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Oral History
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Just so I was a graduate student at MIT. Looking for an appropriate. Ph D. dissertation. And of course there were many classmates there working on a variety of subjects. And there was my feeling that they were all working on a very similar topic which was coding theory and information theory on the record John and and. It was my impression that the really great work had been done by Claude Shannon. And the problems that were left that the students were working on were smaller problems. And really hard ones. And what I had signed up for in my own mind. Once I agreed to do a Ph D. was to work on something that would be more exciting more interesting have impact. And be worthwhile in my mind. Same time I was surrounded by computers working at MIT and of like a laboratory and. It was clear to me that sooner or later these computers would have to talk to each other and yet I could recognise there was no adequate technology to allow them to do so because the only existing broad based network at the time was the telephone that for the A.T.T. telephone network. And the technology. In that telephone network is circuits were chain which basically commits the communications path to a given conversation. For the entire duration of the conversation. Was there or not you go silent have a cup of coffee. Smoke a cigarette or whatever. And you in those pauses the line is being committed but wasted. Now that's perfectly OK for voice communication because you're silent about one third of the time. But in data communication was clear to me that somebody sitting at a keyboard or to keep you to console. Keenan characters or scratching their head wondering why their programs not working. Was a situation which was highly bursty which means that most of the time. There's no data being transmitted between the user in the computer or computer to computer and in that case to commit a communications path to a car. A data conversation which was silent most of the time was terribly terribly inefficient. So the new approach was needed. It was also clear that the way to do it on the approach I had was to allocate communication capacity. Only when something was being sent. And when a particular session had nothing to say and it would release those resources and allow those communications resources to be used by other communications. Now there was a clear model for how this was affective already in the environment at MIT. These computed with which I was surrounded with timesharing computers. In innovation timesharing. Is that you don't permanently assign a computer. Processor. To a job. Unless there's work to be done. In fact you allow many people to access that computer. At the same time in I'm something called timesharing were first i use of the new use in the third person use it as the jobs come in as the work needs to be done. It gets shared in this dynamic. Resource allocation of computing power. Well I said look let's take that same idea and apply it to communications capability and see if the idea of dynamic. Resort Sherene was the approach to use. Now there already was some systems out there using this kind of technology and the Telegraph network. Uses that kind of technology. And there was a switch in just I'm by Western Union. That was basically out there. A very structured. System with very similar computers with a very limited kind of traffic. But the idea of using it for the generalized heterogeneous computer to computer

communications with the approach I talk. Yes there I describe some of them in some detail. In my dissertation as models of how this new resource sharing technology could be used for this. More head of a genius. Computer to computer communications. It says. Well it was also clear that there were no analytic models or basic understanding as to what the predicted before means would be. As such a system would grow into a computer network of Meena into a HAD IT WOULD YOU news world with mixed kinds of traffic and. No characterization of the randomness of the Trafford that was coming in which is typical of what computer communications would be. So I decided to use that physical and you knew in model. Based on the time sharing idea. And on the telegraph. Type network the message switching network and try to create in mathematical model. To analyze it. To solve it. And then to find some design. Guidelines. Optimization principled. And hopefully some of the underlying reasons why these networks did so well and she could predict the performance. So I started set up a mathematical model to do this and happily. There was already in the literature. Some work by James Jackson when he talked about networks of waiting lines. Namely cues that fed other cues that fed other cues. Well my mine. Those the network nodes feeding other network nodes feeding other network nodes. As traffic bounced around from site to site. In this computer network. And so there was a need. Want to handle both the traffic. There was an engineering approach. And now there was a mathematical tool that I could use to put it all together. So that's how I got into. And I presented that is my thesis proposal. Now. This career. In fact in the same year one hundred sixty four he published a series of reports. All about data networks. And in looking at his work I found to a lot of similarities between what he had done and what I had done. Clearly we were can independently of each other lean. Neither one of us still reach others work. Later we became quite familiar with it in fact I gave a presentation up at Berkeley. And as part of a short course and Paul Barron attended my lectures on that cross. And I began to read his report so I began to see there had been other work going on. Meanwhile eighteen T.. The company that it was basically supporting providing the voice network. Expressed distain. At this kind of technology they looked down upon it. Were is I and Paul independently approached them and said You guys ought to be thinking about creating a dated network. Their response was it wouldn't work. And in fact they want to follow it to say even if it does work we want nothing to do with it. And I remember distinctly in the mid sixty's. Attending these large fall joint in spring joint computer conferences at these plenary sessions with a computer guys in the telephone guys would get up on a panel. And that have the following discourse. The computer guys folks like myself and others in the computer field would say to a teensy would you please provide is good data networking we want to connect our computers together and eighteen T. said. Well what are you talking about the United States is a copper mine. It's full of our telephone wires buried in the ground and microwave cable. Use that network. And I respond to as well. You don't really understand your network. Takes basically twenty five seconds to dial up a call. You charge a minimum of three minutes of communications time. And all we want to do is send a few hundred milliseconds of data. Occasionally and their response was go away. And so we couldn't get any traction from eighteen to. Paul met the same kind of resistance on their part. So continuing to work on this and U.C.L.A. opera the Advanced Research Projects Agency

about which you know so much. Had already been formed in one thousand nine hundred eighty three in one thousand fifty eight and one thousand nine hundred eighty three the computer group began to support researchers around the country and around one hundred sixty six. Bob Taylor who was then director of the information processing techniques office. Recognized that every time he brought on a new researcher to university that researcher. Would ask for a computer. And Bob was happy to buy them a computer. And then they asked for all the capabilities that all the other researchers in the OP acumen that he'd already developed. Like the graphics. At Utah. Like the database he does so I like the high performance Illinois I like the simulation and modeling stuff or U.C.L.A.. And Bob said look we can afford to give every one of your researches all the resources. But if we put you in a network. You could access the graphics. At Utah. By connecting to their machine. Through this network. From your machine. And so the idea of implementing a data network. To connect computers together in a head of a genius environment. With very varied applications. Was now born with an opera. Process. What you are so when the concept of building a network. Came alive and became real. It was then necessary to put together a plan. Set up a schedule and get this network built and deployed. And what. What Bob Taylor did as he brought in one of my former classmates at MIT Larry Roberts as chief scientist at the information processing techniques office. To basically plan and guide and manage the implementation of this network which would eventually be called the opera network. The opera net. And so what Laurie did is he looked around the community. For people that he knew had some capability and knowledge in this area. And he brought together a few of us myself included because Larry in fact was well aware of my work we were classmates we officemate. And in fact in the process of doing my dissertation we always exchanged information. Where he was doing what I was doing what I've been settled in with doing with the rest of our classmates were doing. He was aware. Not only did this technology exist in terms of a proven. Theoretical capability. And a simulation capability. But also that it would work. That the package wouldn't fall on the floor. That the messages would get through in reasonable time. And to dictabelt time. And so he. He brought a few of us together to begin to lay out what this network would look like and various meetings were held in sixty seven for example. To begin to lay out the spec. To lay out a plan to put out an option a plan. And then to solicit a contractor to implement these plans. Sure those meetings took place here at U.C.L.A. at the incorporation at OP or in Washington. Larry met some people at a Gatlinburg conference. That's when he met first met the Davies group. To talk about what they were doing in England. In the mid sixty's. Sixty five sixty six Donald Davies. At the. National Physical Laboratory intended to England was beginning to think the same way. He had read my book he had was aware of Paul. Barron's reports. And he decided to implement a network like this so they were thinking about this and Lane plans as well. So these meetings were among some of the contract is that will be unsupported. And addressed by the OP with humanity. And anybody else why information about it and a variety of us were brought together. We each assigned some work to put together this plan. What should the network look like a member very innovative idea came out of one of the meetings at which Wes Clark was present. And he made the point that is he going to connect a network of computers together. Well you don't want to do is Bobby each one of those computers. Who has its own work to be

doing. You don't want to bother computers with all of the networking technology. Basically the error correction. The packetized seen the deployment. Watching the lined maintaining them. Put all that function in a separate little machine. City next to the host computer and see the idea of what we now call a router. In those days we called him an interface message processor was conceived by by West. In fact it's very natural West would have thought of that because he had already developed a very small mini computer called the link computer. Wanted link a laboratory. To do just that kind of thing small focus tasks special purpose. Therefore inexpensive small high powered machines. So yeah. So Larry Roberts. Needed to put together a group of people who could advise him. And work with him on helping him. Write this up in a plan. And consider what the network should look like and how which operate and so the people who brought together. From around the community that OP was supporting people like Elma Shapiro about Sri. People like west of fell from Michigan. Barry Bay MN Paul Barrett Ray and myself at U.C.L.A.. And some of the Opera folks as well himself Bob Taylor. Would come around and Wes Clark is an example. Mel Pirtle was involved. From Berkeley. So of course a community. He put the people together and asked them to sit down and think about what this network should look like fact I believe Barry was the was there as well one of the meetings and. As I said we began to specify what should be the characteristics of this network. For example from a timesharing point of view the folks who were very very knowledgeable or timesharing said if this network can't deliver. Short messages in half a second round trip. It's useless for timesharing you need this human interaction time. So the spec was made short messages who gets his network in half a second. And for example a liability. Was a major issue this network needed to be robust. Now there were various ways to specify what robustness meant in a network. Wait eighteen T. did it was to say this network. Then network was liable to five nines which meant ninety nine point nine nine nine percent of the time. It was running. But that was really a an artificial statistic. Because that number typically was the network will be up at that percentage of the time when it's running. Not one some failures occurred. And a network is down. So it really wasn't operationally useful. Instead. What was decided is a network should be such that if any one piece the network breaks. A switch or a line. Everybody else I was still connected could still communicate. So the idea of robustness and parallel pads and a distributed. Apology. Which is already present in the early works of Baron. As well as myself. Kind of grid network. A day a distributed. Arbitrary network I believe that the way in which Baron referred to is like a web. Type structure. Not the current notion of well but a spider web notion. So that was a liability concern. And since I was very much concerned with analytic predictions and performance evaluation. I said this is an experiment we're running. We better put some software into this network so we could measure was going on and experiment doesn't exist unless you measure what's happening. And so we said these switches should allow measurement to take place to gather the measurements to send it back to some centralized measurement center. To generate artificial traffic. To trace. Messages and packages and move to the network etc So these are some of the kinds of constraints that we put in. And that eventually was folded into the plan that Larry vote. Us. Contract. And. So when it came time to select the contractor. Some of the potential winners of the contract. Were made aware of what the spec was the spec

was sent out. And some of the contract is came to some meetings. At Washington to talk about these capabilities. Among those was both the running in human. And when the request for proposal went out in one thousand nine hundred eighty eight. Among those who responded was both a mannequin Newman. And they responded with a terrific. Proposal. Not only did they address the needs of the proposal. Of their code. But they did some additional engineering. They actually began to designed in that work in their proposal and so was present it was a very powerful proposal. The work there was supervised by Frank caught. Bob calling with a system design a. People like Dave Walden severe on Steen. Willie Crowther a number of others. All involved in putting together a really powerful Pozo. So when it came in. I was not involved in selection by the way that was done it. Oppa. They won the proposal. And I believe it was announced to them around Christmas time of one hundred sixty eight. And so in January sixty nine. They were launched with the task of providing this network. By the way they propose a particular machine to service this impetus. Router. Was a Honeywell D.D.P. five sixteen. They were not the only one to propose that mini computer in their in their response. That that particular machine. Was a state of the art machine with a very wonderful interrupt structure. So it could be interrupted by messages as they appeared and disappeared. Passing through the switches. It was a perfect machine for this job. OK so the. The idea that such a center should exist began to Germany in these early discussions will marry put together a bunch of us. It was pretty clear that we would need such a center. And so we laid out some specs as to what it could do what the software would do in terms of what kinds of measurements we would make. What kind of traffic would generate. And along the way. Larry decided that U.C.L.A. should be that network measurement center. Lard to because I was very heavily involved in proposing. The structure. And that was my expertise in terms of performance evaluation and measurement. So it was in mid sixty eight when the idea. Began to germinate. I believe that the formal contract to support me and my group was in early sixty nine when the contract actually came through. And it was called the network of the OP and that network management center and films of the team. There already was some auto worker the unsupported here U.C.L.A.. Out of my P.T.O.. And Jerry astern with the principal investigator. He basically had purchased a timesharing computer to be used for the computer science department and to conduct some of the research that we were working on largely his group. And he put together a software team of people like Steve Crocker like Vince or of by John Postel like Charlie Klein and. When it was decided to U.C.L.A. the network measurements and the contract. Came in my name. And the computer we were going to use as a host computer was this time sharing machine the Sigma seven. And so I inherited that software team from Jerry astern. I added to that some hardware people. And I basically append the that. My Ph D. students who are working on these problems from an analytical theoretical and simulation point of view. So the team consisted of a group of Ph The researchers program is some hardware. And some staff. Secretaries programmers and cetera. And it began to grow but that was John. Genesis of of the group that I was handling. Well. Your question suggest it was a process. It was a was a very casual loose process Laurie knew me he knew my work. He was able to allocate funds and he did. It was in a formal proposal. It was an agreement whereby I would look at the following kinds of problems. Helping about the capability for the network measurement. As

well as the analytical work to support. What these measurements. Should be what they meant. What the architecture should look like it said or was very informal. So. This. There was very little stipulated dream is very short contract. The work statement was rather short. The boilerplate around it was typically boilerplate which was standard for most contracts. But it did not specify that it did not specify what we should do specifically how we should do it. When we should do it over or. You know what tools to bring together what people etc. Was basically has a job to get done. Go do it. You decide how when. Just make it happen. Results were important. Not steps along the way. And so was a very wonderful arrangement. The. The concept that was prevalent in the environment at that time. Which Larry. So well exemplified. As did Bob Taylor. I did look lighter. The people at Opera was to be willing and prepared and anxious to delegate orthography to trusted parties. We know you can do something while you're in this domain. Go do it. Tell us along the way out what's coming if you like will help. If you don't help fine. Just make a result. Well in my own research. I came out of the philosophy that you wanted distributed control. In an environment be it a technical network environment. Or in this case. In a personnel. Personnel Management philosophy. These folks that I was working with here at U.C.L.A.. All very capable they were throwing in Ph D. students. Zillions protocol. Design is programmers. Hardware design is. And in many cases their software skills were far better than mine. I could see where they were going what I wanted them to do but I delegated in the same way that op ed delegated to us. Principal investigators. I delegated them the task. Make a host to him protocol. Think about a host host protocol. Ask yourself what happened to the network at large and traffic behave this way. And it was my own Ph D. student I work very closely with them. With this water group. I let them run. It was clear what they needed to do. And I delegated the same way OP was delegated authority. Because I trusted them. And that trust was well placed. That's a great question. The idea that this. Delegated authority approach. Was it really prevalent. Well. For the sites that I interacted with. I saw it almost universally present. For example. The folks at Utah. On the Dave Evans. I knew some of them. Tom Starcom I knew Alan Kay. In fact. Danny Kong was there for a while I've been settling with there for a while they was a magnificent manager and he did exactly that. He got some good people around them and let them run. Glen colored tent the bob or similar. Put together a group like that the folks in Illinois. Same thing. They were building. High Performance hardware. They let their people run with it a bit northern California Berkeley. Stanford those folks also had groups of very powerful. Graduate students and software engineers. And they let them run. When we get together with principle investigator means. It's not as if that particular topic was discussed. But you could see by the way in which the. The results were presented to each other we would describe our work. And how was done. It was all a graduate student. And the staff that they were running. Guided by the high level goals and and guidelines and capabilities of the P.R.I.. It was very distributed. Do you can do best. Without a lot of heavy overhanded oversight. So the answer was yes he was traveling throughout the community. With which I interacted. Them. Well I'll give you one example. There was a student here at U.C.L.A.. Was not in my group who hacked our central computing facility the campus good facility. And the university was repaired to discipline this young man and. My software group and I decided let's hire

him. This young man is capability. And we did with disaster. I want to say he was uncontrollable. Well one trying to control him but he did things that needed control. He went off the deep end. There is an example where you can basically bring in someone give them. Capability no authority. And the Libyans it misuse it and wonder what to do with it. So that's one example I can see from my own environment. This process. Of. What it is that the population. Well. The common characteristic was. If you find someone who's demonstrated capability than my own Ph D. student demonstrated that capability in the classes I taught. They performed well. They interacted with me out of class. I could see there was strength and creativity there. An example. I had a a freshman. You know nothing to me an undergraduate program or working with one of my Ph D. students. And I did not interact with them. But it became clear along the way that this. Undergraduate who was running a simulation for one of my advanced graduate students. Was explaining to the graduates to the why the results coming out of the simulation were they were. That's an example of demonstrated capability and creativity. I hired that young man he eventually became my Ph D. student. So it. And the same with the with the other software programs that came in there was like to because they knew their capability. They saw it they observed it. And it was demonstration. Not necessarily a test. It was out of the environment. Things suddenly pop up and grab your attention to some good work going on here. That person is doing good work. Let's bring the man. Sure. So the first thing we did. The first thing we did was to make sure that the Imp specification. Included. Measurement. Hooks in it's own architecture sorter architecture. Once the network began to be deployed in those first few nodes. We began to exercise some of the capability. The folks from B.B.N. came out here bought conking out here. I had my students Bill Naylor. So example. Begin to run some tests. We ran tests we made observations. We saw things that. First we didn't understand them by looking at the underlying structure and the theory. And the expectations the engineering. Yes he is why it's working. Nice surprise bad surprise. Is an error here let's fix it. So we can to make measurements early on we began to report them internally. And then eventually in public papers. There's a one hundred seventy four paper for example that my student Bill mail and I wrote which went over. What the underlying capability of the measurement software was and what some of the results were. However it was B.B.N. that implemented. The specs. And they added their own capability. They provided the hooks. They decided how they should be visible to the programmers to the uses of this network measurement center. And there was very much involved in bringing about the measurement capability. But ironically once we had this measurement capability. We took it as as as a given that it was our job to try to test the network and see what its capability was not at the test a network you have to stress it and push it to its outer limits. And so here you see a we did that in a very purposeful way. In a coordinated way. We tried to send a lot of traffic to one node. We tried to send a lot of traffic everywhere. We tried to trace packets. And in so doing we would often. Uncover problems in the network protocol design. Which is the whole purpose of the network measurement center the whole purpose of an early often that experiment. And we find these areas. We'd call back to B.B.N. particular Franco and say Frank. The network just behave this way. He really needs to be fixed. And we do expect them to fix it and eventually they would fix it. So the interaction with B.B.N. on the

softer that we had to help specify that they had helped design and build. And then that we had been exercising and running. Was a very interactive. Relationship. They didn't always fix the problems as quickly as we would like or Eventually we were given the code. Of the operating system of the amp. So we could tell not only what was wrong but how to fix it. And so about interactions place over a number of years. And that continued until one thousand nine hundred seventy five when the. When network measurement function. Was taken away from op or and basically given over to the defense communications agency. And at that point we stopped making formal measurements on the opposite. But. Yes. Yes as I say we stop making measurements at that point. We were no longer basically contracted to do so but by that time even earlier in the early seventy's. There was a whole of the wave of research and technology. That was beginning to manifest itself. And that was the whole radio technology the wireless technology. In fact in the very early seventy's. Norm Abramson made an appearance at Opera and made them aware of a network he had been developing at the University of Hawaii. Called a lot on net. Using a particular wireless protocol called Aloha. And that piqued the interest of a number of us. Liar Rob is it OP or in fact did some interesting research on and extending some of the work that. Norman done. We had U.C.L.A. saw that as a very exciting interesting. Communications problem. How does one manage. Communications in an environment where everybody is stepping on everybody else's communications in this wireless world. So we began to do some research here at U.C.L.A.. Off of began to do some implementation and kind of to the to the Aloha net. Following that there was some work on satellite communications. Also wireless technology. And then the. The broader concept of a multi hop. Wireless Network. We deploy radios in a disaster situation in a military situation and have to create an ad hoc network. A mobile ad hoc network for data communications magnificent. Issues very hard problems still many of them unsolved. Today. As to how to exploit the wireless technology how to model it. And that led to a great. Basically not a shift but in a large amount of the cons work we were doing here at U.C.L.A.. This. This. OK So let's look at the work but that a deal with the I love. We are making measurements. We measured. We measured instances of network. Deadlocks and lock ups. Many of them were predictable. Some were surprises. We measure things like store and forward lock up. Like reassembly lock up. Like Christmas lock up. We had these interesting names for these these ways in which a network would freeze because of protocol issues. And it was never the measurement Center along with not only Bill mail and myself what other students as well. And some of the folks from B.B. and Bob Kohn A particular was very interested in making these measurements and evaluating them. So we began to report on them. Publications came out. I had students working on a number of areas here. Why these deadlocks were occurring. What kinds of protections we could have to prevent them. And so my. My research group was doing a variety of things looking at routing issues. Looking to deadlock issues. Look at the protocol issues. Look at design issues. Look at a performance issues. And as I say. Began to move into some of the radio issues as well in the early seventies. As I say. I work with one of my students so I'm in lamb. To look at the performance of this aloha protocol that agents and it produced in Atlanta we had extended. Larry created a thing called slotted Aloha. And we found that that particular protocol was unstable. Something I was unknown. The time we recognized just by looking at the performance characteristics it would

go unstable and it did. And then we showed ways in which you could protect that lead up. Lead to what we called a back off. Algorithms which are now used in Ethan it example. Another issue was that Abramson came by a second time and introduce some the core carry a sense multiple access in Aloha what happens is you transmitted a time you want. And if somebody else is curious meeting you're going to step on them they're going to step on you and crash nobody gets through. In carry a sense multiple access before you transmit you listen to the channel. You carry a sense. If you send somebody else's using that you keep quiet. Now. I was sitting with one of my students forward to bodgy at a meeting where a simple center that. And they've been presented an equation describing the performance. And I looked at for Y. and he looked at me and he said that doesn't look right. So. I believe that this meeting took place. Some with the Midwest and Texas I think somewhere on the way home on the airplane he and I solved that problem and that led to a whole study of carry a sense multiple access which led to a variety of it up in a box for the whole field. And it's that kind of architecture that Bob Metcalf uses we know for Ethan it. This. Ha. Does not. And. He's. OK. So we were doing this work at U.C.L.A.. Writing papers. Giving lectures giving presentations. Pumping out students who typically would go to work at universities or research laboratories. And you would think that B.B.N. was the natural of the sippin of this information to prove or modify the way they were and large in the network. That was not the case. The interface the impedance match between our work. Our analytical and performance evaluation work and networking here U.C.L.A. and elsewhere. Did not then and still does not to this day. Easily find its way into implementation. B.B.N. on the Frank ought to diligence and direction. Was clearly an engineering organization committed to deploying a network. Maintaining it and running it. And they really were not interested in innovative. Or disruptive ideas. That would cause them to change the design specification characteristics and implementation. So we did not easily find its way into their wrecked networking design. Eighteenth he was not A.T.T. didn't come out with a pack of networks one hundred eighty three years. It has. You. I heard. Well op or The A stands for advanced advance research. They were always interested in looking at future architectures new architectures improvements to the network understanding and architectures whether or not they got implemented immediately. And so their philosophy was. Let's not think so much about today's systems. But let's anticipate will going to need in the future and lay the groundwork now for intelligent decisions. And so they were very happy to continue that kind of support. But in fact it was then that was prior to then it still today the fact that the theoretical research that people do. And the world of implement this. Are really two separate worlds. They don't speak the same language. You think the interface would be a natural one would have results. Have impact on the physical limitation. But you know engineers and programmers. Typically just want to build a system. And if it works in quotes. Fine. Let's run with it while in the analytical and evaluation. Works is a very loaded word. How well does it work. Does it have a fail. What's the cost. Now courses course and engineering thing that industry so much concerned with. But the idea of performance can you double the performance. Last I really question that the implementors ask up front. Once it's running they're happy to have an embedded investment now. What they've built. And so the implement implemented and the design is. And the theoreticians that interface is a very poor impedance match

as I said earlier. OK There were a number of researchers and. P.R.I.'s mainly researches. People like Norm Abramson who brought in some of the wireless thinking. There were people up at SRI with the network. Information Center and. We work with them in terms of providing a result for them and trying to match their formats. I met with a number of P.R. is the wonderful P.R. meetings in that year. Those P.R. meetings were phenomenon. So often had an annual P.R. meeting where they gathered all the P.R. is that they were supporting in a potato. And it was a rather small group maybe twenty P.R.I. from across all the disciplines they were supporting or you see Minsky There you see McCarthy There you see the the hardware guys Slotnick from Illinois. All across the community. And we would present. Our basic findings in a collaborative way. And you would learn about things that were really at the Vance's of technology. At the forefront. That are not yet been published. Was still works in progress. And it would influence your thinking the graphics work at Utah for example. The in to change among these really smart people. Critiquing each other's work. When they themselves are not experts but they could look at it from outside the field. And either say. Well he is an approach that makes sense or he is a relationship we know from our domain. Which seems to have an impact on what you're doing it may be a cooperation or a shift in focus or a new insight. Those And those are boodle meetings in the center of brutally honest. I mean there were criticisms no holds barred it was not. It was not mean spirited. But it was intellectually honest. And the curiosity level is was very high. One small anecdote I remember. By the way these meetings were held up at most the AT ALL to Utah. Many of them are. And we'd sit there in our ski clothes in the mornings waiting for the meaning to. And right after lunch so we get up on the slopes. And we could see the slopes from the alter lodge ride. So was a wonderfully exciting environment. Full of intellectual and physical challenge and simulation. But one of the stories I wanted to say was the one meeting a began in the evening John McCarthy arrive in Iraq late about fifteen minutes late. And he sat there in about another fifteen minutes. He piped up in the middle of a piece in Taishan I forget who was presenting and McCarthy says you know. I have no idea what you're talking about. And he McCarthy then added But I know I was like those fifteen minutes late. So it's understandable however I have a feeling for Iraq here on time I still would have no idea what you're talking about. And that's the kind of direct challenge you know say look you're not making sense body. And of course the reaction was very positive and you know. Went back explain try to articulate. And the little exchanges were just examples of these brilliant. Researchers going through a process. So the P.R. interaction was was very good. From other fields. They were NOT topic specific they were not you know. All networking people all AI people know. It was a whole group. And for example. I mentioned. Dan Slott naked Utah. At the to me University of Illinois. He was building the machines. Talking about how to get high performance in machines trying to use Paolo processing. Really advanced hard problems many of which is still not solved today. So it would influence your thinking there was an insight. Well. You'd want to try to hide the latency. In a power system. Well let's do that well gee that applies to networking as well. So the interaction of that level was very strong. Some of the graduate students at these institutions at these P.R.T. supported groups office appointed groups would travel there was a lot of travel among the graduate student population. I think the member Alan Kay coming here from

University of Utah. While he was a graduate student. And we had a wonderful discussion about the work he was doing the work I was doing in our group was doing. And the stuff that Dave Evans was doing. So it. It wasn't specifically focused on the topic. It was more an environment and an approach and an awareness of new ways of thinking about problems. And the potential applications. Now one community that did. Interact across many sites. Was a simulation community. There was work taken place at I.S.I. at U.C.L.A.. At MIT at Ball Pernick and Newman. And in fact some of that and the simulation. Work was about networking for example or applications that would live on a network. And an example of how that led to an interesting. Demonstration of collaborative work. Was when we ran the October one thousand nine hundred seventy two. First public demonstration of the opposite in Washington D.C.. What we did is we brought lots of toys toys in terms of demonstrations for the public to see. And one of them astray sions was a distributed simulation. And I believe that Danny Cohen was one of those. He was working at I.S.I. the time was responsible for big piece of that. The application was. It was an air traffic control situation were simulation running in Cambridge Massachusetts I believe was on the B.B.N. machine which started simulation of an aircraft taken up. Taken off. Out of the Boston has space. Flying down the East Coast. And if it cost over the New York area. It would shift. Control to the air traffic control over New York. While in the simulation of this. The control actually shifted to another computer. Pretending to be the New York. Air traffic controller. And I think approach Washington. Yet another computer would take over. So this is a distributed simulation shared among many machines. Passing control. And that require the cooperation of many people in the community. To bring that about was a very powerful demonstration. As an example. This was a loss of moderately. I want to say well I don't say well no partially in that community where ideas flowed back and forth freely and without proprietary feeling. Without jealousies. Certainly among the research community. That was the main place but the thing I described is P.R. meanies were the ones annually. Focused on generality. There was some smaller meetings smaller group more focus groups like the one we're able to an attendant talk to us about the C.S.M.A.. That was a meeting focused only on networking. And in those times you get much more deeper interaction among the people working on specific problems. The graduate students would attend that the P.R. meetings typically graduate students were not present. But the more focused meanings they were. And the collaboration that took place there of course was very natural and the students. Basically perpetuated. That interaction even after these meetings on their own. Using the OP a net as a communication medium. As well as the the airplane industry when they would travel and meet each other there was a lot of travel. Among the researchers and the graduate students. There were other contractors we worked with with B.B.N. it was a very strong. Interaction. Although I must say that the two research groups. Commit the two groups. The research and measurement group here and implementation and money and group of B.B.N.. The interaction was a little bit weaker. It's more segregated first it was a country apart. And secondly the focus was different but there was a lot of interaction but it wasn't. It was somewhat competitive as opposed to collaborative. Because we were the. The bad guys. Breaking their network. And they were the bad guys not repairing it fast enough and we were creating the software group. New protocols. And they would have to implement a B.B.N..

And the time in there. And in order to him to create those new protocols we need information from B.B.N.. As to the specifics of what they had implemented so we could see what the modifications would be that. In the change was OK it wasn't wonderfulness. So at SRI the main interaction was with the folks at the network. Information Center. In terms of formatting. Presenting them. Reports letting them file them away and thinking about the largest truck however the Gangle bot who was running that group who was one of the augmentation group there. The knowledge augmentation group. His ideas were flowing freely. He had brilliant advanced ideas. And they seed the community. Into various ways of thinking ideas like of hypertext were coming out of this thinking. Just knowledge acquisition and application. There was in the wireless effort. We work with Rockwell. Collins in implementing some of these packet radio. Ideas and test beds. Network Analysis Corporation. On Long Island. Glen Cove Long Island. They were how Frank who ran that group was a good friend of mine. We had interacted way or early. Even before the op in the idea came about in the early sixty's. In fact I recall he was very upset when my book came out. Because it used the title that he wanted to use called communication that's because he was working on network flow theory which is a related. Area focus on the graph theory side. I don't even read Network Analysis Corporation his company was contract by author to do the top a logical design which was then implemented by B.B.N. in their deployment and analyze in other aspects here at U.C.L.A.. Worked with that group I knew most of the people there. In fact one of my students went to work for them. Upon graduation Mario jailor worked there for some years. How we Frank Ivan Frisch. Tannic Lightman very strong powerful group. So the interaction. Was not by fear. It was by interest. And by opportunity. If some was doing something. We had to help. Have them help you implement or you receive in their results. Then they would be an interaction. So I'd offer. The structure was there was a director of Doppler. There was an office director of the information processing techniques office the computer group and. Bob Taylor was the office director. When I came on in sixty six. And I and I worked with him through sixty nine Laurie eventually took over that position liar Roberts and beneath them were program managers and these were the people who interacted more directly with the P.R.I.'s as time went on in the early days. The Office director did a fair amount of specially when Larry was Office director. He serve the role of director. As well as if you will program manager. He interacted with the people he was supporting because Lariam self was as capable of researcher. As any of the P.R.'s he was supporting. He had ideas he had great ideas. He could help. He could could take he could Ed And so the function of a program manager was basically to to be the direct contact for the P.R.I. to Apia and to discuss results. Not to be given directives. But to interact and if the program manager was strongly capable. In the domain that you were working on. There'd be a stronger interaction. Because they could see the rest of the community as well as you could. And typically they were some of these program manages would have been perfect principle of us to get this through gravel Steve Crocker one of my phone software. People here. He had charge of my thought i go. Who is a Ph D. student here as well. On the Jerry astern. He went on to opera and Vince arrested. So these guys were powerful. The interaction with him was very strong. But while I was in the early days of P.R.I. with Laurie Rob It's like Robert didn't have many program manages. I mean Barry Wesley was sort of a program manager

at the time. And we interacted some with him but. Barry wasn't specifically technical. Larry was the strong. So the interaction. From my viewpoint was strong doing Larry time and after Laurie. Bob Kahn stepped in. Bob look. Strongly at the packet radio material. So Bob and I had a very strong relationship as well I knew Bob from way back in the early days. So in my particular case the interaction was relatively strong because the. The OP or office directors were very well first in the technology I was working on. In other cases. He was not a strong. And some of the program manages were not as well versed in the research that they were responsible for. So the interaction was on and. If you were on an opportunistic. Self. Driven interaction it wasn't a dominant oppressive. Oversight role that the PM Saturday was one of cooperation and. Show me good results. Yes. It's exactly right. It was one where. If there was value to be gained in the interaction. That would bubble up. But it wasn't one of dictum that we shall do this about shalt not do this and a kind of. Oversight for. Bureaucratic reasons there was no sense of Burak receive here at all who was a very I'll use the word casual collaborative flowing environment which engendered good ideas to bubble up. And good results to come out. It was a much more relaxed. It was not a competitive environment. There was no sense that you were competing with others. For the access to the funding. There was competition. To do good results. You know. My results. As good as yours. That was an academic a scholarly and. Approach. As opposed to a funding. Business competition no there was none. And I'm assuming I'm talking about the sixty's. As the seventy's evolved. Things change them. Too. So as the seventies rolled around in the the Mansfield amendment came in and and put certain expectations on how the government funded research. Few things happen. First of all the OP a budget actually increased. And so the number of P.R. has increased. And so the P.R. means got to be unwieldy. Unwieldly just too large and so some cases they broke into the specialty meetings. So the cross collaboration. Was lost. Even the special the groups got very large in the media became more formal more structured rather than easy flowing. Ideas. The idea of a broad area announcement came in I forget exactly when it did but that meant. In order to get funding now. It was a kind of competitive environment where you responded to a request from offer for a specific kind of research. With focused goals. Focused deliverables focused timing. And so it got more bureaucratic. As you move through the seventy's. The need for reporting. The number of site visits. The project reports. And the oversight. And the the flexibility in terms of where the research could go. And what domains it could occur. What the manger could cover. And how far out. And how finished. The results were all pulled in and got tighter. As time went on and the. It did change so most of the culture I described to you was in the late sixty's in the early seventies. Not into the late seventies and early eighty's. That was. Was So the answer is yes and no. For those of us who are fortunate enough to be funded in those early days where the basic philosophy was. You're a good researcher. You've got some good ideas. Yuna good domain here so money. Go investigate that domain. Those of us who rose up and not Iraq. And were funded. That way with large amounts of money for long durations. We were lucky in that that kind of funding. Approach. Persisted in a somewhat diminutive way. But the idea was that there are a new PM or a new office director would know that you missed a P.R. I have been doing the work your Minsky. We're going to fund you. And even if there's a B.A. and you

respond to it. If you send in something reasonable. You know you're going to get funded. But for the younger generation of new researchers which is now increasing in numbers of such research is it did become more competitive. And in order to accomplish that competitive process. The researches basically. Listen very carefully to what the broad area announcers were asking for and directed their replies in their research goals. Very specifically what the BE A was saying. Instead of having a sense that. Yes I'm moving to this area. But there's much more I'm interested in and is a bigger picture that maybe the BE A is not expressing the in clinic in inclination was to narrow down and limit. So that one would win the award and that was a slow process. And in my mind a very deleterious process. That limited the vision. The the. The nature of the results. And the the environment. Yes. So it's easier to answer the first. There were many influences this was an community that interacted. We published papers. We had P.R. meetings. We had focused meetings and. Besides having collaboration. Through the opera. Umbrella. We were collaborating. Through the academic and research. Umbrella. If you will. There were reasons we needed professional meetings. So the interaction is very strong in there was a very easy flow of ideas. And one always knew pretty much where the front his work. There were not hidden like in days of yore from the seventeen hundreds. When the researches hid their results. We're publishing we are interacting and we found it a a very open an effective way to work after all our graduate students were moving all around the country in the world. Interacting with other research groups and. So those philosophies were brought back. It was an unconstrained easy flow. Exchange of ideas and issues and problems to look at now in terms of the imposition of constraints by the funding community. There were they were not strong from my viewpoint. But I could see it appearing. Elsewhere in the B.A.'s in some of the research projects that were being funded. In the. If you will the. How far out. These research efforts. Which Reiner reach who's pulled in and it became apparent without ever saying so that failure. Was unacceptable. Was in the early days fairly was perfectly sceptical. In fact. To say it. Stronger failure was expected. Because if you want failing. You won't reach it hard enough you don't know when you're at the Baron de of of a hard problem to go beyond that and say ups. That won't work. Let's try something else. So that whole notion of being able to fail and not be shot or actually cute it was a wonderful environment a work in these younger researches. As we move forward in time. Didn't have that sense. And there were correct. They had to produce. And so there were more constraints put on US time went on. But not in those early days. I mean there were specific target. To in some some of the problems in the wireless world. To deliver. I remember a PM coming out one time. And talking to one of our younger researches of say what the problem. I want you to work on. And I just was those words here. The problem I want you to work on is to deliver two bits per second. Out of the foxhole. Liability in a battlefield environment. That's a very specific short term. Not easy but not broad. I mean. Compare that request to come into research or and say. Build me an internet. I mean it. That second approach just opens up a whole vista. Of wonderful things to look at and breakthroughs to to find them and go through. Was this little two bit out of the fog so well you know. OK Our focus our do it for you. But we're What do we gain. What's the brilliant idea what's the breakthrough. No. And that I think those are two ends of a spectrum of the way. The shift

took place. As time went on. This. So you're quite right. The idea of exploratory research looking at hard problems with no known solutions. With potentially wonderful. Vistas and applications. Was created the main I prefer. I that was my personal choice. As a graduate student and from then on. I think that's where the. The impactful results come from offer support of that kind of research. It's what we call six point one money. There was a strong element of six point two money as well. You know the the developmental research if you will. And I lived in both domains. The the research I did on networking. From a theoretical point of view a six one. The OP in a development was six to kind of work but within that domain I continued to six one. Looking where could the OP in a technology go and take us. Radio. Exploration is such an example. So the trend toward less six one and more six two and then eventually six three. Is a trend that has taken place over the years. And I think it's deleterious I think we need to focus more on the. The big thinking. The the long range. Far reaching high risk high payoff. Kinds of problems that offer was so supportive of in the early days. But it has been a migration. Up the numerical change from six one two one six three. Well the motivation that was very clear in my mind was the need that Bob Taylor expressed to connect together the principal investigators the researchers in a network so they could share each other's resources. What kinds of resources. They computing resources the hardware software their services their applications and ability for them to interact. Now. The ability for people to interact in that environment. Was not in the original driving motivation. The original was to let people share resources. People to machines machines machines. The. There has been lots of discussion in the media about. What did motivate oppa. And the. I'll call it an urban myth is that the OP in a was was conceived of in order to protect the United States against a nuclear attack. And to provide a survivable network. And I was there at the time when this network has been cvs and implemented. And from my point of view as a researcher and a developer. That was never the motivation at all. It was as I said to do sharing of resources. Machine services applications etc The. I have no idea what took place at the upper echelons of of the military of department defense of opera. But from my point of view and from my colleagues point of view as far as I know there was no such motivation it was merely to allow these machines. And people to interact. Through this network resource sharing was the key idea. Since. So this is almost a summary of the kinds of things I've talked about but if you asked me to focus on them. I'd say it involved. Long range funding. Large amounts of funding. High risk high payoff. Approach. That was except the both failure. Acceptable. Not competitive. Well you're fighting for resources. But you're cooperating with resources. With the program managers in the office direct this costs more knowledgeable helpful. And not involved with oversight and imposing constraints. But rather removing constraints. To allow you things to flow. The idea of. Again failure was acceptable. Was a very important component. The the lack of a lot of site visits. Project reports. Meeting in the usual. Paraphernalia. Of corporate management was not present. And again the lack of competition for these resources. Was very important not fighting. Your fellow researchers for a finite pool. It was it was not a sense of it all you had to be good and it. And the idea taken pride in what you're doing it being. If you will. Rewarded for the nature or the results. And the the quality and the and the. The risk you took and the successes he have had and. And also the idea of being able to support a

group of people to whom you could delegate. We felt we were delegated authority the things we needed we delegated of that authority. Down to the people around us and below us. So they could shine. And it was a research. Engineering. Though it was not a business. Production. Profit making approach. It was all about the wonders of research and science.