JOEL ENGEL

An Interview Conducted by

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INTERVIEW: Dr. Joel Engel
INTERVIEWER: David Hochfelder
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Hochfelder: Thank you for agreeing to do this interview. First, let's talk about your education.

Engel: I grew up in New York City and graduated from City College in New York with a Bachelor's in Electrical Engineering. Then I went to MIT, where I worked in their division of sponsored research, at what was then called the Instrumentation Laboratory and is now called the Draper Laboratory. We worked on inertial guidance, navigation, and stabilization systems for space vehicles. My first job was developing a system for a spy satellite, (back in those days it was a security violation even to say those words), to keep the camera always pointed at the earth. I received a Master's degree from MIT and then joined Bell Laboratories in 1959 and worked on the first data communication systems over telephone lines until the early '60s. Bell Labs gave us time off during the day if we wanted to pursue graduate studies, so I went to the Polytechnic Institute of Brooklyn, then known as Brooklyn Poly but now called Polytechnic University, part time. Once I accumulated all the course work I needed and passed all my qualifying exams, Bell Laboratories gave me a year off to work on my thesis at the school. I wrote a thesis on the work I was doing at Bell Labs in data transmission over telephone lines and got my Ph.D. in '64. That was right at the time that the Bell System had been asked by NASA for assistance on the Apollo program.

In 1960 President Kennedy laid down the challenge of putting a man on the moon within the decade. After he was assassinated, President Johnson continued that project. This was a huge undertaking for NASA, with a great many interdependent tasks that needed to be accomplished, and they looked to the Bell System as an organization with experience in dealing with projects of great complexity and magnitude. They asked AT&T to form a small advisory company in Washington, D.C., which they did. There were about 150 professionals plus an additional 100 support staff, and we were an advisory staff to NASA on many aspects of the Apollo space program.

I was there for about a year before I was tempted away by an offer from a company in Washington, D.C. with a big increase in responsibility to head up a government-funded group doing communications R&D. Accepting that position was a mistake. I discovered fairly quickly why I didn't want to work in government-funded R&D. The head of the group is responsible for bringing in contracts for the group to work on, and that was what I was hired to do. I became a traveling salesman, and got to know places like the Rome Air Development Center and Wright Patterson Air Force Base, but it really wasn't what I wanted to do.

After a year and a half, I contacted Bell Labs about the possibility of a return, and fortunately they took me back. It was a very lucky break, because I ended up in exactly the right place at exactly the right time. I was put into a group working on the systems engineering aspects of mobile telephone. At that time mobile telephone was not a high priority subject at Bell Labs, and the group was somewhat out of the mainstream. There were two rather primitive systems, operating at 150 MHz and 450 MHz, with only eleven channels at 150 MHz and twelve channels at 450 MHz. These channels could not all be used in any one location because nearby systems interfered with each other. For example, in the greater New York area, the eleven channels had to be parceled out among Manhattan, Newark, White Plains, Hempstead, and Belle Mead, because these locations all interfered with one another. Manhattan got three channels, which meant that in the entire New York City coverage area, only three mobile telephones could be in use at any given time. Anyone else wanting to make a call would be blocked and get a little red light indicating all three of the allocated channels were busy. Since there were about 300 people riding around with telephones in their cars, this happened most of the time. There were long waiting lists of people who wanted the service, but adding them would have made the problem even worse. Another problem was that not enough revenue could be collected from 300 subscribers to support the cost of the system. The systems at 150 MHz, which were developed first, were not profitable, so very few telephone companies implemented any at 450 MHz. That was the state of affairs for mobile telephones in the late ‘60s.

Hochfelder: How many subscribers do you think there were for that system?

Engel: With 300 in Manhattan, you could probably multiply that by fifty to a hundred nationwide. It existed but was not well known.

Much earlier, in 1946, AT&T had filed a request with the FCC for spectrum above 450 MHz saying, “If you’ll allocate a big block of spectrum we could have sufficient channels to make an efficient, cost-effective system.” The television industry made a competing request for spectrum at that same time for what became UHF television, channels 14 through 83. The FCC, explaining that they were faced with two requests for highly desirable social uses but could only grant one of them, allocated the spectrum to UHF television. Apparently, though, the FCC kept the AT&T request in mind, although people in the Bell System lost track of it.

I came back to Bell Labs in 1967, and in those days at Bell Labs, a staff member was given specific assignments to produce, but was also expected to spend a good deal of time, maybe as much as 50 percent, thinking about more forward looking things that nobody had even thought to ask for. This had to be in the general field in which one worked, and for me this was mobile radio. I became fascinated with the cellular concept. It's important to understand that the cellular concept was not "invented" in the sense that you could identify a point in time at which it was recognized or a person who was responsible. Actually, all radio systems are cellular. In the eleven-channel system described earlier, Manhattan used three channels, Newark used different channels that would not interfere with the Manhattan channels, and White Plains used yet other channels that would not interfere with Manhattan or Newark. Those could be looked upon as cells. They were very large cells, but cells just the same. Philadelphia could reuse the channels used in Manhattan, and the same thing further south and west. That is a cellular system. Our over the air broadcast TV system is similar. In New York we broadcast on Channels 2, 4, 5, 7, 9, 11 and 13. New York and Philadelphia are close enough to interfere with one another, so in Philadelphia they use Channels 3, 6, 8 and 10. Then in Baltimore the New York channels can be used again, and the Philadelphia channels can be used again in D.C. All of these systems are cellular in that sense, and that was understood.

For some time, people were conjecturing that, “Maybe we could shrink the cells down and make them really small,” but nobody actually pursued the question. I started doing theoretical studies trying to figure out how small the cells could be, how close together frequencies could be repeated and how many different frequency sets were needed to assure cells using the same frequency were far enough apart not to interfere with one another. Mobile radio used FM, which has a capture effect; if two signals are received, the stronger one “captures” the receiver and is enhanced and the weaker one is reduced. The higher the modulation index the better the capture, so as the channels are made wider they can be used closer together, but more spectrum per channel is used so that there was the question of what was the optimum bandwidth. Another question was how to determine which cell the mobile phone was in as it moved through different cells and how to hand it off from cell to cell as it crossed cell boundaries.

I was still relatively young at the time, and I met two other young people, Phil Porter and Dick Frenkiel, who were in a different department at Bell Labs working on similar problems. We began meeting for lunch or afternoons for blackboard sessions. We wrote Bell Labs memos and papers for the IEEE Transactions, and, over time, a system architecture began to emerge. Bell Labs let us dabble like that, but there was no thought to actually develop such a system.

But then, unexpectedly, the FCC came back to AT&T in 1969 and said, in effect of course, not actually in these words, “Remember that request you made back in 1946? UHF television hasn’t developed the way we thought it would, so we’re thinking of reallocating the upper end of that spectrum, Channels 70 to 83, which is about 75 MHz of spectrum at about 900 MHz. Before we do that, we want to hear how you would use it. We want to make sure it's a system that will be spectrally efficient and economically viable." That caused a flurry of discussion in AT&T. Nobody had been thinking about that request filed back in 1946. The big question was, "What are we going to answer?"

They had a big meeting at Bell Labs about this. The vice president of engineering from AT&T attended, along with the vice president for federal regulatory, the vice president of marketing and a number of Bell Labs vice presidents. Of course, the three of us were not involved. We were young and unproven, but our dabblings at a proposal were all they had. They made a cautious response to the FCC saying, again in effect, not in these words, "You're asking a very interesting question, but it's an expensive question to answer. It's going to take us about eighteen months to answer that question, and a fairly big investment of resources. We are not willing to make that investment if there is the possibility that you will come back with a 'Thank you very much, we were just curious.' If you will make a commitment that, if we come up with a viable solution, you will allocate the spectrum, then we will start this study."

At Bell Labs, we thought the study would require about three years, but the regulatory experts at AT&T felt that the FCC would consider that too long, so they said eighteen months." Fortunately AT&T started us on it right away, and the FCC took eighteen months before they came back and said they would make the commitment, so we got the three years we needed. I was promoted and made the head of the group to perform the study. They assigned Dick and Phil to the group, as well as some others, and over the course of a few months, the group grew to about a dozen. In addition, they brought in a whole department of microwave experts to work with us. These people had been working on the anti-ballistic missile defense system. That program had been terminated because of the anti-ballistic missile treaty, and these people were transferred from military work to mainstream commercial applications for the Bell System. They had a terrific background in radar and microwave electronics, and were assigned to assess the cost of the system hardware.

At the end of three years we produced a very thick report, which we submitted from Bell Laboratories to AT&T, and a somewhat thinner version that AT&T submitted to the FCC as their filing. That report is essentially the blueprint for the current analog AMPS (Advanced Mobile Phone System) cellular telephone used throughout the US today.

Hochfelder: Generation One?

Engel: Right. Generation One. New digital systems are currently being introduced, to take advantage of the advances in digital signal processing, using Time Division and Code Division Multiple Access, but at that time it was analog FM. In fact, because the US has not settled on a single digital standard, no one type of digital mobile telephone will work in every city. So, in every city in which a digital system exists, an analog AMPS system also exists, to provide universality, and many digital mobile telephones are dual use, with the ability to operate in the analog mode.

It turned out to take another twelve years before the FCC allocated the spectrum and allowed the Bell System to use it. In that period I was promoted and moved on and out of mobile telecommunications.

Hochfelder: Were the frequencies reallocated in the mid-1980s?

Engel: I think 1986 was the very first commercial system. In the mid-1970s the FCC allocated the spectrum on an experimental basis and allowed the Bell System to build one test system, which was in the Chicago area. They allowed Motorola, AT&T's chief adversary in this matter, to build another test system in the Washington-Baltimore area. There was a lot of opposition to the proposal. The television broadcasters didn't want to give up the spectrum. Companies like Motorola and General Electric dominated the mobile radio business at that time. The Bell System did not manufacture mobile units, even for its own mobile telephone systems discussed earlier. Motorola had about 90 percent of the US market and GE had about 10 percent. Maybe fewer than 1 percent were built by other companies. Most mobile radio systems were private systems, such as taxi fleets and truck fleets. If a taxi company or delivery service wanted to build a system, they usually went to Motorola, who would analyze where the headquarters and routes were and design, build, and maintain a system. The company could either buy the system or lease it from Motorola.

Hochfelder: It was essentially turnkey.

Engel: Yes. In the system proposed by AT&T, the telephone companies would build and maintain the base stations and connect them to the landline telephone network. The radio interface would be an FCC standard, and any manufacturer could develop a compatible mobile unit. The FCC would publish a list of type-accepted mobile units from which customers could choose. We tried to convince the mobile unit manufacturers that their market would be expanded by orders of magnitude, but nobody believed it. The AT&T marketing department hired a market research firm to interview people to determine willingness to pay for mobile telephone service. The research firm reported that no one was interested in the service and that there was no market at any price.

There was also skepticism at Bell Labs as to whether the system would work. Some thought that the system was too complicated; others were concerned that it relied on a number of very new technologies, such as microprocessors. Some radio experts questioned the cellular concept, saying, “Radio waves don’t travel in hexagons.” With some highly regarded technical people at Bell Labs questioning whether the system would work, and the marketing people being advised that there was no market for it at any price, AT&T and Bell Labs are to be admired for allowing us to proceed. Fortunately, we were allowed to design and build a test system, and it worked. And, when the FCC finally allowed a commercial service, it has proven to be a tremendous market success. In 1987, three of us from Bell Labs were awarded the Alexander Graham Bell Medal of the IEEE. Then, in 1994, two of us received the National Medal of Technology from President Clinton.

Shortly after the filing with the FCC, I was promoted and spent two years on a rotational assignment at AT&T headquarters, to broaden my experience with non-technical aspects of the industry. I worked in the corporate planning department, on regulatory policy. It may sound like a strange assignment for an engineer from Bell Labs, but my work on the cellular mobile project involved dealing with the FCC, the Office of Telecommunications Policy, the White House staff, and some Congressmen. That experience gave me an understanding of the regulatory process not normally available to an R&D engineer. After those two years, I went back to Bell Labs and was there from about 1975 to 1983. I was in an organization that was exploring new services for residential customers, over and above basic telephony. We conducted trials of a service called videotext in those days, which was a primitive version of the Internet and ahead of its time. This was before so many people had personal computers; it used the home television set as the display, with a terminal that connected the television set to the telephone line. The customer would dial in to what now would be called a server, which offered a variety of services. We conducted a trial in Coral Gables, Florida, with the Knight-Ridder Newspaper Corporation, with a couple of hundred subscribers. They got news reports, weather reports, games, and a bulletin board service similar to today's chat rooms. This was during the 1978 oil embargo, and there was a service that would tell what gas stations were open, and what the price of gas was at local gas stations. We also did a trial in northern New Jersey with CBS and did some work with Citibank, but, as I said, it was ahead of its time. For an information service to be popular and attract a mass market of users, it needs to have sufficient, varied, and changing content. But, to motivate service providers to invest in creating that content, there needs to be a mass market of users. Neither one will come first. The Internet and the ubiquity of the PC created an environment in the mid-‘90s that caused both the number of service providers and the number of users to grow together. But, in the mid-‘70s, it was ahead of its time. We also explored energy management systems because of the fuel and energy crises at the time. These were systems that allowed the power company to control air conditioners, heating systems and hot water heaters during periods that otherwise would have cased brownouts. We did a trial with about a thousand customers in Charlotte, North Carolina in partnership with the Duke Power Company. The trial was quite successful, and demonstrated considerable energy savings, but, as you know, the energy crisis of the 1970s went away.

In 1983, shortly before the breakup of the Bell System, I left Bell Labs to become vice president of engineering for a company called Satellite Business Systems (SBS), which was a joint venture of IBM, the Comsat Corporation, and Aetna Insurance. SBS was established to provide high-speed data communications via satellite at 45 megabits per second, which was a precursor to Asynchronous Transfer Mode. The target market was for intra-company data transfer among the locations of large corporations, using an earth station out in the parking lot or on the roof of the building.

Hochfelder: Why was Aetna interested?

Engel: Aetna looked at it purely as a financial investment. For Comsat, it was another application for communications satellites. IBM was interested primarily because they planned to develop applications that they anticipated would require this capability. As it turned out, there wasn’t enough intra-company data communication to justify the investment in an earth station costing about half a million dollars, so they started to put voice on the network as well. Then SBS built a public network of earth stations and switches in major cities and started selling long distance service, like MCI and Sprint. At that point, they needed someone with a background not only in data but also in telecommunications, and they recruited me. However, IBM's original purpose had been to create a data communication company, and they weren't really interested in the voice telephone business. When I had been at SBS about two years, IBM bought out the other two partners and sold SBS to MCI. I was vice president of R&D for MCI for about two years, when I was offered a wonderful opportunity at Ameritech. The Bell System was broken up on January 1st, 1984 and was split between AT&T Long Distance, Western Electric and Bell Laboratories on the one side, and twenty-two local telephone companies consolidated into seven regional companies on the other side. A portion of Bell Laboratories went with the seven regional companies, as a company called Bellcore, to be their jointly owned R&D and standards organization. By 1987, for reasons having nothing to do with any deficiencies of Bellcore, the companies began to realize they needed their own technology organizations. There were a number of reasons for that. For one thing, they needed a group of technologists to oversee and manage the Bellcore budget and work program, and to then integrate the products of that work program into the infrastructure and operations of the telephone company. In addition, they were already beginning to anticipate competing with one another and didn't want to share all of their technical intellectual property. The markets in the various regions were not the same, and their priorities began to diverge. Between 1986 and 1988, the seven regional companies each formed their own technology divisions. In 1987, through a mutual acquaintance, Ameritech approached me and offered me an opportunity I simply could not resist. It was an opportunity to apply all of the lessons I had learned from the Bell Labs, IBM, and MCI cultures, to start with a clean piece of paper and build an organization from the ground up. It grew at one point to about 350 people, with birth to death responsibility for all the telecommunications technologies. We would meet with the various suppliers and their R&D organizations and tell them what we thought their next generation product line should be three to five years down the road. We wrote the requests for proposals, evaluated the proposals, negotiated contracts with suppliers, managed the life cycle of software upgrades, and decided when to retire equipment, and move on.

This was during a ten-year period of incredible change and growth in telecommunications brought about by forces that were interrelated. Changes in regulation allowed the traditional telephone companies to move much faster. More rapid depreciation schedules allowed equipment to be turned over faster, allowing the introduction of new technology. Regulation shifted from rate base regulation that measured the cost of everything in the system and allowed a fixed rate of return on that investment to something called price regulation. The telephone companies started with their current rates and committed to annual reductions based on projected improvements in productivity. If they could find a way to improve productivity at a faster rate, they could keep the benefit. That, and competition, stimulated innovation. The stock market began to view the telephone companies as growth companies and started to value revenue growth as well as earnings growth. These were companies that had historically grown revenue at a rate of about 2½ percent a year. Now Wall Street was looking for double digit growth every year. A lot of innovation was stimulated, and the technology exploded.

Hochfelder: Ameritech went from a utility company in that sense to a high tech business.

Engel: It became a high tech telecommunications information company. The equipment suppliers were similarly stimulated. There was intense competition among suppliers from the US, Japan, Korea, Canada, Sweden and Germany, and they all had to innovate. In addition, the PC explosion created a collateral demand for telecommunications. I used to say, "If you want to know what our customers will want from us next week, find out what they bought from IBM last week." It was a fascinating era. We went from analog to digital, microwave and copper to optical fiber, voice to data to ATM. Usage grew from voice to fax, data, and Internet access. Most important of all, we went from communications that was real time one-to-one, where two people would converse together, to non-real time communications consisting of a series of one-way messages back and forth. E-mail and fax are the most obvious modes of non-real time communication that began to flourish, but even voice shifted from being real time to non-real time, with an explosion of voice messaging systems. The reason was sociological. Companies were becoming global and spanning multiple time zones. The work week was expanding from a regular schedule of five days a week eight hours a day to seven days by twenty-four hours on call. Use of telecommunications exploded, and because of that we ran out of telephone numbers. You would think that the change from having a three-digit area code that has to have a zero or one as a second digit to a three-digit area code that could be any three digits would be a trivial thing in this age. It isn't. The change in our network caused by that was just incredible, because the developers of the switch software had taken shortcuts to take advantage of the fact that that second digit was always zero or one (very much like the Y2K problem). Undoing that was a phenomenally big job. A number of factors spurred a great change in switching and signaling technology. The fact that we now had competition, both long distance and local, required us to provide something called number portability. Suppose you're a customer of the established telephone company, and a competitor enters the market. They install a switch, interconnect to the network, and offer telephone service. Maybe you would like to try their service. However, the way the telephone network worked was that the first three digits of your telephone number defined your switching office. To use the services of the competitor, you would have to change your phone number to incorporate the three digits defining their switch.

Hochfelder: It's your exchange.

Engel: Your exchange. So, if you're a business, you think, "Wait a minute. Everybody knows my number. I've got all this stationary, Yellow Pages ads, and people all over the world with Rolodexes with my current number. I can't change my number." That's why the competitors demanded something called number portability. The way the network is built now, those three digits no longer define your switching office. Technically, you can have any telephone number in any switching office.

Hochfelder: Around the late ‘80s or early ‘90s where there was a proposal to have lifetime phone numbers. Was it a 700 number?

Engel: People discovered that there were ways to make money using telephone numbers, and some companies applied for and kept telephone numbers for which they never acquired customers. There are 800 numbers that we are all familiar with where the called party pays. Then there are 900 numbers. When you call a 900 number, the company you’re calling is allowed to charge you for the call, and it can be pretty steep, and the telephone company is required to collect that charge from you and pass it on to them. And yes, there were 700 numbers. They were not really lifetime numbers, but geographically independent numbers.

Hochfelder: I see.

Engel: If you were a company with branches all over the world, you could have a 700 number. You could do that with 800 numbers too, but with the 700 numbers the calling party would pay.

The point is, all these things caused a tremendous churn in the technology of telecommunications and in the specific technology that we were buying, installing and using in services we were offering to customers. Everyone is familiar with the growth of the Internet and what that’s done. Phone companies are the invisible providers of service. You can’t point to a fiber cable, switching office, or microwave tower and say, “That’s the Internet.” There is no physical plant called the Internet, except for some routers at the edges. It’s all run on the traditional telecommunications network, and the network has had to adjust for it.

Hochfelder: Going back to your work at Bell Labs, you mentioned Phil Porter and Dick Frenkiel as two people you worked with to develop the idea for first generation mobile telephones. Would you tell me a little about them? I'd also like to hear about any other talented engineers that you worked with at Bell Labs.

Engel: There were very many talented engineers, and I'll only be able to mention a few. I apologize for the injustice to the ones I leave out. Dick Frenkiel was a co-recipient with me for both the Alexander Graham Bell Medal and the National Medal of Technology. For reasons I don't understand, Phil Porter never got the credit he deserved. Many of the features in system we developed were his brainchild. In most radio systems, the transmitter is at the center of the coverage area, radiating in all directions, and when people thought of cellular systems with hexagons they thought of the same thing. Phil came up with the concept of putting the base stations at the corners of the cells with directional antennas aiming inward. That gives further isolation from the other antennas, the other cells further away, and that's the way they're all built these days. That is only one of his innovations.

Hochfelder: Simple, yet brilliant.

Engel: Yes. That was not the only idea he had, and he never got the credit he deserved. He was at Bellcore after divestiture, but I've lost track of him. I suspect that he is retired, because he was a bit older than Dick and me. Dick is retired and at the Wireless Information Lab at Rutgers now on a part time basis.

Hochfelder: I'll look him up. He would be worth talking to.

Engel: Yes, he certainly would. He's a terrific speaker, a terrific guy, very entertaining and very different. His reputation at Bell Labs was as an iconoclast, a guy who kicked over pedestals, but he was very respected because he knew what he was talking about.

Hochfelder: Being an iconoclast at Bell Labs was acceptable?

Engel: Yes, if they were very talented, and Dick was very talented. Then there were the people who came from the military work I described earlier, the anti-ballistic missile work. There was a department head named Bob Mattingly, unfortunately now deceased, who brought with him two very creative supervisors named Reed Fisher and Jerry DiPiazza. I once told Bob Mattingly that every time I had what I thought was a great idea I would discover that Reed Fisher had thought of it first. To give you just one example of the caliber of the people in Bob's department, there was a young engineer at the very beginning of his career named George Zysman. Today, George is at the top of the Lucent division producing mobile telephone systems. There were people at the Bell Labs in the Chicago area in Naperville who worked on the switching portion of the system, headed up by Zack Fluhr. I keep in touch with Dick Frenkiel, and I bump into Jerry DiPiazza from time to time. Bob Mattingly had a big influence on me in regard to personal management style. He was a southern gentleman and taught me how to be less the abrasive New Yorker and more the gentleman. There were really a lot of great people.

Hochfelder: My impression of Bell Labs in 1980 and Telecom Research after 1985 is that they're very different. Would you talk a little about the breakup of the Bell System and the effect it has had on research and telecommunications in general?

Engel: The breakup is one reason for the change, but not the only one. The old Bell System was vertically integrated. That is, Bell Laboratories developed the technology and specific products, Western Electric manufactured them, and telephone companies used them to provide service to customers. There was a direct link between the customer, the telephone company, and the engineer doing the basic R&D for the manufacturer. Bell Laboratories' salaries were paid in part by the telephone companies through AT&T, with funds collected by AT&T and fed back to Bell Labs. I was one of the people at Bell Labs who had the responsibility of putting myself in the telephone company's shoes and telling people who were developing for Western Electric, "This is what my stakeholder is going to want from you."

With the breakup of the Bell System that linkage disappeared. The telephone companies formed organizations like the one I headed at Ameritech to perform that function, but it wasn't the same as when we were one company. There was much better communication. That was lost.

However the major change was something that occurred externally, even before the breakup. For decades, there had been an understanding that a private company called AT&T was essentially given taxing power to do R&D for the good of the country.

Hochfelder: The fabled 1 percent.

Engel: Right, the 1½ percent license contract. The telephone companies paid AT&T 1-1/2 percent of their revenue, and this flowed to Bell Labs. The government regulators, Federal and State, considered this an allowable expense that could be passed on to the customers in their rates for telephone service. This went on for a very long time, but it started to unravel in the late 1960s, when MCI was allowed to start selling long distance services and when people were allowed to start buying and plugging in their own telephones. Little by little, over the course of about a ten year period, the government came to the conclusion that the old model no longer applied. Nobody suggested that the nation hadn't gotten its money's worth, but it didn't match the new competitive approach. Hence, R&D doesn't get funded that way anymore. Today the funding for R&D at Bell Laboratories comes the same way it does at IBM, Bell Northern Research, or any other company. They do R&D because they think it will result in a product that will sell for a profit. Research and Development is no longer done simply for the good of the world because it is no longer funded by the tax.

Hochfelder: Radio astronomy for instance.

Engel: Right. Remember I said we were supposed to devote up to 50 percent of our time to things that were related to our field? Radio astronomy at Bell Labs was very much related. It grew out of trying to understand where the noise was coming from that was getting into our microwave systems. Arno Penzias and Robert Wilson didn't develop the Big Bang Theory, but they found the noise that supported the Big Bang Theory. They were not intending to do that. They were trying to find the source of the noise and concluded that it was the residual noise from the Big Bang. It had a telecommunications purpose behind it, but they were allowed to branch out. There was also the issue of publications. When I first started out, publication was encouraged. It enhanced the image of Bell

Laboratories. Now it's, "Why do I want to give my intellectual property to my competitors?" The external environment changed and Bell Laboratories had to change with it.

Hochfelder: Would you also talk a bit about your involvement with the IEEE and the Communication Society?

Engel: My involvement with the Communication Society has not been extremely active. I started out when I was working on mobile radio. I was a member of the communications group at that time, but was more involved with and vice chair of the vehicular technology group, and was review editor of the *Vehicular Technology Transactions.* Although I published some papers in the *Communications Transactions,* I published many more in vehicular technology. The vehicular technology group and communications group put out a joint issue of the *Transactions* devoted to mobile telephone, for which I was guest editor. That was around 1973. I got to know a lot of people in the Communication Society when I did that. That was right in the period when it was becoming a society. I made a lot of contacts and friends, but was not ever an officer.

I was very involved in what used to be called USAB, the professional activities side as opposed to the technical side of things. When I joined MCI, I learned that there was an IEEE group called the Committee on Communications and Information Policy (CCIP). A vice president of MCI had been on that committee for a couple of years and asked me to replace him, which I did. I've been on that committee ever since, and, for a while, was vice chairman. Since I retired, I'm still on the committee and participate by e-mail, but I attend the meetings only infrequently. Recently I was asked to serve on the Field Awards Committee as vice chairman, and I'll be chairman next year. That will be a two-year term. I'm active in IEEE on that side of things, but that's about the extent of my involvement in IEEE.

Hochfelder: By way of conclusion, can you give some thoughts on the future of telecommunications in the next ten to twenty years and the technical challenges you expect engineers will face?

Engel: Convergence is a word that's been greatly overused, but that's going to continue in the sense that the distinctions among information processing, information storage, and information transmission is going to blur. These various functions will be done wherever they can be done most economically, and will be networked together. Entertainment and commerce are going to blend together. It's just a question of time before virtually all entertainment television is going to be delivered over what may or may not still be called the Internet. People will decide what they want to see, dial into it and have it downloaded to them. People around the country will not be watching the same program at the same time anymore. Some programs like the World Series and NBA Playoffs will be watched at the same time, but they will be the exception..

Ameritech formed a cable company that's up and running now, and I was very much involved in choosing the technology for that infrastructure. When we first started, I learned a very interesting statistic. Although there were dozens of cable channels, during the prime viewing hours 85 percent of the people were watching the over the air broadcast channels, even those who had cable. All the other channels, even the non-premium ones such as CNN, ESPN and Madison Square Garden, divided up the other 15 percent. Two years later the ratio was 60:40, and today over the air channels are probably watched by less than 50 percent. There has come to be what is called narrowcasting to specific groups of people. My wife and I love to watch C-SPAN. I tell people that and they look at me like I'm strange. They say, "Do you also go out and watch the grass grow?" But we love C-SPAN.

Hochfelder: That's almost as bad as The Golf Channel.

Engel: Probably not as bad. There was a column in the *New York Times* the other day about the Rider Cup, and it said it was probably the first time that somebody used the word "golf" and the word "exciting" in the same sentence. I see where a lot of this drive toward non-real time communications will increase, even between just two people communicating. They're going to communicate by sending messages back and forth in one medium or another. Moving pictures are the most captivating, so that's going to be a medium of choice. I don't know if personal telephone calls with picture phones will become the norm, but the communication of information by sending moving pictures is going to increase.

The ubiquity of communications is going to grow even more. People like me who are annoyed by seeing people sitting in restaurants or driving cars with cell phones glued to their ears are going to have to get used to it. In the streets of Manhattan everybody's got them. People are never going to be away anymore, will always be in touch. That's okay because of non-real time communications, making it so that even though people will always be in touch they'll be in touch by choice. We don't feel the compulsion anymore to jump up and answer the phone when it rings. If we're doing something else, we do something else. If it's important enough, they'll leave a message. All of that is going to continue, and costs will be driven down. Moore's Law, that applies to capability doubling every eighteen months for roughly the same price, is happening in telecommunications as in other technology applications. The difference is that in computing you can experience and take advantage of it on the individual level. You can buy an individual chip and put it into an individual PC. In the case of telecommunications, it's happening at the macro level. For example the capacity of fiber just about doubles every eighteen months. However that fiber has to be shared by a number of people because individuals don't generate enough data to take advantage of that doubling. The law of scale economy that caused people a century ago to talk about natural monopolies isn't going to go away. We may have deregulation and competition, but the competition is going to be for the top 10 percent of very high profit customers and everyone else will be served by two or three very large companies. We're going to see an awful lot more consolidation, like we are seeing now with Bell Atlantic buying NYNEX and GT&E, SBC buying Ameritech and Pacific, and so on. It won't surprise me if one of the Bell companies merges with AT&T.

Hochfelder: That's almost a reintegration of the Bell System.

Engel: No, not really, because there is no single franchised monopoly; there will be several equivalents of the "Bell System". The split of the Bell System separated local services from long distance, but was not the cause of phone companies breaking into seven regions. They could have made it one big telephone company. The division into seven was an historical accident having to do with the way the Western Electric supply system was structured, but the mergers are undoing that. A big change will come about from allowing AT&T to offer local services, and I read that imminently Bell Atlantic will be allowed to provide long distance. That's the reintegration. There are so many phone companies now that it's highly competitive anyway.

Hochfelder: What do you think will be some of the technical challenges for communications engineers in the next generation?

Engel: I see fragmentation as the biggest challenge. I'm going to sound like an old fuddy-duddy, but when I graduated engineering school I was required to take civil engineering courses to learn how to design steel beams and concrete columns. I had to learn mechanical engineering, thermodynamics and how automobile, diesel and steam engines worked. I had to take fluid mechanics and study electric power too, and my teachers complained that I was specializing in electrical engineering. When my teachers were in engineering school, they graduated as engineers, period. They knew everything about engineering, but I was focusing on electrical engineering. I have a son who went to engineering school, and when he started, computer science was part of the electrical engineering department, but it was a separate department by the time he graduated. There is a joke in computer science he likes to tell: "How many software engineers does it take to change a light bulb? None. That's a hardware problem."

We're getting more and more fragmented to the point where it's very difficult for anyone to have a broad enough view to be able to step back and see the big picture. In my mind, that is going to be the biggest challenge. People are getting more and more specialized and simply don't have the time, intellectual power, or memory to really master the broad range of subjects. That is going to inhibit the growth of technology because things are so interdependent.

Hochfelder: Do you have any concluding thoughts?

Engel: I wish I could be around and active for many years to come. Being a consultant is not the same as being in the thick of things. I envy people who are entering today, but I guess the people who taught me envied me. That's about it.

Hochfelder: Thank you very much.