.T. had more reason to worry about that. And so it should be a civilian program. Never happened of course because the in programs were organized to do anything serious like arpa. But in fact most programs. Anything I proposed we got through alright. And that's because I thought about it. And of course they thought about that in this was from the seismic office I think but they thought about it but they didn't want to. But they believe that they had the technology that could attack the problem and it would be a big help and it would be. We still haven't done it already. By. Well. Eat each program like in the area programs they built devices. Various kinds but that wasn't the program. I mean they did that percent of their research. Like if they built a robot or whatever. It wasn't a robot program moving cut. It might be today in effect or has won today. But they make it a challenge. No I wasn't it wasn't separating hardware and software it all whatever was needed to get a job done. There was the Mansfield I'm in the cause that. Now. Well yes because what. Look started was funding. Project Mackworth out. Telling them what to do. And they they could do anything that their bright people were excited about. And that's fine. I mean that worked for basic research by. Fight. Well I had big argument about the compilers. Because there's one scientist at MIT all in the compilers that's all they thought about. And he didn't want to hang out. But you know we had so many by then that it we weren't going to see much change in fact we haven't. But we only had like a mess. Well I don't know about shooting to the moon but you know the projects that were

like speech understanding I saw went shooting for the moon they were trying to improve the technology. But in an area where we know it would have application. And we could argue that the. The benefit. Was there for the military. And in fact it is but in large part it was to try and. In get the programs to be more effective and more potent as well. Put up with this fact you for a strong. I did respond by adjusting how we did. The projects we undertook and inside an institution what they did. But it but it wasn't anywhere near as dramatic as it is today. And it was it was trying to guide them in keeping the money to the three things that were going pay off as much as we could. But but but the reason was we had to reduce the amount of six one and increasing out of six two in the plans. And for each university that was a separate issue. You have to have some sex one in order to get new ideas. Today it's even worse. Well I was able to work around it pretty effectively because. Well first of all I found big programs that they could understand like the network. And the parallel processing. The speech. The issue with respect to today. I have a hard time evaluating because I haven't dealt with the name but a couple programs I've done. But the. But it's very specific and very detailed as to where the outcome should be. And you've got to solve this problem or whatever they want to problem solve. And so it's really starts with our folks coming up with the with the goal. And not a bright researcher saying here's something new now. Unique a chipmunk for change. Talk about that. I was changing directions. Yes. You know that was about the light years away. Yeah yeah yeah. I reckon. Yeah. Your Yeah. I think so because in fact for anybody communicating email works. Much more effectively. Then if I have a need to communicate with somebody and they're especially if when there are different time zone it's difficult. You know way. It clearly was a majority of the traffic in the seventy one seventy three. Timeframe. Later on I'm sure. It changed and today it's not that big of that total network. Activity of course video was huge today. But as there are panet progressed. Now their applications became better but do you mean I was simple and everybody had it quickly. And so it became the majority of the traffic. And that let people communicate with each other which. In fact wasn't the original reason we started our. Keep going back to just how we're with you on your ego. The. Well there's a big barrier between video any and you know I saw the only person I talked was a director so I can't say how much he talked to D.D. Ernie but from what I heard in terms of the questions. It was that that's the place where that DARPA director gets chosen. But it's not where we get our orders from. No way that they might have some goal at some point and they might have and might have been passed through I don't know but I didn't see any of that I thought I saw that when we had a program that made sense like the network. The D.D.R. and he had no involvement whatsoever. And in fact D.C. area being so opposed to it didn't have any involvement either. They venture Les went with trying to really read you out of the end because it was so silly. But that was a disaster after disaster in terms of them. Managing it even so it didn't happen very quickly. But eventually all that technology went to use an inside the government is idiotic. It was clearly more important in the administrators part of the O.T. than even in the field. Hell yes. You know. Financially. Well. I think. Oh well I had. I had worked out the details of what I wanted to see this. Put together as. I didn't. I knew what would work and I didn't want it to be dramatically different from that. So I outlined specifically. The kind of. And since we were talking about fairly minimal. Memories and fairly

minimal. Package is even on to get the performance. The the result was we don't have a lot of choices. And I gave them to lay out the specs of what we needed. And a tentative routing algorithm. Of looking for a nearest neighbour and neighbour next to that and so on to show that there was an algorithm that would work. Now obviously. That got changed. And got changed again later on the equivalent. But the. After I was really putting together all the words just make it into a document. Rid if I shall effectively. So I don't mean I'm not. I couldn't go to a single number and say that there was no interaction. But I would say I suppose if I had most of it. And they put it together and cross-checked it is obviously. And so they did a good job and I got I got the written things that I could turn it out quickly and it. Well the plan was written before I funded. Much of anything so. Had to be. I can take up to date. I don't have it in my head for safely but it was. It was in sixty seven and pretty sure he came in and. Well I. Well I don't know the exact number. I think it was around twenty the. The two that were outstanding and seem to have the right. Discussion in the right conclusions. Raytheon and B.B.N. and. I had a review committee with working with me and we concluded those are the two best. And then I chose between them based on the management structure because the management structure at B.B.N. was very flat and there was one director in a hole and a bunch of people doing the job. And otherwise it. And it was a hierarchy which I found to be inefficient and costing a lot. I don't like steep. Hierarchies. You know like to see at least seven people were going to reach person. Not more where she in that sense I think so although there may well have been differences but we judge them is basically both competitive in that respect. Me. The majority of them. I think it was to the did you know it well or something like that I mean it was a large proportion. I didn't know back into their decision. Matrix I just monitored what they said. Both I.B.M. and C.D.C. declined to bid because it would be too expensive with their machines or any machine. I just didn't think it could be done. But in fact it was. It was a good response from a number of organizations. Well. The problem is that protocol is a fluid thing in the networks because it has to evolve. We started with a pit. Dresses. And that clearly was good for their experiment. But we didn't expect that to last and C.P. was a was you know and I first attempt that process then. Basically the next thing it happened was I tried to get rid of the network. And he wouldn't take it. I then went to Bernie Strasburg at the F.C.C. and said What would you do to you know is there any way I could. Get this to happen. And somebody to take it over and he said we'll start a company the only way you can do it. And we're open to that now and C.I. A started you can start a company. So when B.B.N. came up with the first piece of money to approach that I thought that was quite reasonable and undertook to join as soon as I could I had to find a replacement. But when I did I saw worked with. The crew which was basically fill a book or so to Madison and Perry and took on being the C.E.O. in October of six sixty three seventy three. And the clear thing to me was you needed a standardized protocol in order to get the world involved. You couldn't do it was something where they couldn't communicate with the same thing and that's what every carrier in the world. Basically said to leave resign or anybody else who came up with protocols that were in space completely unspecified. You know you can say he wanted it was good for experimenting but not good for a carrier at all. Secondly you needed X. twenty nine. Incorporated. Thing it took terminal to IP. Because you had to be able to say what the

terminal interface was so you could build it and use it. Throughout the world. So the first thing I did was then it take to try and build the protocol to do that and get standard eyes and started in seventy three and went to see C.I.T. and collected for the for other countries to work with on it and get the X. twenty five. And then X. seventy five past. An X. twenty nine and twenty. So that we had the. A standard protocol it all the carriers could work with. And it was sort of a step up from C.P.A. quite a step in terms of address space and and structure and throughput but it basically. It was aimed at digital trunks not analog trunks. So we could have less noise but still it was digital trunk still had some noises were better. Fiber and then. So what. Then sir if Bob are thinking of who had all the fiber. And we don't have that we can go and and and have the computers do it. So the network don't have to do as much. And it was a minute. Minimalist thing in terms of trying to make sure that we didn't spend too much on the computers but of course we're going to anything we want now almost without much trouble because we have so much memory available. So. Things that evolved by seventy five to where X. twenty five was ideal and it was affective for everybody in the world and that became the standard activity. Even with U.D.P. running over it. When that happened. But through eighty three on into the ninety's there was a. Well. I didn't take an attempt to improve it. Yep I did make an attempt to improve the thing. It could have been improved to stay with it because the fear was that it wouldn't work on T one in her speech but that I don't. I didn't never believe you could have done it almost any speed. But still T.C.P. moved along by a freedom where they had made it. The standard. So it became very frequently. Mandated and worked throughout everywhere. What. You. That's why I supported it but I didn't have a role as a get up. I knew it was happening and I knew that was necessary. But that was something that all of the projects were responsible for helping. And this were a good group. But some but not a huge amount because we as soon as email worked. We have huge activity going on and. Whatever. And of course. The demonstration in. I triple lie. Triple I. Well. There was a conference where we demonstrated a. And so that everybody worked hard to have different things to show. But I missing part of what you were asking. Yeah I think. I think the problem is we're overestimating the importance of the protocols. Because basically. There has to evolve. When we've got to evolve to something like I've done now. Although it could be something else but we've got to evolve to something where we can do it faster and handle four K. Take a T.V. and so on and. No application needs really. Load. Delay Telamonselect remote surgery has even been tried hardly. Because they know it will work. But if it needs a millisecond. Behavior it doesn't work and. We've got those things now and we've got those things that need microseconds a New York is for retraining go. So it's basically. We've got to keep evolving. The protocol. But the basic changes back into a change. And that's the story I'd like to get clear. Because that's what are privileged and. They also worked on the protocols couple of them. The new and P.V. six was done by the committee. It wasn't done by any individual particularly. My question. Like. Joe. Well it was my decision each in each case. Until I left. But basically it was who needed to go next and how far away and how expensive the lines were the original experiment was all done in the west coast because that kept the line cost down. And those organizations were the only ones who were reasonably cooperative with the concept. After this if you seven meeting where most people weren't. Whereas. As soon as a student that was

working. We had other people. Clearly trying to get B.B.N. on so they could manage the network and other places. And in some cases. You know it was because I started a contract with the low and people. And he did it and needed to show that we could work over those distances and and connect to them and there when their wireless network. And so I set that up with a priority over some of the other things in the same with going to and I did. The satellite. Protocol which actually got implemented after with. But. But basically the satellite protocol was. We used to go to Europe finally after the Norway. Connection. The packet satellite. Concept was tried it hasn't been used much I don't think right. Now. Well in fact. The proposal came out of a set of proposals that were sent. I forget the name of it but there was a. There was a request for proposals that was made in a lot of people turned in ripples. I forget how it came about it was a hit with me but it was. But I got a number of the proposals that were sent in because they were related to computing and communications. And they allow a proposal was very interesting because it then expanded it to wireless. And I've been thinking about the packet network. Experiment and the developing packet radio. But they had a working system. So. Connecting their men so that we could have the two interconnected was important things that we had to tune in or connected networks. Of course there were lots more of those MIT had lots of computers. Tied to their amp and they talk to each other more than they did a hangout. You had several I think it U.C.L.A.. And so we had a lot of local networks. But this was a. This was a better case of really because of the wireless I wanted to get that incorporated into a network. In other cases along the line and I did in I.B.M. because they had something to contribute. They didn't have a contract at all other people like that as we progress. And if you have a military site. Very active. You might see your. What the experiment. You know it was to extend the network. To Europe and just to get it closer to worldwide and get a more spread. It wasn't on a satellite link. Actually it was a lease lines. To Norway and then down to London. But all of that was economically easy to arrange because of various the contracts that were in place. And the U.K. helped with the line up to Norway. So that in reality it was to get Peter Christan involved and get all of his English computers. Tied in because he did the translation. Gateway to all of the European. Mainly English. Computers. Thank you. Well first. I forget exactly the names of them. But a couple of the European networks and the network throughout England. As people heard about the technology had started getting connected to it. Basically they all wanted to be incorporated. Involved and so they. They bought a P.V.P. if he won or something and connected to a line to University of London and got their things connected. That was a much larger interconnected network. We probably had in the States as for the whole network connected. Which was one of the reasons why going there was valuable because we got a lot more people involved. But it was not much you could do it. Secondly it's because basically they didn't have a protocol. It just had random packets and. Yeah. If you knew what he was sending what his protocol was Kirsten could convert it. But it was sort of one by one. It's not very attractive. I've recently read a report on. And I Tripoli. Spectrum they were asking about heroes and. He had the old people like. Grace Hopper and the level. And then he's just mentioned you and I are obviously not important to him because he has listen to somebody else. But but but basically. He was asking about the way preside and his. Why wasn't that more important because he got turned down it's

easier. When I got turned down because the carriers wouldn't have anything I do with the protocol this protocol. You know where it was no standard. There was just no interest whatsoever. It was hopeless. Whereas France had a representative from the carrier Louis. Anyway. He basically worked with the protocol wanted his extra bit. But outside of that. It was fine and in fact he never used a bit to do anything but it was. It was certainly not a viable proposal. It was a good research proposal between a couple schools maybe. But it wasn't it wasn't something we could work with in fact I wouldn't done it in a state where everybody could have their own protocol it wouldn't have me and I might have had Minsky talking to McCarthy but I probably never would have gotten even there. Or the CIA was learning. Over time as what we were doing. It did work. And they needed something better themselves. But then they want to manage it themselves and not just have us do something for them. So basically they tried to contract out for the next. Auto dent in it I don't even remember the entire mess. But it didn't work very well. And eventually Bob didn't mean it managed to give them part of it so that. That was the military part wasn't left with the part that he turned over to S.F. later. In fact. The plan all along. As I said in the program plan was to get rid of it. Funded indefinitely. But once tellin it was operating in are operating with England and Canada and everywhere else because we sold them the equipment it was easy to get everybody going. The result was there was plenty of capacity for people to move the traffic around the world. And around the state. So they really they could put T.C.P. over it it doesn't really matter what you put over it as long as you had a media. So in fact. You know it. DCA could could easily then use that course there are standard equipment they didn't need. You know use. Odeon they contracted with people to build back here. Oh yeah. Well I don't think that the improvements. I've done more recently. Protocols and that works and things could have been done back then because we didn't have fiber we didn't have a speed. We didn't have the memory. We didn't have any of that. And so what's happened in the meantime is memory has gotten cheaper so much faster than computing. That the whole ratio has shifted. Where you can now keep track of every flow. Rather than computing the road every time. Since you see another packet you know where it's going because you've already done it. So the reality is things have shifted so much that we do something different today the fact we need to get down to millisecond networking or the second networking is something you can only come after the underlying facilities are there. And we can see that it could work. And most people don't realize how bad. T.C.P. operates today. Because of overloaded routers. Or even the whole concept I mean in our original amps we didn't have enough memory to play anything. So we had better response time. Most Likely to the speed. But today. There is a buffering involved is so huge that it can be a very slow. Anyway. So things had to evolve over time in large part. I might just spent more time on the radio. Earlier. But with that took a lot of Harvard about it and that took time and so it got started but it took quite a while definition. So I don't. I don't know of many more things that would have done differently except maybe P.R.. Well I mean as time has gone on it's been very clear that the history his. Has been written by the people who talked about. And it's not necessarily clear that that's really the. The importance of the sequence of events or anything else I mean in this hero's article. Bob invent are claimed as the co-founders of the Internet. Founding an Internet is something you do by

being the person to start it and build it. That's a founder not somebody who writes a protocol and changes it. For an improvement. That's that's an upgrade. And in fact there's gonna be more appraises. I P V six which is been very hard. The new protocol I'm talking about is much easier to involve. Because it can just slip in without any impact. In fact during the DARPA contract that I had last in a grin. Microsoft did write the code to fix it into the microsoft. Interface and problem was I think that's been lost I don't know where it is because DARPA just terminated the whole thing. Momentarily because he was tired of prime contractor in like them. Well the whole concept that I saw when I was there was this is the way to run a program. This is fantastic the way I was organized. Well that way was basically to get very bright people into the offices not too many. My view was a program manager should be handle handling. Ten twenty million. Themselves and not. Two million or whatever and. In fact that's continued it up in large for large part because the budget so much bigger. But the concept basically is. Stay out of it. You know contract with great groups. Choose them well. And so on but the other thing that's changed is now DARPA is deciding what they want to do not. The not getting for POWs mean they may get proposals but they decide more or less what they want to do and know anything he can usually do is respond to be a. And so they simply. It's a different environment. From the outside. From the inside. It's much more structure. I don't know all of it. I spent time working with them but I don't see all of it but it's. It's very difficult to Rick recreate what was there at that time. Because basically you brought in people for a modest number of years maybe four to six years. And they knew their technology extremely well. So they could choose the right per se as and make sure everybody. And contractor them. And there wasn't much overhead management of that except whether it fit within the military context or not. You. Well one of the things that I knew it. That point is nobody's just a whole lot. I don't think that's been in force at all but it's. It's happened. People do over time. But I think. I think it's much more of a job down than it is as. Short term diversion from your technical activity. And where you're at the top of that knowledge E.U. know everything that you need to know. And you can go work with the people. But I think the constraints are a lot stronger to in terms of meeting. Your goals of your. I.P.T. director whatever and the director. And having more reviews and more oversight. I've talked with P.M.'s about their their activity and it's very difficult for them. In many cases. They're not anywhere near as happy as we were back then. And it's. It's mean the concept is carried over to the ARPA. And people are trying to use the same model. But it has to be done very carefully and not keep people around too long and and they make sure they're the top of the crop. OK. I think I have during the question that. It's basically I'm seeing a lot more clearly now. That evolution. And that telling that we're really a big piece of it actually. Because it spanned it. Fifteen years that. Everything else wasn't there commercially and gave people the same capability basically. It wouldn't have lasted indefinitely because it wasn't designed for the speed and it wasn't designed for the dress space. And so we had to keep upgrading that and unfortunately. D.C.P. got it wrong again. So they had to go to the section. We may have to move from that. On we get all the planets involved. But in fact the evolution is always associated with with the changes that occur and technology. Across the memory. Across the computing. All of that keeps changing and changing the mix. And what we should be doing. And what we need to use.

About course that changed after communications became unregulated and dropped. Very rapidly with the ever D.M.. So that in fact. You know. It is possible to get high speeds or circuit switching. It still isn't very effective. On that circuit because you don't have the traffic. I mean. You might be sending a video which is OK but outside of that Suppose you're interacting. And it's very very very low hill is a sion. So there is more and more of it. And it should work fine as if we did it right. If we don't do it right today. Well that's what I have a new protocol for so it can stream through and keep the throughput. So you can stream at any speed you know. You can. And the trucks are high enough so you know with ten in a hundred gig megabit gigabit speeds. OK. Yep. OK.