Interview of Gordon Bell

Interviewed by:
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Gordon Bell: Basically, I'm a technologist at heart that, although a computer guy, I really believe that I have to credit the evolution of semiconductor density as the main thing that's driving us. I will give virtually no credit to the individuals per se, after von Neumann, except I do credit Cray with some architectural ideas, so I tend to credit everybody else as kind of pluggers, and von Neumann and [Seymour] Cray as the few original thinkers in computing. Anybody in the circumstances—for example, I don't consider the microprocessor an invention, per se, because it was simply the evolution of the fact that that density—we were all talking about processors on a chip long before they happened. The computer people were doing it. Once they saw semiconductor density increasing, they said "Oh boy, this is going to be great when that happens." Now, I'll say the reason computer people were not interested initially in semiconductor microprocessors, were they weren't really real computers. The 4004, no computer person would go near a 4004 or an 8008, etc. "We're having a lot more fun. Why go do that?" So I say Ethernet was...

James Pelkey: You must put Grove and Intel people as high on the list.

Bell: Oh, yes.

Pelkey: At the integrated...

Bell: Sure, because they were the guys providing the four, the forcing function. For example, here's how I consider the evolution that had taken place. If you look in generations, you start with the single transistor and what the components were, and as you moved into the various generations, you got different capabilities and finally in the fourth, fifth generations, you started getting these...

Pelkey: Computers

Bell: Processors, then computers, and then things like the transputer and stuff where you're integrating a whole system on a chip. Then, in the late '90s, shit, there's nothing I can think of today that's not going to fit on a chip, by even the most conservative means. So that's the long—that's to set my bias about invention and where I think things come from, so I would put the mini as the driving force for ARPANET [Advanced Research Projects Agency Network].

Pelkey: Right, it was.

Bell: Because the availability of that—in fact, I would ask you...

Pelkey: I think there was a second factor. It was not only the mini, but it was the desire to not have to duplicate the work of a few people...

Bell: Oh, that was a need. No, no, no, I'm talking about technology drive that's market pull.

Pelkey: The mini.

Bell: Then, these ideas of packet switching and stuff like that interfaced fine. Anyone would have invented them, and I claim, if you look—I think you ought to look very carefully now, because I think you will find inside of TimeNet—what's the network that came out of here?

Pelkey: Tymshare? It was Tymshare versus Telenet.

Bell: Oh, no, this was much earlier than this. The guys who had the first SDS-940s—was that Tymshare?

Pelkey: I think it was. In terms of networking?

Bell: In terms of providing network services. Is it the Tymshare network that's still in the news today?

Pelkey: Yes.

Bell: Okay. That network, I believe you will find packet switching in that.

Pelkey: You find packet switching, but you find it not what we call 'packet.' It's a message-based system, but it was refined for a timesharing application, as opposed to a general purpose kind of X.25 and so on.

Bell: File transfer—sure, but it was at...

Pelkey: But it's the same architectural concept of using the channel more efficiently...

Bell: And that there was multiple routes. It was a network, as opposed to a tree, and then also, as you get into IBN, if you look at the Sabre System and stuff like that, there were multiple routes on some of that, although they had really Crum and DataNet-30's and stuff like that, and I believe you'll find crude equivalents of ARPANET prior to ARPANET.

Pelkey: Although Tymshare came well after this fact. Mid '70s.

Bell: I thought they had...

Pelkey: The timesharing applications are all star configurations, point-to-point modems...

Bell: I thought they had...

Pelkey: You never really had any of that in '65 '66. Way back when—I started this last fall—this is the chart I drew. Data communications has these overlaps, and I'm going to treat these as derivations of this structure. I had technology. I went out and talked to a bunch of semiconductor people, and said "What are the profound implications of semiconductors?" The first one happened to be the op-amp, operational amplifier. You had to take the operational amplifier down before modems could become economic, because you couldn't do logic design and so on, because these things were big clunky boxes. That was in the mid '60s. Obviously the Ethernet controller chip, the LAN controller chips were a specific <*inaudible*>, but was not...

Bell: Sure. Well, shit, that wasn't until 1980.

Pelkey: Now, the microprocessor memory, you couldn't have had all this without that, but when you start to think about semiconductor chips that were specific, you think about the fact that there were some chips that related to the communications industry, but for the most part, the people haven't gone out and built chips with data communications in it, as they did for voice (i.e., the Codex chip), but they didn't for the data communications industry.

Bell: Right. I agree.

Pelkey: The UARTs [Universal Asynchronous Receiver/Transmitters] was...

Bell: Oh, but we did that. That came out of DEC [Digital Equipment Corporation]. I invented the first UART.

Pelkey: Did you really?

Bell: Yes.

Pelkey: Now, when did you do that?

Bell: That was in 1962, and that was built around an IT—built to do telegraph-line switching for ITT. We built eight UARTs in a rack this high, built them out of those DEC modules, and then the next—I think it was '64 or '65, we took—they were built discrete—I mean, just wired up. Then, we took all the logic and stuffed it on a large printed circuit board about that long—the receiver and the transmitter—and so we had the receiver and the transmitter on two separate boards, and then once, in 1970, '72, we made a deal with General Instruments or somebody like that to integrate that and put that on a chip.

Pelkey: GI, I think, <*inaudible*> said was the first place they recommend, and thought the UART came from...

Bell: Yes. DEC drove that, and it was based on the design that I did in 1961, '62, namely the notion of counting from the transition and then building this little state diagram that sampled the line the right number of times. Ultimately it got more sophisticated; their integrated, usually can handle noisier lines, but basically that whole thing.

Pelkey: But the semiconductors have been an enabling technology, but not—it was driving in the sense that they made the economics cheaper, so you opened up more and more applications, but it hasn't had as big an impact. The markets haven't been large enough for semiconductor companies to focus on data communications. They're beginning to now, the small start-ups around here are.

Bell: Well, but I submit that that's because of the telecommunications industry, the structure of the telecommunications industry; the fact that prior to—it has been controlled by a single phone company, and that's what's done, and the phone company is not effective.

Pelkey: And the prohibitive factor.

Bell: Oh, yes, they had their own semiconductor facilities, and they haven't gone outside, and they haven't—nor have they innovated especially.

Pelkey: The latter for sure, even though they had a local area network in the late '60s—[David] Farmer/[John] Newhall. [John R.] Pierce, that loop.

Bell: Oh yes, Pierce loops and all that.

Pelkey: They owned the modem business at one point in time, and they let that get away from them.

Bell: That's right.

Pelkey: They were offered the ARPANET, to build that, in '67, and they turned it down

Bell: Yes, I was part of that, and I tried to get them to build ARPANET.

Pelkey: How were you part of that?

Bell: I was—when that was happening, I attended a lot of the early meetings, the ARPANET meetings about what to interface, what the interface was going to be.

Pelkey: Where were you then?

Bell: I was at DEC. I went to—I was a consultant at DEC at that point. I was at DEC from '60 to '66, and then I went back to DEC in '72. I was at Carnegie from '66 to '72.

Pelkey: Okay, so you were a consultant. Were you doing anything other than consulting?

Bell: At DEC, no, I was a professor...

Pelkey: At MIT [Massachusetts Institute of Technology]?

Bell: At CMU [Carnegie Mellon University].

Pelkey: So you were a professor at CMU in the early '60s?

Bell: '66–'72.

Pelkey: What about before '66?

Bell: I was at DEC.

Pelkey: As a full time consultant?

Bell: No, full time engineer in charge of computer design there.

Pelkey: How did you become aware of the ARPANET and how you did you get involved?

Bell: Oh, I was part of the ARPA community, one of the consultants to ARPA. There is an ARPA community, you understand?

Pelkey: Yes, because Licklider did his first interactive timesharing computer, if you will, on a PDP-1 at BBN [Bolt, Beranek and Newman], in '62.

Bell: Yes.

Pelkey: So you were aware of this activity going on?

Bell: Oh, yes, I designed the drum that he used, that BBN used for timesharing there. In fact, the first—we don't know where the first timesharing machine was exactly, I think you have to go back and look at it—but the PDP-1 was maybe the first one, because we had a swapping drum that we used to swap programs and share <*inaudible*>.

Pelkey: So you were aware of what was happening in the IPTO [Information Processing Techniques Office of ARPA] office, the creation of that, and what was happening. When did you first become aware of this concept of an ARPANET?

Bell: I think right at the time it happened. I can't remember when the taxi ride thing was...

Pelkey: That was in '66.

Bell: Yes, that was...

Pelkey: Were you at the Michigan meeting?

Bell: I think—let's see…

Pelkey: It was early '66.

Bell: I'm trying to think whether I was at the Michigan...

Pelkey: That was the cab ride with Wes Clark and Licklider and Roberts where the idea of the IMP came up.

Bell: No, no, I don't...

Pelkey: And then there was a subsequent meeting that went on, where [Keith] Unkefer and [Leonard] Kleinrock, Shapiro, Baron and Taylor in Washington, D.C., in the spring of '66.

Bell: Okay. No, I was not part of that. I attended meetings later on when we were talking about the interface and what that was going to be...

Pelkey: Now this is after BBN won the RFQ or prior?

Bell: Right around that time, and in fact, a friend of mine bid a DEC machine against the BNN...

Pelkey: For the RFQ, which would have been in '68?

Bell: Yes. Tom Merrill at CCA [Computer Corporation of America] was trying to get that business.

Pelkey: Okay, and Art Carr was there at that time, too. He was there before he went to Codex. He went to Codex in '69. Tom Merrill was—Tom Merrill had written a paper with Larry Roberts...

Bell: The first timesharing thing.

Pelkey: Yes, and he was at Lincoln Labs.

Bell: He was at BBN at the time.

Pelkey: So you were aware of this bidding process going on, and aware of the design concepts, and obviously had interactions with BBN. Did you know Bob Kahn at this point?

Bell: Yes, I had just met Bob.

Pelkey: DEC obviously didn't bid the...

Bell: No. Well, we bid it with CCA.

Pelkey: And obviously didn't get it. Did you or DEC play any role in '69 or '70? You were never a node.

Bell: Not really. The role we really played was supplying PDP-10s like crazy as the hosts.

Pelkey: Yes. Then you left in '69?

Bell: No, I left in '72. I left in '66. I came back in '72, so I had been following the ARPANET, and what I did at DEC was got Stu Wecker to reproduce all the ARPA stuff. The place I disagreed with ARPA was the fact that hosts—whether hosts could or couldn't be IMPs [Interface Message Processors], and all the DEC work was based on the notion that a host could be an IMP. We were building IMP-sized computers,

so I didn't care whether you actually computed on that, too, or whether it was switching and computing, and everybody said "No, you can't ever have switching and computing in the same box." No, we've got so many computers, we're not going to force our users to have a whole switching network with IMPs around. This is crazy, because if you want to put up 20, 30 machines, no big deal, because communications isn't the end, it's just a capability that you want these machines to have. So DEC-Net was predicated on this other notion, and by the time we got—when I looked at—DEC got, I don't know how many computers they've got running DECnet together now, but on the order of 10,000 or so. When we built that net, the engineering net, because at DEC—and I think we, at DEC, at one point certainly had the largest network in the world—based on ARPANET ideas, but as load increased, you would essentially—you would no longer have the—you go to another IMP. You essentially make an IMP there. The site machine is doing—Here's the main site machine doing all the switching, and then also you want to collapse the net so that you don't have as many hops. You're trying to minimize hops and you're trying to minimize...

Pelkey: So therefore it would be natural to gravitate towards an IMP when you had the density.

Bell: Sure.

Pelkey: Now, when did you start DECnet up?

Bell: The DECnet research activity was started in '72.

Pelkey: When you came back?

Bell: Yes, and DECnet phase one, and the coalescing of DECnet to have a product—I think our first DECnet I or so was probably 1974, '75. The guy...let's see, I was just trying to think. Oh, the guy you really want to get in this is Stu Wecker. He's at Technology Concepts, that's recently been bought by Bell. He was just awarded the [Koji] Kobayashi Medal of the IEEE for his work on DECnet.

Pelkey: Where is Technology Concepts?

Bell: In southern Mass. He can basically talk about all of the origins of DECnet.

Pelkey: That was very important.

Bell: Yes, because basically we went off and created—I think created something substantially better than ARPANET, and in a commercial environment. The problem with it was we absolutely did a shitty job of putting it out into the world…standardizing it. We didn't claim it was our—was proprietary; anything like that, there's a mistaken belief in the world that DECnet is a proprietary network. It isn't. It's just that the—the protocols are well published, the protocols are well defined, anybody can link into it, it's just that we really didn't support—we didn't go out and sell...

Pelkey: DECnet independent of your own systems, therefore it's perceived as proprietary.

Bell: And I tried to get the engineers to go into the standards committee, and they were really loathed to go into that process, because it's a very hard, time-consuming process. Then, ultimately, DEC had to join with ISO, and in fact DEC has always been good at the standards world.

Pelkey: Did you really just kind of pick up what was the ARPA technology?

Bell: No, absolutely not.

Pelkey: So you went off and created your own?

Bell: Yes, but with all the knowledge of what was there, because—my hang-up on ARPANET has always been BBN. I think BBN had...

Pelkey: The subnet level.

Bell: At all levels. I think BBN has damaged the—has significantly impeded...

Pelkey: —the evolution...

Bell: I mean, for a tiny company to have become what I consider to be a retrogressive—they are probably one of the largest small companies I know. Very, very poor company in every respect. They did the worst of the worst. The government funded it, goddamn it, and I own that stuff. The stuff was—sure they published papers on it, but then they tried to—they got government funded R&D and they kept it proprietary.

Pelkey: Yes, I've talked to a number of people about that issue in '73, when other people wanted to build these ARPANETs. They just refused to give the technology out to other companies.

Bell: I think that was—I think the government, compared to giving everybody cars, which the government is doing now or something, I think that was a form of illegality that shouldn't have been allowed. Particularly that the protocols—fine, they can have the code or any of those kinds of things, but goddamn it, that stuff should have been standard.

Pelkey: Now, there were two issues. There was the BBN 1822, which defined the interface to the subnet between the host and the IMP...

Bell: Yes, but that had to be done. That's one of the things I had worked on...

Pelkey: The host to IMP?

Bell: Yes, to make that a clean interface, but Jesus, this other part...

Pelkey: Yes, the subnet stuff. It's really unfortunate.

Bell: Now, when DEC picked up on DECnet, in '72, you had this embryonic host-to-IMP protocol that came out of the Network Working Group and so on, but it wasn't until Cerf came out here to Stanford and you really started to build up TCP. That happened in parallel with DECnet. DEC built its own layered protocols.

Pelkey: Was there any communications between the stuff that was happening in ARPA—TCP, Cerf...

Bell: You better ask Stu. I think the community was small enough, at that point, that we were aware of it, because I used to be very adamant about coupling into the research community, so I think Stu was totally aware of this stuff.

Pelkey: Did DEC, during this period of time, ever sell board-level interface to/from the PDP machines to an IMP?

Bell: Sure, because, if you look at the original ARPANET, the main thing they had on them was PDP-10s.

Pelkey: So was that a product in your price list?

Bell: I think that was a product in the price list.

Pelkey: Now, local area networking, the issue of Ethernet?

Bell: By the way, I had a student who also did a ring, and I'm trying to think of when he did it. His name is Peter Cook, by the way, and he's at IBM research, and you can find out when his thesis came out. I forget when his thesis came out. It would have been around 1970.

Pelkey: Really? Where did the concept of the ring technology come from? Do you recall?

Bell: He and/or IBM, and we really...

Pelkey: It wasn't IBM.

Bell: Okay.

Pelkey: I shouldn't say that, because IBM had this front-end processor, communications processor, which was really a ring technology.

Bell: Oh, no, this within research. He's always been in research. A lot of it—he and I invented a whole ring, a whole collection of ring...

Pelkey: What prompted you to do that?

Bell: He was a PhD student of mine at Carnegie—in a funny way, we worked on a lot of stuff. Let's see, virtually all of it's coming into being now.

Pelkey: A lot of people make that comment about you.

Bell: At the time—I don't mind working in any space. For example, one of the wildest things that—a student started working on it. It wasn't my idea, but he appealed to me, and he was a bright guy, and I had a lot of fun with him on it; the whole notion of programmable logic array—not PLAs—I mean Xilinx—there are two or three little companies now doing it, this programmable logic where you can vary the program. Essentially you use a cell to control the wiring of all this stuff, and I thought “Oh, shit, this thing will never go anywhere—"

Pelkey: Go anywhere.

Bell: What would you ever do with it? I just found it incredibly fascinating, so we went off and he wrote a literal thesis on it. We dreamed—in research, Maurice Wilkes pointed out to me once—what you do is that you pick some mythical point in the future where you make a dream of “What if this thing didn't cost anything,” and then you go off and predicate a whole world on these conditions, and then if you pick the right conditions, like the PARC [Palo Alto Research Center]: "What if computers didn't cost anything?" God, everyone would have one. Everyone would connect their computer right to the tube. Well, in 1971, that was not—or when PARC started in '72, that was not a condition, and you just couldn't imagine that—why would you ever do a research project on giving everybody their own computer, because when will that ever happen? Well, it didn't take a hell of a long time.

Pelkey: Where will I find Maurice Wilkes?

Bell: Maurice is now at—he's back in Cambridge. He's one of the fathers of computing.

Pelkey: Cambridge, England. Has he written anything?

Bell: Yes, he wrote the first book on programming. He built the first computer.

Pelkey: That mental concept of imagine—yesterday afternoon I was with Roger Needham and Bob Taylor.

Bell: Oh, by the way, Roger Needham...

Pelkey: Followed Maurice.

Bell: Yes. He's his protégé.

Pelkey: His name came up yesterday, and I remember in one conversation, but no one was explicit as you just were. It was clear that that concept of imagining something had permeated their thought process, because the way they were talking about that, that was an implicit logic set they had. Let me take you forward to a point in time, and maybe you could back me back. My understanding is that in roughly February of 1979, that Robert Metcalfe became a consultant to DEC, and that there was...

Bell: Right. If you got—I hope in this thing that you get the whole, whole Ethernet story consistent and...

Pelkey: I hope I do, too. I'm going to do my damnedest.

Bell: Bob, to me, has probably got the best, and maybe only set of—I hope he kept excruciatingly clear notes with dates on them. Did he? Do you know or not?

Pelkey: He was better at it than most people have been. Some people have just been miserable about keeping anything, dates and so on, but Bob was good. We spent six hours one night together.

Bell: Okay, the only way...

Pelkey: There are certain things he can not document? In other words, when he read the Norm Abramson article on ALOHAnet at Steve Crocker's apartment, he can't determine whether that was post-MIT and where that sat in terms of his thesis, because of the need to put more math into his thesis. Two of those things coming together, but he shared with me that his recollections was February '79, there was a very important meeting that the two of you had, which I want to come to and dwell on it for a moment, but between February '79 and where we were just in terms of how you started DECnetin 1972, was there anything you were doing at DEC at this point in time in communications other than DECnet? Was local area networking starting to become an issue?

Bell: Oh, yes, we had local area network experiments going on. I think we had three of them going. I think we had a ring. I'm not sure that we had a CSMA/CD [Carrier sense multiple access with collision detection] going. I don't remember—the trouble is I have wonderful notes on all this stuff. They are all at DEC. All of my papers are locked up in big boxes. I would like them all back. I haven't approached DEC recently for that, but we had all this network. We had networks going, and the reason was—it was needed

for the architecture of the machine we were building. This was in the History of Personal Workstations Conference. I'll get you the one that's in here [sorting through some papers]—this paper was in a sense—they asked me to keynote this thing, the History of the Personal Workstation in terms of what they were and thoughts about them, and it gets into how computers form, and a model I had of where the world was going based on memory pricing and evolution. What I thought of, in 1975, I have a paper that I wrote in '75 that really talked about the notion of hierarchy of computers, that was roughly equivalent to organizational—not organizational hierarchy, but it's like an organizational hierarchy; mainframes are now regional computers that communicate, large machines that are facility oriented; minis that are department/group project oriented—now kind of another machine that's forming right now are machines like that—project. It's around, you just put that in there as another member of the team; and then personal machines, and then you're getting into sub-personal machines.

Pelkey: This is 1975 you put your comments forth?

Bell: Yes, I put the thesis forth that there was a three-level hierarchy.

Pelkey: Had that thesis been evidenced anywhere else?

Bell: No, never been evidenced before. This whole theory of computer evolution I think I—I believe I totally invented. It certainly was well documented by this book. This was DEC's 20th anniversary book, and this came out in 1978. You probably ought to get it, Computer Engineering, because a lot of the points of view of technology change are expressed in that.

Pelkey: Who is the publisher?

Bell: Digital Press. I'm sorry I don't have another copy. Anyway, later on, Dave Nelson, who's now at Apollo, used to be at DEC, had refined a lot of these ideas, but he had basically credited me with the origin of them, so he, at the time—I used to say about machines: "You buy them by the pound," which you still do, and that they form these tiers, organizational tiers. But this notion of a three-level hierarchy and what they do, that was all wound up in here. In December '78, here's the notion of a LAN. I made this diagram the night before I went to the board of directors to get approval on the VAX strategy. Now, VAX came out—VAX Project started April 1st, 1975, and it was relatively well documented, what its goals were—a factor of a thousand in performance, a factor of a thousand in price—and didn't say a lot more about it at that time because I didn't want to frighten everybody. When we built the first 780—the 780 was introduced, came out in early '78—and it was sort of an immediate success. At that point—and then two

other machines were in the womb at that time, the 730 and 750, so we could sort of expand the size base. I went to Japan that summer, and then I went on a three week trip to Tahiti, and at that point I said "We're going to get rid of all the other DEC machines, and go build a new architecture according to a hierarchical model, so that we will have computing across this total range of collected—" in fact it had—the three level model, really—I said "A, I don't believe in mainframes, because I believe that if you want mainframe capability you're better off having a high speed LAN.

Pelkey: Do me a favor, use my book for the drawings.

Bell: So essentially we were going to have high speed LANs for mainframes. By the way, this project was underway, and this we would call a VAX cluster. One goal was to go against Tandem on it, but the other one was, in fact, against IBM for size. Tandem really was for fault tolerance, but the issue against IBM was size, because I know the cost to build high performance machines goes up radically with the power of the machine. Anyway, we had a bunch of VAX in here, then we also had built another gadget which was a disk server, and that was as big as we were going to get. Then we had our tradition, our old friend the mini here, with VAX, and this was the central facility. This was the department/group level. We were trying like crazy to get down to the personal level, and then you could also have a lab assistant level and stuff like that. That was the model, that's the way the whole thing had been written up, and this was—'78 was the approval by the board of the VAX strategy.

Pelkey: So implicit to this was communications strategy.

Bell: Yes. It was total—people say “What was the enabling capability," and it was “DECnet/LANs and VAX and the fact that we could see how to get down to the personal level here." The night before the board, I drew this drawing to sort of ratify what it was, and I put these together, and I hadn't solved this problem yet. In fact, we were looking at a bunch of different solutions here for lower speed com links to get down working at this. It was exactly that figure, because it came right off my slide. This was 64 kilobits. Well, this high-speed was one to ten megabits that we were communicating at up here.

Pelkey: At the mini level. You had experiments; not only DECnet, but you also had some experiments playing around with...

Bell: We had a 422 contention based thing going. We had a ring going.

Pelkey: At this point in time, Data General had some kind of a networking sort of thing that was kind of extended bus—Prime was doing something.

Bell: Prime had a ring after that. That was after that. See, these were all going prior to—the network was going prior to this.

Pelkey: Right, your experiments about networking.

Bell: Yes, and I was looking for a network, a physical network—DECnet was the protocol. We had a world of experience knowing how to connect computers logically with all of our software. We didn't have any damned good physical thing. I didn't want to go off and make the <*inaudible*> thing. I used to draw it as a—the usual thing, like that. In fact, ultimately when we did it, I used to draw it as a cloud here, and you had the hierarchy talking to the cloud. We were all...

Pelkey: You were ready and wanted it.

Bell: Shit, I was—I didn't know what the hell I was going to do here, because we were in the throes of deciding between—I had never met with the guy from Sweden about the ring.

Pelkey: [Olof] Söderblom.

Bell: There was the ring cloud. The ring looked good to me, but there was only <*inaudible*>, didn't know how to deal with it...

Pelkey: Were you aware of [Dave] Farber's work at UC Irvine?

Bell: Oh, yes, we knew all of the stuff that was going on.

Pelkey: Had you visited PARC?

Bell: I'm not sure I visited it at the time or not. I certainly knew all of what they were doing. Whether I had seen an Alto on an Ethernet or not, I probably had. I had visited PARC at various times during the '70s. In fact, Wes and I came out one time just as PARC was forming; talked to George Pake and Bob Taylor

about what they should be doing in hardware. This whole thing of building—well, they built the PDP-10. The notion of what the LAN was—we knew that it was a LAN. I don't know whether we called it a LAN or not, I think we were. We had kind of adopted the model. The only difference in the model we had was, from DEC's point of view, was that the world was going to evolve [sorting through some papers]. Here's this notion of evolution; that you start with a system here. "Here's our model of computation from '65 to '85," I said. Here's the model, '78 to '85, where you've got this thing, and now you've got it and you don't have enough capability, and you're linking it in. We were going through that. Then, here's the other model of the world, of you fully distribute the thing.

Pelkey: Post '85...

Bell: Yes. This is—in reality, we're not here at all, but these were the models...

Pelkey: That mental set was driving the world, although we're not there.

Bell: Yes, and this was what I had—these were the diagrams that we were using internally to say “Here's what it is. Here's the current state, and we're heading to that. Now, how do you get there?" It was all a LAN-based thing. Of course, now, I'm involved in the campus oriented nets, and fast what I call “GLANs,” global local area nets, but we're a long way from that. So these were...

Pelkey: So that was '78...

Bell: We had to have it, and we would have invented our own. We had two or three different schemes, and I was just turning to that problem when Bob walks in the door, and says "Would you be interested in a collaborative effort with—" No, wait. He came in; there was a consulting activity going on for a while.

Pelkey: So he came to you just to do consulting.

Bell: Yes.

Pelkey: With Sam Fuller.

Bell: Sam brought him in, or...

Pelkey: But he was prohibited from doing anything with Ethernet by the nature of his contract.

Bell: I didn't know that.

Pelkey: He couldn't consult to DEC on Ethernet.

Bell: Okay. In terms of realistically, my memory about what happened on all of that is very foggy, without any notes or documents or stuff like that.

Pelkey: Do you recall, was it you or was it Bob who proposed sending a letter to Xerox to see if they—"if we could work together." Bob remembers there was a meeting in which you asked him to write the draft letter. He doesn't remember whether it was he saying to you "Why don't you go to DEC?"

Bell: Believe me, it could have been either of us because my interest in that whole thing was that technology…

TAPE SIDE ENDS

Bell: ….You probably ought to go to Sam and see if you can get—How did it happen? I don't know. I know my interest in Bob. The thing I am pretty strong on was my interest in Bob was to solve the local area—Why he was there was to solve a local area network problem.

Pelkey: Do you remember asking him to draft this letter?

Bell: It could have happened. I really don't know.

Pelkey: You were pretty familiar with Bob's work, right?

Bell: Oh, yes, sure.

Pelkey: You had to review an article he submitted for the IEEE.

Bell: At that time, there's the famous Carnegie paper on workstations. Let's see if that's in here <*leafing through papers*>. No, it isn't here. Basically, the Carnegie paper on workstations was, I think, in '78 or early '79. Basically, it said timesharing is dead. The world's going to this workstation environment.

Pelkey: This is in '78, '79?

Bell: That's the famous 3M machine; one MIP, one MIXL and...

Pelkey: Do you know where I could get a copy of that paper? Could I contact Carnegie-Mellon?

Bell: Sure. One guy you could call is either Raj Reddy...

Pelkey: Do you know Margaret Serbo. Margaret <*inaudible*> got the <*inaudible*> paper.

Bell: Oh, he's writing...

Pelkey: On LANs, some stuff on LANs. So anyway, there was this meeting with Bob, and his recollection was that a letter was then sent to Xerox, to three people within Xerox: [David] Liddle, and Campbell and...

Bell: To get the thing started? Fine.

Pelkey: But then you got cold feet concerning legal issues; anti-trust, you largely thought you couldn't do anything...

Bell: No.

Pelkey: Help me understand.

Bell: Lawyers and all that shit never bother me. I don't ever worry about that. That I can guarantee you. I never get cold feet on deals, so that's not—Xerox might have gotten cold feet on deals.

Pelkey: Tell me from February, this letter, what can you recollect?

Bell: The only thing I can recollect for sure—I can recollect them as two events. We had a meeting in a room at DEC.

Pelkey: Who was there?

Bell: Liddle was there. I'm pretty sure Metcalfe was there.

Pelkey: And when was this?

Bell: It was between DEC and Xerox.

Pelkey: When?

Bell: No idea. It was in a room in Parker Street. Parker Street was a prison-like building, a big concrete building in the corner. We were sitting there, and I came into the meeting. They had met all day, and I said "Okay, where are you guys on this thing?" They said something like “Well, we'd really like to do something, but it isn't clear—" I said "How do we get it going. How do we get this goddamned thing going?" I don’t know if I said exactly those words, but I know that I would have said that, given the following action that occurs. They said "Well, you know, you'd better write a letter to so and so." I said "This thing isn't moving fast enough. Tell me what the letter should say and, furthermore, we will write the letter right now." So I went next door to a word processing system, and I think it was Liddle and X, we composed a letter right then. It's got to go to so and so at Xerox—I don't know who the hell it was at Xerox. I knew Xerox was a large company, you couldn't make decisions, all that shit, and I said "We want to do some kind of a joint venture to get a local area network that would be public, a network that would be used by both companies." I viewed Metcalfe as the behind-the-scenes oiler/greaser that made all of this happen. Then, the next action after that was—I can remember that.

Pelkey: Excuse me, who was there from DEC?

Bell: Potter wasn't involved yet. It was prior to getting that whole thing going. I think Dave Rodgers was probably involved. Dave was the guy who really drove it more than anybody. Dave Rodgers is now head of engineering at Sequent, so he will remember a lot too. He was in the communications group. Bernie Lacroute, head of the communications group. Bernie is CO at Sun. Now, the next event I remember after that was we wanted to get a semiconductor group involved. I said "Let's get Intel. They're good friends

and this is the kind of thing that needs high density, and they've got the best technology," so suddenly we had them involved.

Pelkey: Bob's view was that he went to NBS, and the guy at NBS says "Intel just came here with a 25 megahertz chip. They don't know what to do with it. Do you have any ideas?" He came back and proposed to you that there's this technology—does that make any sense?

Bell: Could be. Anyway, the next event that I remember with Intel, for whatever reason, was our meeting with Intel. We tried to arrange some meetings, and we couldn't get it together. I said "Hey, there's this new PicturePhone meeting service. Let's get together over that, because we don't got anything to say. We might as well not spend three days saying it to one another. Why doesn't everybody lay their cards on the table at that point and see if we can get an agreement." Basically, there were four or five people from DEC and some number from Intel. The guy I remember driving it from Intel was Kaufman, and he went to San Francisco, we went to Boston; had a meeting, basically, and said "Great. You're the guy who's going to do the chips." Later on DEC also went to AMD to get AMD to do a chip set, because we were dissatisfied with the Intel chip interface, because it didn't fit our model of computing...

Pelkey: Which became <*inaudible*>.

Bell: That, to me, was a tactical thing, and Intel got very pissed off at us. "We wanted a monopoly," and we said "Come on, you've got to open this thing up. The more who do it, the better for everybody." I remember all that. I remember the famous collection of road shows that we did. The road show that we did was between, again, DEC/Intel—I'll give you all the events, but unfortunately I can't give you any times. Another event was Ed Fredkin was starting Three Rivers, and they were building toward the Carnegie model of distributed machine. Three rivers was about to put their own network together; another CSMA/CD or some hokey thing. ICL had invested in them. Rob Wilmott, who was head of ICL—or Fredkin said "Why don't you get ICL? Then you can get the Europeans to agree. Rob can bring Olivetti, everybody else in," and I said fine. "We're going to get a hold of Rob Wilmott." He said "Why don't you call him right now?" I said "Okay, what's his phone number?" This was five o'clock Saturday evening, and I called him at his office, so it was about 11:00 o'clock. I don't know whether I had met Rob before or not. We basically said "Let's get together on this thing," and he said "Fine, I can bring in the Europeans. Let's get the agreement." Once the DIX [DEC/Intel/Xerox network) had been announced, IBM thereafter said "Don't do anything. We've got this great ring that's coming," and then all these things were coming out of the woodwork.

Pelkey: Now, was this pre- or post-Blue Book?

Bell: This was right at the time of the Blue Book.

Pelkey: Was it spring when you announced that you were going to come out with the Blue Book or was it September of '80 when the Blue Book was...

Bell: It was pre-Blue Book.

Pelkey: Pre- announcement of Blue Book?

Bell: I don't know. It was pre-Blue Book in that there were still issues that we were addressing, and I got calls from a bunch of places wanting to be part of the design team. Intel was pressuring me. Intel sent Olivetti after me, and I talked to the head engineer at Olivetti, or somebody, and he said "We want to be part of that." I said "No way. We've got eight of the best people I know designing it now. Any more people will hurt it. We've got plenty of people inside of DEC that would like to be part of it. I'm sure Intel's got a lot of people. Xerox could probably drum up people. This thing is going so well. Let's not fuck it up. We've got a processor. We're going to submit it. You can comment once it's available. You can give your input to us or to Intel. I don't care where it comes in." So we buffered the input until there was a proposal, and then we went out with comment. HP had made some comments about the grounding that were important. I don't remember anything else about this at all.

Pelkey: You were talking about road shows.

Bell: Okay, the road shows. A lot of crap was coming out. Wang announced WangNet. [Bob] Noyce and I, and I think Liddle, gave a big press thing in New York, and then we did it later on in Europe, and I took the point of view that the main—we wanted Ethernet—Ethernet was critical for minis and mainframe kinds of interconnections, for two reasons. Computer to computer communications and for solving the wiring problem, the terminal wiring problem, with concentrators. So DEC was building the concentrator, which we did. We built one and then—actually, when I went to Encore, first thing we did was build a super concentrator. <*Leafing through papers*> This is how we predicated our machine which was lots of concentrators to get rid of the wiring problem, and gateways. So, I saw Ethernet—this is why I wanted Ethernet. Sure, I believed the Sun environment, but I wasn't building a workstation then so I didn't give a shit whether it did that or not. I knew what it was for. My friends at Encore, they OEM'd these to Gould and a bunch of others guys. This is the best concentrator. If Encore could ever market anything,

everybody should be using their—Annex is the best concentrator in the business. Unfortunately, nobody knows about it. Anyway, on those road shows, my story was that it was fundamentally, Ethernet—in fact, I called it Unibus—Ethernet is the Unibus of the '80s.

Pelkey: This was a critical and important event then.

Bell: In fact, I think I used this here in the road shows. <*Leafing*> The diagram I used was in here. Here's the diagram I used in the road shows. Here's Unibus. You made a single computer out of that, and now what we're doing was simply doing all of that.

Pelkey: This was an important event in terms of...

Bell: One other comment on the road shows. I remember, particularly the road shows with these idiots from—I don't remember which idiot it was, but it was from Business Week. Make sure this doesn't end up in the book, because it may disclose how I feel about some reporters.

Pelkey: Anybody who had been on the other side of the fence knows how we all feel about reporters.

Bell: Anyway, this lady was going “Okay, what about broadband versus baseband?" That's the big issue, and I said "Oh, fuck. This is ridiculous. You don't understand. In principal, you could do that." In fact, she prompted a wonderful analogy. I said "Yes, we could take and make one pipe and carry water, gas, and sewage. Think of the economics of laying the pipe. It's just a problem of sorting it out."

Pelkey: That was mean. She didn't respond with “That's a good idea."

Bell: I said "You've got all these installed bases. Does it carry telephony? No. All the theory of all these mixed communications, do you have a cable TV that…" Hey, first, cable doesn't carry any voice now. Oh Jesus, terrible. We've got all of the installed stuff. I don't see how this sorts out, but certainly I know that these current networks are not capable of—we certainly don't know how to use them right now for that, economically, and we don't really want to spend the money when we don't know what to do with it. We don't want to force our users to install complex broadband nets if you just want to connect a few machines together. So Ethernet was carrying a large...

Pelkey: You were the lightening rod, because at that point in time, certainly in '80 and '81, it was the broadband, baseband, star, rings, buses...

Bell: It was all up for grabs, absolutely up for grabs.

Pelkey: No one knew what to do. You were talking about uses of it and they were talking about technology.

Bell: I know, and it was all that argument. I knew exactly what we were going to do with it, and what we did. We could afford the cost of the thing. PCs were just coming in. There were barely operating systems. Then IBM was coming in with “Never mind that it takes a million transistors to do a token ring. Transistors don't cost anything anyway." They had TI [Texas Instruments] doing the chips, and I knew that was going to be a failure. I talked to Bob Evans, and I said "Geez, you could have really come into that thing, and made a good thing," and he was "Oh, no, we're not going to join part of that. We have our Token Ring going," so he had kept IBM from really connecting to Ethernet and being part of that.

Pelkey: How much of it do you think was because the ring—I have this view about rings as being very consistent, ideologically, with IBM's nature of synchronous protocols and their polled-modem networks. It was philosophically aligned to have this ring going around. Yours was kind of this...

Bell: Yes, Unibus thing. I think there was a lot of that. "I don't want to do anything that's statistical."

Pelkey: And they had forced it on the world, this idea about synchronous stuff, high cost terminal...

Bell: And then IBM went ahead and made that crazy announcement, that wiring announcement. I think, do the world a favor and put in that wiring announcement.

TELEPHONE INTERRUPTION

Pelkey: That was a very important chapter. Let me explain. The issue of the three of you getting together was a relatively unique event outside of the research community. I would say that the NBS workshops on OSI [Open Systems Interconnection] is, conceptually, an institution that followed the success of what you did, and was instrumental to the US ever getting going in the OSI world.

Bell: I agree with that, by the way. The thing that was critical about it was the size of the effort. We could have done it, to believe there was momentum there. After we had a couple of the ideas—actually, the thing we wanted from Xerox was the patent. That's all we wanted. They had the CSMA/CD patents.

Pelkey: Do you remember the Mitre conference that was held in the Copley Plaza in '79?

Bell: I don't know if I even went to it. I didn't go to it.

Pelkey: What happened after the Blue Book went out and the IEEE 802 stuff started getting going? Did that bog it down for you getting a product to the marketplace or was it...

Bell: Oh, no, we marched ahead as rapidly as we could. We didn't take too many detours because of the 802 stuff.

Pelkey: So DEC just said "You know what you need."

Bell: Yes, absolutely, because we felt we had momentum. We said "Shit, the chips are going to define the damned protocol, not any goddamn committee." Artifacts trump specs any day.

Pelkey: So the 802 stuff was something that you were aware of. Potter represented DEC at these sessions, which then spun out, but those are inconsequential events to DEC's thrust. You were showing good colors and participating. You were interested, obviously.

Bell: Oh, sure, and we wanted the world to be there, but we had inside—by the way, I played the thin incredibly low-key inside all the time.

Pelkey: What is it that played low-key?

Bell: Ethernet. I said "Hey, we've got to have it. It's just a wire that connects all these things. No big deal," because DEC had enough controls that you couldn't go off and make deals like this without taking it to the executive committee. I always had very low-key kinds of presentations. "Yes, these guys are coming through. It's just a wire. Don't worry about this agreement." Meanwhile, the press is *<inaudible>*. "Nothing's happening here. It's nothing."

Pelkey: "What are you not telling us?"

Bell: I don't know if this stuff will ever be important, but we needed to connect machines together. "Why are we giving this to the world?" I said "Wait a minute, we're not giving anything to the world." We didn't have a protocol; we don't happen to have the patent on either CSMA/CD or on the ring, and we've got to have this," but we were always there; "How do we make this proprietary" and all this shit. I said "You don't want that," but DEC managed—today, Ethernet could not work inside of DEC I don't think, because DEC has become...

Pelkey: You had come from the Unibus, Q-Bus...

Bell: Oh, I'm an...

Pelkey: You fought anybody who would try to build boards that would fit into it, so you had—and people started to realize what you had put here, that this is an extension of Unibus, and they said "Wait a minute. We need this to be proprietary, because if we don't, we're not going to be able to sell more equipment."

Bell: People will be hanging stuff on it. Can anybody hang a disk server on it? Yes, as long as you meet the protocols, but the problem—that wasn't my attitude. My attitude in DEC, which I drove most of the time, was that things should be open. We always had war inside of DEC. I had a lot of people with me. Sometimes I had enough, sometimes I didn't have enough, but things like opening up the PDP-11 chips; bitter war that I lost.

Pelkey: Some of it is demonstrating—although their going to—this stuff with UNIX, it's bad news. So IBM announced, shortly thereafter, this wiring announcement and the...

Bell: Well, the token ring was first, and then, as Ethernet started being put in, they had nothing. Then, they were doing the typical IBM preemptive of “Here, wire up your stuff," and then, the amusing thing about IBM is you get “Fine, I just wired my building. I've got this cabinet full of wire," and then they came out and they say “Oh, by the way, add two more wires. We didn't tell you about Scitek, which is based on broadband." Those bastards!

Pelkey: That was a real...

Bell: It was the usual dirty tricks.

Pelkey: Were you involved in DEC's involvement in OSI?

Bell: No, that was after I left.

Pelkey: They must have gotten involved in it earlier.

Bell: Yes, but I wasn't concerned. No big deal. I might have been involved with it. It was just "Yes, you've got to get the standards together, sure." I guess I was. The open systems...

Pelkey: '78, '79, that stuff started, because the Europeans were driving this at that point. And the TCP community, this community that really got this stuff going, put its nose up in the air about what was happening over in Europe, like it didn't matter.

Bell: Yes, right.

Pelkey: I can't think of anything else relative to this period of time. Let me ask you a couple more general questions. The issue of research, of how we're doing fundamental research in this country, strikes me as a real issue. ARPA was obviously critical to the computing environment and to the communications environment. Bell Labs was a national funded research center that happened to be part of AT&T. I notice both of those organizations have changed profoundly and continue to change profoundly. NSF is trying to pick some of it up, relative to funding individuals and universities, but a lot of these projects now are systems project, where any collaborative effort between multi-disciplinary activities and very few institutions—MIT may be an exception—have the talent pool necessary to be able to pull off these big projects. I don't see how we're addressing this and what we're doing about that. Is that a concern?

Bell: I think that's a very wide concern. Yes, absolutely.

Pelkey: Is there anything we've learned through this process of the last 20 years that can be instructive in terms of what we need to be doing about it?

Bell: The notion of funding larger projects, or even people proposing larger projects, is not—within universities, it's a very hard one, because there are so many—the stronger computer science kids, as a discipline, the weaker this is going to be, because they're going to be more individuals wanting to do individual research, rather than any large scale systems research.

Pelkey: It's paradoxical.

Bell: Oh, yes. I was talking to Adele Goldberg at ParcPlace Systems, and she said "The trouble with university research today is it is incredibly dull and mundane." She said "I don't see any exciting work at all" because these projects are all bigger projects, and people just don't have the...

Pelkey: Where's the vision coming from that's going to drive this research? Some of it requires vision. It's the issue we were talking about before.

Bell: Oh, yes, absolutely.

Pelkey: Assuming it doesn't cost anything, what will it be like?

Bell: For example, I'm trying to do this now, this fucking gigabit network, trying to build—you saw the article?

Pelkey: This is the metropolitan? Yes, in the IEEE, yes.

Bell: I'm part of that, and there's a gigabit working committee. By the way, I know how I would build it, too. I know...

Pelkey: Conceptually, how you would approach the problem.

Bell: Yes, but I don't see anybody that has the energy or...

Pelkey: Funding power...

Bell: —or vision, whatever, go approach that and look at what it would be like.

Pelkey: One of the dilemmas of standards at this point in time is standards are wanted by the big users, because it doesn't mean they get locked into a vendor, and the big corporations—the DECs and IBMs—want standards because it slows the rate of technology change down and bigger companies can't be as nimble about technology innovation as smaller organizations. You don't want all these little things nipping at your cords, so what you do, you try to use your distribution and your muscle and your customer base as your defense. We're slowing the rate of technology change down. There's momentum to it, so it's going to continue to look good for a while, but 20 or 30 years from now, the investments in research are required today to cause that part to come into being.

Bell: That's all pretty convincing.

TELEPHONE INTERRUPTION

Pelkey: One other question, this issue about—where we are in terms of information networks is kind of two-lane dirt roads, and we need modern highways, just like in the Eisenhower administration we invested $50 billion dollars into the interstate highway system. The RBOCs [Regional Bell Operating Companies] are putting all this fiber in and all this T-1 stuff. It's nice, but it's the wrong paradigm for information networking. Having all these central switches is just wrong. How are we going to put these networks in, these gigabit networks?

Bell: That's what we're trying to do. We've got a gigabit—we're trying to provide a vision which would allow that to happen. We've got a draft of a paper about how we could actually—what are the research questions and how to make this all happen.

Pelkey: And under what auspices is this being done?

Bell: This is being done through DARPA, so I see the only way—I guess the only possibility is DARPA. It's got to be DARPA again.

Pelkey: Their charter has changed...

Bell: Oh, I know, DARPA I'm very worried about at this point, and DARPA should be worried about itself. DARPA just got SDI—it just got loaded with a whole pile of stuff which resembles—some of it's almost development.

Pelkey: A large portion is development.

Bell: And then it gets mired into the whole...

Pelkey: One other view that I hold is that one of the great advantages of the ARPANET was the fact that graduate students—of forcing into the university, and if you look at the shakers and movers at some level, a lot of these industries today, they were graduate students who came in contact with this activity, and there were no experts, and they became experts, and all of a sudden they gained the self-confidence, and they developed the networking of people, and that networking of people survives today when people call each other up and are a help to each other. That SDI test bit that was given to Martin Marietta should have been put to the university environment, as opposed to sitting out there in the commercial side where it's going to be buried. We're not putting these kinds of issues, and therefore we're not developing research managers and we're not developing the systems to be able to...

Bell: I don't know how you change that or how that gets changed. I know that I've always been part of the ARPA community. I'm part of this, and I'm part of a thing called the Tera-Op committee, which is a thing about how you get to a Tera-Op computer, and then this summer there's a study group, the DARPA summer study group that's going to be meeting to look at all the issues that they're working on.

Pelkey: Vision is mandatorily required.

Bell: Last year at this summer group, I tried to provide people with a vision of how to deal with and start tackling the manufacturing problem. I think in all these it's a question—vision, management of this stuff. In fact, I considered staying another two or three years and running DARPA, but I just—I didn't like the...

Pelkey: DARPA is compromised.

Bell: At one level I love DARPA, and I felt bad, that I shouldn't—at one level, I think I was one of the best people to do it, and maybe still should.

Pelkey: Do you think Bob Kahn's national research initiative will get anywhere?

Bell: I don't know.

Pelkey: Are you supportive of it?

Bell: Oh, I encourage Bob to try it. We need to try a bunch of different things, because who knows what's going to work? By the way, I was behind NCC too, in terms of “Let's try that."

Pelkey: You've got to try stuff.

Bell: Got to try stuff. SRC and all these things, because we don't know yet.

Pelkey: And we need more institutions to be involved. We've got to change the way institutions work together in this country. One other question.

Bell: By the way, I think that's one of the things that a large net would allow.

Pelkey: One last question, I believe that there is a paradigm shift that's going to take place, that this concept of an information economy is not so much access of anymore data. That's a part of it, but it's connecting people up, and allowing people in time and space, and the fundamental premise is that this von Neumann architecture, if we can bring everything in, and if you look at the way businesses run, which are the primary users of computers with the government, is we can collect all this information, we can model it, we can make better decisions from it. Some of it is transaction oriented, but there's an assumption about reality that exists, in the abstract, that it's out there. If we can just collect enough information about it, we can know what to do. That's not true. Reality comes as a result of interacting with things; people with people, organizations with organizations; organizations with markets. The value in this information economy is everybody kind of talking to everybody else within the organization, so that they can react to things, and meaning comes forth out of the interactions of people within organizations, and people’s expectations, interpretations, views about what's happening outside the organization, how the organization gets matured by all these external stimuli. Therefore, the management of these new technologies, or the management in the information economies must manage in structure. That is, I have to put an organization in place, bring all the information up to me so I can make better decisions, they have to manage process. How are we reacting things? Are we making sure the right people are getting connected to the right people? Are the right things being reinforced in the organization? That's not the way we've run businesses before. I believe that we're profoundly impacting the way business has to be run.

Bell: Yes, but you see—I guess my criticism of business today is that the leadership is mostly managing process, not involved in the content.

Pelkey: We use 'process' differently, but I would agree with that statement. It's form over substance.

Bell: Exactly. "Well, let's call the right people together—"

Pelkey: I call that structure, that is the right organizational elements and the right titles and the—surface stuff.

Bell: Well, you must have structure to have a process, but the structure—you form some ad hoc structure so that process can exist, because you're really looking at what are the programs that run through this structure that allow you to product certain kinds of goods? I view...

Pelkey: …structure and process as being irrelevant. Content is the issue.

Bell: Yes. I don't give a shit about this stuff, I care about what comes out the other end. I care about the bits that come out the end, not whether—hey, I got 17 people together in a committee. I've got this committee talking to that one. The decision process goes up this tree, on and on. That, to me, is boring. What I care about is—now, did all that thing, I made this supercomputer, I made this great giant tree, I've got all this paraphernalia, best brains ever, what came out? Did something great come out of all of this? To me, the only was things great can come out of that is inside that black box of people executing this process, everybody had better be concentrating on the thing, rather than how information flows and who signs off and—that's where the problem is.

Pelkey: I think that is the paradigm shift at management level. That's going to be an important issue when everybody gets connected up to everybody else and all this happens. We're not prepared to manage in that new environment.

Bell: By the way, I have a radical proposal I'm going out to the IEEE with, that we're going right up in spectrum. I just gave a little talk last week. I'm proposing to down-size engineering organizations by somewhere—about a factor of five. One fifth go to start-ups for things that are irrelevant to the company—where people are working, there's no way that thing can ever be useful. Actually, it could be useful to the company, but the company can never make it. Tester's a great example. Any processes that

the company may not be using, but could ultimately maybe be developed. One fifth go to manufacturing; one fifth remain in product; one fifth go to the educational pool, either as consumers or producers, and one fifth go into sales/marketing, what are you doing with this thing, rather than—helping that process, to understand why you made this thing—working on that. Just as a communications thing back into the rest of the organization.

Pelkey: Effectiveness is more important than efficiency, which underlies that concept. It's better to build the right things and do the things that cause things to be used and accrue value, as opposed to trying to do things faster and better. A lot of engineering organizations, our approach to engineering, is trying to make engineers pump more stuff out, as opposed to being concerned with whether or not they are pumping the right stuff out.

Bell: Well, this certainly deals with—once you ask whether it's the right stuff, that thing you;re spending an enormous amount of time in soul searching. I'm more the Japanese thing. I go to Aki Harbor and I look at that stuff. Let the market decide that stuff. I read a little, because I'm writing this book on high-technology start-ups and how they work and a way of grading them—essentially a rule book that VCs would use to know—and a bunch of heuristics for grading them. I believe that we’re...

INTERRUPTION IN THE INTERVIEW

Bell: DEC has 18,000 now, and there's no output.

Pelkey: None, zero. Same with IBM. How many tens of thousands of those.

Bell: Yes, they've got five times more. They've probably got 100,000 engineers.

Pelkey: Right, and look at the output. The thing is, IBM and DEC have got to get creative and start pushing the states of technology and the art of technology, and stop trying to be protective of customer relations and the current products, and get aggressive, if you’re going to change the nature of our economy.

INTERVIEW ENDS

