IEEE History Center: Amos Joel Abstract

Amos Joel Interview

Amos Joel was born March 12, 1918 in Philadelphia, but soon moved to Atlantic City and then New York City. As a child, Joel became interested in mechanical and electrical devices, including electric trains and radio. It was Joel's curiosity about the dial telephone system and circuits, however, which would shape his later career in telecommunications. As a young man he became fascinated with reading patents, particularly in telecommunication switches, and in high school he enjoyed his mathematics and science courses. He even invented his own switching system in the early 1930s. Joel was accepted into MIT and received his bachelors (1940) and masters (1942) from there in electrical engineering. In 1940, Joel went to work at Bell Labs, and over his long career there he worked in many areas and projects, such as the accounting center, operator services, transistors, electronic switching system at Whippany, Stored Program Control, No. 1 ESS and Traffic Service Positions System (TSPS) to name a few, as well as becoming a director. He received many patents himself, and also many awards including the Kyoto Prize, and at the time of the interview Joel was looking forward to receiving the IEEE Medal of Honor and Patent Recognition Award from AT&T. Joel was also very involved in IEEE, including being a part of the formation of the Switching Committee (1947) which he eventually became a chairman of, head of the Nomenclature Committee at Bell Labs, chairman of the New York section, and president of the Communications Society. Joel also has numerous publications to his name, including books under the IEEE Press Book Series imprint. Joel's retirement from Bell Labs in March 1983 did not stop his involvement in the engineering world, as he became a consultant for Bell and other companies, as well as continuing to write, teach and lecture about switching systems.

In his interview, Joel talks about his experiences both at MIT and Bell Labs. He discusses the program and people at MIT, especially the emphasis upon problem-solving and design over rote learning, which fit with Joel's desire to be an inventor. Joel's description of Bell Labs covers not only the projects and departments he worked in, but also the people he knew, the expansion and additions to the company – including the teaching program Joel helped put together on switching which he believed helped to spawn the Kelley College which held courses on many subjects important to Bell – and various important episodes in the company's history, including a visit by Alan Turing, the early 1970s investigation of AT&T by the FCC which had as one of its focuses an electronic switch which made Joel involved in the process, and the divestiture of AT&T and Bell Labs in 1984, shortly after Joel retired. Joel also talks about the importance of teaching switching systems to engineers because he believed that, even at the time of the interview, switching systems were not well understood, indeed were often oversimplified. Even with the continued success of the International Switching Symposium, which Joel helped start in 1957, he still thought that switching was seen more as an 'art' than a true engineering subject, something Joel regretted in the profession. Joel also discusses what he saw as 'hype' in electronics in the

early 1990s, and he talks about what he saw in the future of telecommunications.

1	Introduction, only child, Philadelphia & Atlantic City
2	Father's occupation
3	Childhood, public school
4	Studies in High School, B+ student
5	Teachers and friends, who introduced him to telephone technology
6-7	Began self-study of telephone-related patents at the age of 13-14.
8	College days, when he had the first opportunity to talk to people working for the Telephone Company.
9	Dream to invent the "Joel All-Ready Dial System-the very first idea of his own switching system
10	Hobbies; how he spent his leisure time.
11	Reading patents was no so helpful for his later invention; loved musicals.
12	Practiced clarinet and saxophone; How his public school education helped him pursue higher education.
13	College days, when he finally became determined to be an electrical engineer; why selected MIT; Education in MIT.
14-15	Reminiscences of MIT faculty; finished all the coursework, including graduate classes, in four years; worked on his master's thesis in non-residence.
16	Friends and co-workers in MIT and Bell Labs.
17	Electrical engineering education in MIT.
18	No one else in MIT was interested in switching technology.
19	Part-time job; dormitory life; and the first meeting with his wife-to-be.
20	How he came to know her.
21-22	How he started his career in the Bell Labs.
23	Sizable initial monthly salary; Master's thesis.
24	Master's thesis; His experience while he was working on the Rockefeller differential analyzer.
25	Reminiscences of Norbert Wiener and Ernie Gillman.
26	Practically oriented MIT education with problem-solving and design as its core; Genera description of the Bell Labs in those days (location).
27	General description of the Bell Labs in those days (location; personnel; difference between daytime and nighttime degrees; work schedule).
28	How the Bell Labs were organized at that time.
29	First assigned to a cable-wiring shop.
30	The second assignment (frame building), which he did not like; the third assignment (relay shop).

31	The third assignment (relay shop), which he enjoyed fairly; often wandered over the laboratories to meet people; the fourth assignment (testing laboratory).
32	Assigned to crossbar systems testing; met circuit designers.
33-34	Great learning experience while he was working in the testing.
35	Began working on cryptographic systems; development of speech-generating technology in the Bell Labs.
36	The relations between speech-generation technology and cryptographic systems.
37	Reminiscences of Harry Nyquist and Alan Turning.
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39	The beginning of the digitalized speech technology.
40	His patent on generating keys with prime numbers; reminiscences of Sam Williams.
41	Cooperated with Sam Williams working to break the Purple Code.
42	Rewrote Stibitz's patent on the first programmable calculator; participated in the project to develop computers for the fire-control stuff for the government.
43	Reminiscences of Warren W. Carpenter.
44	Practical outcomes of moderately-secure system development.
45	Postwar development of transmission and switching systems; the invention of the No. 5 Crossbar.
46	Assigned to Andrew's department, where he engaged in designing the circuit for the Model 5 or 6 computer.
47-50	Description of AMA and crossbars; how telephone accounting and billing were done in those days.
51-52	How telephone accounting billing were done in those days; early magnetic-tape-based accounting system.
53	Top-down job assignment system in the Bell Labs.
54	From Vacuum tube to transistor.
55	From Vacuum tube to transistor; the Williams tube.
56-57	Various technical problems, which accompanied the development of a new switching system; Reminiscences of Ted Brooks, Benny Lewis, etc.
58	Various technical problems, which accompanied the development of a new switching system.
59	Application of transistors to a switching system; Started school to teach switching.
60	Switching school in the Bell Labs.
61	Lack of information dissemination about switching; the origin of Kelley College.
62-63	Chet Brooks' efforts to acquire funding fort the Exploratory Development Department, in which an actual switching system was now under development.

AMOS JOEL

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William Aspray

IEEE History Center

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Date: February 4th and February 18th, 1992

ASPRAY: This is the 4th of February 1992 in South Orange, New Jersey. An interview with Amos Joel. The interviewer is William Aspray. Let's begin by having you tell me about your early life. First of all, when were you born?

JOEL: I was born March 12, 1918.

ASPRAY: In where?

JOEL: In Philadelphia.

ASPRAY: In Philadelphia. Mmmm hmmm. And where did you stand in the number of children in your family?

JOEL: I'm an only child.

ASPRAY: An only child. Mmmm hmmm.

JOEL: An only child, so that was it. And I lived in Philadelphia for three years or so. My father worked out of Philadelphia. And we moved to Atlantic City after that.

ASPRAY: What did your father do?

JOEL: He was a traveling salesman. He sold wholesale menswear. And the company that he worked for manufactured in Philadelphia. So he went on the road regularly. And it was just as easy for him, even the times when he was home, for him to commute to Atlantic City from Philadelphia, so we moved to Atlantic City.

ASPRAY: Did your mother work also?

JOEL: No. She worked before she married, but not afterward.

ASPRAY: And did your father keep that job during most of your...?

JOEL: He kept it up until 1929. He didn't lose it because of the Depression. But he made a job move at that time, which wasn't the best time to make it. But he made it in '29, and we moved to New York at that time, into the city.

ASPRAY: All right. And what did he do then?

JOEL: He worked for his uncle--my great-uncle--who was the president of a company called A. Solk, which is a haberdashery company. I don't know if you've ever heard of it.

ASPRAY: I know the company.

JOEL: You know the company? A. Solk is Amos Solk, so that's where the Amos comes from.

ASPRAY: I see.

JOEL: And so he went to work for his uncle and stayed on and became an executive vice president of Solk just before he retired. That's why we moved to New York.

ASPRAY: I see. And tell me about your early life. What were your interests?

JOEL: Well, that ties in with my professional career because, you know, I was always interested as far back as I can remember as a kid with things mechanical and electrical. I used to really enjoy electric trains and erector sets and all kinds of stuff and crystal sets at that time. And in radio. And I played around with all that sort of thing and always sort of curious as to how they all worked. And liked to create things.

ASPRAY: Was this an interest of your parents?

JOEL: No, they had no interest along this line at all.

ASPRAY: Did they encourage or discourage you?

JOEL: Well, I wouldn't say they did either. They did certainly provide me with the wherewithal to do these things. I never had any problems if I wanted...you know, for Christmas I'd get a new set of trains or something. I always had what I wanted along that line at that time. But it was the thing that really got me into telecommunications. Because it's a rather famous story. I don't know if you heard it. In 1928--I can't actually recall the date now but I believe it was toward the latter part of the year--they came to our house, and at that time we had a desk-stand type telephone, and they replaced the telephone with one with a dial, and after a certain day you were supposed to start using the dial. So I got very curious about this. I said, well, how does this thing work? And I used to write a lot of letters. I wrote a letter to the New Jersey Bell and got a booklet back--"the magic of your dial"--but it didn't tell me enough to satisfy me. I've always been interested in circuits. I made my own little railroad signaling circuits and things of that kind. So it never satisfied me. And that was really got me into this business was the curiosity about how the dial telephone system worked.

ASPRAY: Let's just take a minute more to talk about your childhood. You just mentioned railroad signaling. Tell me about that?

JOEL: Oh, yeah. Well, I had the electric trains, and I used to always try to work out arrangements for controlling them. And I used to-- I had a great fascination with trying to make unusual track layouts and things of that kind. I used to draw them up and things of that kind. And I used to then try to figure out how I would put signals in and so forth. In a time of desperation a little later, it had some bearing on my career, a slight bearing. But I was always interested in railway signaling. I used to accumulate books on that subject at that time.

ASPRAY: Tell me about your education.

JOEL: Well, I went to public schools in Atlantic City and later on in New York. And I don't think I was unusual.

ASPRAY: Did you go to any of the special schools in New York?

JOEL: No, no. I went to-- In fact, I went to the--the biggest high school at the time was all boys' high school called DeWitt Clinton. It was a very, very large school. I mean, like there are 10,000 students or something there. It was a tremendous institution in the Bronx. I actually lived in Manhattan, and I used to commute every day. During the last year which you had to go from the same building. Annexes all over New York--all over Manhattan and the Bronx. But I went to annexes in Manhattan and then later on had to go up to Mosholu Parkway where the main building was. And it was a long commute on the subway every day--on the elevated. But you could do your homework and so forth on it.

ASPRAY: What kind of student were you?

JOEL: I don't know. I guess I was a B+ something. I was not a top student. I was a member of what they call Arista, which was sort of an honorary society, but I didn't really have the top grades all along. I had good grades.

ASPRAY: Were your math and science grades better than...?

JOEL: Oh, yeah. Well, I loved mathematics. I really liked mathematics, and science, too. And so I specialized and I got good grades in those. The one I got bad grades in was foreign languages, things like that. It took me four years to pass three years of French [chuckling]. At any rate, I liked to do mathematics, and I took it as much as I could.

ASPRAY: Were there teachers who stood out during that period of time

JOEL: Yeah, I can remember a science teacher I had in public school, in sixth or seventh grade, in Manhattan, who made an impression on me. I don't even remember their names, but they were very good teachers. I don't know that I remember anybody who encouraged me in mathematics. It's just that I liked mathematics and so I just continued with that interest all the way through. Very early I got interested in this switching thing and that consumed a lot of my time after a while

ASPRAY: Did you have peers who you did science things with or shared your switching interests?

JOEL: Well, I had friends who-- I lived on West 86th Street in New York from 1929 on. And so I had a number of friends there. One of the very interesting incidents was that during the early 'thirties, I set up a telephone system along-- Eighty-sixth Street, then as now, was made up of a lot of tall apartment buildings, you know, 15-story apartment buildings. And we all lived in these buildings. So I set up my own telephone system and ran wires down the back fences along West Eighty-sixth Street. [Chuckling] And had a little knife--used knife switches--for switches and manual switches. And we had a switchboard at one end and one at the other end of the block. We had wires going up the sides of these buildings. At that time I acquired telephones by going into empty apartments and taking them because the Telephone Company would leave them, and there were plenty of empty apartments during the Depression. So there were plenty of telephones available. One of the incidents that I remember the most, a friend and I were sitting in my apartment, and, you know, we weren't using the telephone system at that time. But the telephone system went to about eight people. And all of a sudden the telephone bell rang. We couldn't figure out who it would be. So I answered the

telephone, and it came in clear and louder and clearer than ever before. And, you know, I immediately said, "Oh, it's never been this clear before," I told my friend who was sitting with me. And the man at the other end said, "This is the telephone man. Where are you located?" [Laughter] He didn't like the fact that we ran the telephone wires down along the cables in the back of the fences where the Telephone Company wires were.

ASPRAY: I see.

JOEL: And then I think he also looked-- One of the switchboards was in a first-floor apartment in one of the buildings, and I think he noticed in there were telephones that belonged to New York Telephone that shouldn't be. [Laughter] So I think he wanted to re-acquire them. So we had to give our telephones back to the Telephone Company. [Chuckling] But we had a good time with that system. So I remember that. It was fun building it and trying to solve some of the problems.

ASPRAY: I read in your Kyoto speech that you had started by a quite early age--was it 13? --reading patents.

JOEL: Yeah. I don't know whether the story was in the Kyoto thing, but what happened was that I pursued this business of how does the dial telephone system work. The New Jersey Bell, as I say, sent the usual literature which didn't really satisfy me at all because it didn't really tell me the electrical circuits and all that that I wanted to know what was behind it. And how the switches looked and so forth. In fact, as I remember, they didn't even invite me to go down to the telephone exchange at that time. But whatever, I continued to write. Like, I wrote someplace, they told me to look it up in the encyclopedia. Well, there wasn't very much in the encyclopedia. A little bit more, but not much. But then I wrote to--I don't

remember exactly how it happened--but I wrote to AT&T. Not about the telephone system in Atlantic City, but about a newer system that I had heard they were working on which at that time was called the crossbar system. And I asked if they had any literature about the crossbar system. And I got a letter back from a gentlemen, whom I later met and got to know, where he didn't want to tell me very much. But he said, well, this is stuff that is all covered by patents. And here's a few patent numbers that describe them. And that's all he said. He didn't say anything about how to get copies of the patents or anything. So I looked into it and found you could--at that time I think it was a nickel a copy--you could buy a copy of a patent. And so I sent away to Washington and got copies. And, oh, this was great! I mean, this was just what I wanted because it showed actual circuits of things.

ASPRAY: Could you understand these?

JOEL: Yeah. Yeah, I think I understood those particular ones anyway. There were only two or three--three, I think it was--patents. I don't know why he did this. I never found out from him why. In fact, he didn't remember the incident at all. But I don't know why he chose to send me these patent numbers. [Chuckling] They weren't his patents or anything like that. So it really got me on a kick.

ASPRAY: About how old were you when you started this?

JOEL: I was about, as you say, 13, 14. Yeah.

ASPRAY: Okay.

JOEL: And that really kicked me off because then I went down to the public library. I learned that there is a journal that comes out every week called The Patent Office Gazette, and in there they show one picture and one claim about each patent that

was issued. And I started going back and looking through these indices and so forth. And eventually started to organize the information about them. I started to actually make little 3x5 cards on each patent and information about it and made a real business out of it. And I started accumulating copies of the patents. Actually I didn't really do that in a big way until I went to college. But in the meantime I started collecting some patents. And I eventually bought a set of patent indices for myself and things of that kind. Just to keep track of what was going on in the telephone field--particularly the switching part.

ASPRAY: Now, did you have other interests that were as passionate as this one at the time?

JOEL: No, no. You know, I liked music. At that time I took lessons on the clarinet and saxophone--all during the time that I was in New York. I took lessons for four or five years. And so that interested me; music always interested me, and it still does. But I think those were the two interests I had.

ASPRAY: Did you have a chance while you were still in public school to meet any of the people that worked for the Telephone Company?

JOEL: No. There was one opportunity I had a little later, just before I went to college, which was in 1936. I had acquired--I don't know how--a copy of a little pamphlet put out by the New York Telephone Company for their people. Part of an education course or something. But it was a little pamphlet; it was a beautifully done pamphlet about the panel dial system, which was one of the major dial systems at the time. And it was written by a man by the name of Ellsworth H. Goldsmith. I remember that. And, you know, I got curious, and I wrote him a letter. He invited me down to the Telephone Company, and I met him. He didn't take me through the telephone office or anything, but I had a chance to talk to him

about it and learn more. I learned, I remember that, that he was a--what do you call it? --a horologes, interested in clocks. He put clocks together and all that. That was his hobby. But he happened to have a job in the Telephone Company writing course material. And that was the only time I ever had any contact with people from the Telephone Company other than writing to them and trying to get information. Which, I would say, on the whole, was not very satisfactory. In fact, it led me later in my career to try to do something about this. Because later on in my career I felt that switching sort of got the short end when it came to telecommunications. That everybody talked about transmission, and they did a great job of teaching transmission in colleges and schools. Transmission had been reduced to at least more of a quasi-science so that you could put mathematical equations on the various things that take place in transmission. But you couldn't do this in switching. And I wondered why, and why couldn't we do a better job in it? And I felt that part of this was not enough dissemination of what goes on in the business of switching. So all this led me in that general direction, I think.

ASPRAY: Are there other things that we should talk about from your early life, your public school days? Are there anecdotes? Were there any other components to your switching story that we haven't talked about?

JOEL: Well, yeah. Certainly in those early days, you know, my friends knew I was interested in this sort of thing. And they'd always have their little problems and things they'd ask me about. Electrical things in general. But the thing I remember the most now is that starting about 1931 after I started really learning something about switching, I decided, well-- First of all, it seemed like an inventor's--it was--an inventor's art. I mean, everything you read about it was always somebody

inventing something about switching. That was certainly the approach I took because I was looking at patents. Those were all inventions. And so the natural course seemed to be, well, I'm going to go out and do my own inventing. I'll invent my own switching system. Which I did. This is 1932, '33. I started growing up my own system, which I called the Joel All-Relay Dial System. I still have some papers on this that I want to show. And then I said, well, I'm going to try to build this thing.

ASPRAY: Well, what was its function, and how did it differ from others?

JOEL: I thought at that time--of course, I wasn't yet that knowledgeable about everything that was happening in switching--but at least at that time I figured that it was much better to try to design, like AT&T was designing, this crossbar system in which the moving parts were very, very small. They were very little. Very small motion. That it would be nice to design a system that had only relays in it that had very, very small motion and no special devices, that you'd use ordinary, general-purpose relays for the functions. So that was my idea was to try to use ordinary relays to do it. The problem was that when I went down to Cortland Street, which was the place in New York in those days where you got radio parts and electrical things, that the cost of relays then were, you know, like even then were a dollar apiece, which was an awful lot of money. And I needed a hundred of them or so just to build a little sample switching system. And there was no way I was going to accumulate that kind of money to go out and do this. I did get some relays and put them together and played around with various circuits. But I really never built the system. And I keep thinking back to those days when the device was fairly big. It cost a dollar apiece, and it did very little. And now, you know, you can get

a little tiny chip that does so much more [Chuckling] of the same kind of thing for so much less. So the technology has really changed tremendously from those days. And the quality of the type of people. Everything's changed. And I'm glad to feel that I had some part in it.

As far as looking back at the school, certainly the people I--my friends at that time--you know, they knew I was into this thing. Perhaps thought I was a little crazy about it, but it was a hobby, just like anything else.

ASPRAY: How much time would you spend a week, do you think, on this hobby?

JOEL: Gee, I have no idea, Bill. I mean, I had my schoolwork to do. And I used to go out and play with the boys, so to speak. I remember a lot of things I did. I used to like roller skating. I did an awful lot of roller skating. Not only playing games in the block there--86th Street's a fairly wide street with wide sidewalks, so you do a lot of playing on the sidewalk. But then on my own I used to do an awful lot of skating all over Central Park, which was great. We used to have a tremendous time and skate all the way from 59th Street all the way up to 110th Street. And I just enjoyed that, and so I did a lot of skating. That's about the only activity I really remember, you know, physical activity. I worked hard at schoolwork. At least, as I say, particularly on the trains going back and forth to school. I used to like to work in school, by the way. I remember being on a committee--they called it a committee--it was just they'd take out a certain group of people who were interested in this sort of thing, and they'd put them to work at doing programming. I used to--I guess for a year and a half--I did work at the high school where they'd figure out the-- You know, people would move from class to class, and everybody had different combinations of subjects they would take. And the idea was to fit all

this together. So I would always interested in dealing with combinatorial problems like this. And so I worked at programming in this programming group. I remember the woman that had charge--she was a very strict disciplinarian because she had to be for that kind of stuff. Of course it would all be done on computers today. But in those days we had an awful lot for 10,000 students--to arrange their programs twice a year was a big deal. And that group that I was in was responsible for that. You know, they put the kids to work to do this. So I do remember that kind of work that I did at school. Then every week I had to go down for my lesson in saxophone or clarinet and practice that. I never became very good at it, [Chuckling] but I enjoyed it.

ASPRAY: But would you say you'd never go a week without doing something in switching or--?

JOEL: Well, once I got this bug which, as I say, started in Atlantic City, and continued in New York--once I got that bug--I think I continually more and more tried to learn more and more about switching. And I had this bug, the curiosity actually, that was never satisfied. The more I'd learn about one thing, then I'd say-- Well, that would lead me on to something else. Particularly patents, as you may know, frequently have references to other patents. And I kept track of all that. And of course frequently that zeroed in on certain key patents. Now, they were key patents from a patent point of view. They may not have been key technology patents necessarily, but they were key from the standpoint of the corporate way of doing business. But, yeah, I think that stayed with me all that time. I kept always doing something in switching. Or at least trying to find out something about switching.

ASPRAY: Do you think that that helped your overall education? Did you learn a lot of math and science from reading these?

JOEL: Not really, no. No, it was completely different. It was like moving my interest in erector sets and trains--although I continued some of that--but like moving from that to this other hobby of finding out about switching. By the way, the other thing I always had in my life, I've always-- It started in Atlantic City, I guess. This was an influence--of a certain amount--of my parents, my mother particularly. Being in Atlantic City at that time, most of the Broadway shows started there. They'd be on the road--

ASPRAY: In previews there.

JOEL: --and preview in Atlantic City. And so I saw all the musicals. I used to love musical theater, and so I went to all the musical shows there. And then later on in New York to the movies and to Radio City. I used to go to all the opening shows there. And, you know, that was always a hobby. I'd always been interested in musical theater.

ASPRAY: Something that's continued?

JOEL: Yeah. In the musical sense. Well, I go to all the Broadway shows that are musical shows. My wife tries to drag me to the other kind, but I try to stay clear of that. In fact, there was a great thing up in your area on Sunday. Rosemary Clooney played at the Morris Knolls High School. Do you know where that is?

ASPRAY: No, I didn't know. I know where that is.

JOEL: Anyway, we went to see her. But we really like musical theater--or at least I do, and she does, too. So, at any rate, that started back in those days, and that's why I think one reason why I tried to play the clarinet and saxophone. See if I couldn't

become a musician myself. But I never really acquired those good skills. I think, like a lot of people, you [Chuckling] try to do these things, but it takes a lot more skill than you may think you have. Especially when it takes a lot of practice on basics, and you're too anxious to move ahead and play the music from the latest musical show or something. And I still have that same problem with my organ playing. I don't spend any time trying to learn the basics. I just try to play the latest stuff that I like to hear. I don't do it very well, but I have a lot of fun at it. But at any rate, that started back in those days. I really, you know, between my school work and music lessons and going out with the fellas and so forth, I didn't have much time left for switching other than to put on it what any other hobby would take.

ASPRAY: How well did your public school education prepare you for college?

JOEL: Well, I think very well really. I mean, well, look at things today. I think it was very good. DeWitt Clinton High School was not the top high school of the city to prepare you for college. I mean, there were better schools for top students particularly. And, you know, in those days, particularly the Depression, everybody wasn't slated to go to college. I don't know what percentage, but maybe 40, 50 percent of the kids went to college in those days from DeWitt Clinton. But I felt it prepared me well. It seemed like fairly early on--I just can't say what the date was, but certainly perhaps two years, maybe even three years, before I graduated, which would have been about 1933--I'd heard enough about MIT to feel that I would like to go to MIT. And the biggest worry at that time was whether my father would be able to afford it or not. In those days--as today--it

was considered to be quite expensive to go there. And especially coming out of--or, we were still in--the Depression then.

ASPRAY: Did you and your parents expect from when you were young that you would go off to college?

JOEL: Well, I don't know. You know, looking back, I would say, no. My parents did not go to college, and I don't remember anybody in their families going to college. So I don't know whether-- I just felt that, I guess, to do what I wanted to do, I had to have a college education.

ASPRAY: What were your expectations for your career, say, when you were graduating from high school?

JOEL: Oh, I think by that time I had really decided-- I knew when I went to school--to college--that I wanted to be an electrical engineer. I'm almost--I'm positive--at that time I already knew the type of engineering I wanted to be in. I don't think there was any doubt that, you know, I wanted to go into some other type of engineering. And so the formative years were probably the three years between 1933 and 1936. And of course culminating in my acceptance at MIT.

ASPRAY: Did you apply anywhere else?

JOEL: I don't remember. We wanted to stay fairly close to home. I didn't want to go a long, long way. And none of the West Coast colleges at that time had that kind of a reputation like it has today--they have today. I don't really remember. I think maybe the University of Pennsylvania, but I'm not sure. Yeah, I guess so, because I remember thinking about the Moore School and learning about the Moore School and so forth. At any rate, I think I did apply to the University of

Pennsylvania; I'm almost positive I did. I don't know. None of the local schools in New York attracted me.

ASPRAY: Not Brooklyn Poly?

JOEL: Not Brooklyn Poly or Columbia. I don't know why. But I guess I had heard some good things about Pennsylvania. Frankly, I had heard--and I don't know where I heard it--but my interests seemed already to be in designing and inventing. That would seem to be-- I mean, I just naturally seemed to want to do that. And for some reason or other, I associated MIT with this, and when I got there, I found it was true. That MIT was more the kind of place where you go to do original work and that sort of thing, not just to study it and go on your way. That they seemed to emphasize more the inventive idea, the original thoughts and so forth, and promoting them. So that also attracted me to MIT at that time.

ASPRAY: Tell me about your course of studies there.

JOEL: There? Really, I took the standard electrical engineering courses. Of course at that time you also had to take some standard courses in English and a foreign language and a few other things. In fact, there's more emphasis on that today than there was even then. In those days the humanities were fairly minor. At that time also MIT had just--in the Electrical Engineering Department--had just come up with a whole new set of texts. They had done some work from about 1929 on developing new courses in electrical engineering. And they had beautiful new textbooks and things on electrical engineering, which were great. And then the other thing was that I met a lot of good professors that I enjoyed very much. Particularly one who was interested in the Telephone Company

ASPRAY: Who was that?

JOEL: His name was Carleton Tucker. He, much later on, became-- Well, he had been class of '18, so he was already-- How old would he have been? Well, he was 45 to 50 years old. But he later on became head of the department. Of course they rotated the head of the department around. But he was always interested in the telephone, and he knew a little bit about switching and transmission--he knew a lot about transmission. In fact, they taught a course in transmission. And he had a lot of friends in the New England Telephone Company. He knew everybody there. And he knew all kinds of Western Electric products. He knew every code number and all that kind of stuff. [Chuckling] So he was a man after my own heart. And I met him fairly early on before I really was in the Electrical Engineering Department taking their courses, you know, as a sophomore. And we got along great. They had an old Strowger PBX in the department that wasn't working very well, so I got my hands dirty by trying to get that things to work. And I really got a lot of benefit out of playing with stuff at MIT, which I didn't have at home. And then through him I met people in the Telephone Company. Went to see--visit--central offices and things of that kind.

ASPRAY: Let me come back to that.

JOEL: Yeah.

ASPRAY: Pursue the education a little further right now. What other faculty members do you remember from electrical engineering?

JOEL: I remember a lot of people there--not all of them necessarily people I had courses with. But one I remember the most that I had courses with was Ernie Gillman, the very famous person in communications theory who wrote a whole series--well, at least two books--on the subject. And a very excellent lecturer in many respects. I

had a number of good professors there. I can't remember all the names. But there were people in the department at the time that you could talk to. People like Edgerton and people like the servo guy--Ed Winer. What do you call it? I had a course--I had a math course--with Wiener, Norbert Wiener. And then the other guy, that became president of MIT. It was Winer, wasn't it? Yeah. Both Norbert Wiener and Ed Winer. Winer was from the EE Department. And there were a lot of-- Bowles was a guy I remember.

ASPRAY: Edward Bowles?

JOEL: Edward Bowles.

ASPRAY: Since you had lots of contact with computing later on, did you have any contact with Bush or Caldwell at the time?

JOEL: I had no-- Caldwell, I did. Not Bush. But I had a lot of contact with Caldwell because it turned out later on when I proposed my master's thesis, that he was the natural one to be my thesis advisor.

ASPRAY: I see.

JOEL: And also during a couple of summers, I worked up there on a differential analyzer that Caldwell was building for Bush which used electrical switching--used switching--to connect the various integrators and other active elements of the differential analyzer. It was called the Rockefeller differential analyzer. It was different than the earlier Bush mechanical one.

ASPRAY: Right.

JOEL: And they had used crossbars, which is the--some very, very early crossbars--that came out of Bell Laboratories. And I had a lot of fun designing some circuits for that. And doing some work on that thing during the summer.

ASPRAY: This was summers when you were an undergraduate or a graduate student?

JOEL: Oh, yeah. Well, I was never a graduate student on the campus. I took enough courses in the four years I was there to get credits for my master's degree, but the only thing I didn't have was a thesis.

ASPRAY: I see.

JOEL: And I had planned to then do my thesis in non-residence if I could find somebody who would back me up. And I got Sam Caldwell to do that, so that was no problem.

ASPRAY: Generally speaking, how did you do in your course work at MIT?

JOEL: Again, I wouldn't say I was summa cum laude or anything like that. But again, B+, that sort of thing. Most of the courses I did pretty well in. Most of the electrical engineering courses. The other kind of courses I didn't do so well in. But most of the electrical engineering courses I did pretty well in.

ASPRAY: Did you have student acquaintances that became important in your career or lifelong friends?

JOEL: Not directly. Lifelong friends, yeah. But, I guess, you know, I had lab partners who became famous who were friends of mine all through their career. Nobody else shared my interest in this switching thing. [Chuckling] But I had a wide-- I'll tell you the one person that I really had more rapport with than anybody else was Claude Shannon. But it was incidentally. I wouldn't have known at the time what he was going to become. [Chuckling] And in fact I think I had some influence on what he did for his master's thesis because we would walk all over Boston together--and later on then when he started working at Bell Labs we would walk around Manhattan together--talking about all kinds of things. And I used to tell

him about the complexities of these switching circuits and how interesting they were and so forth. And, you know, here's a subject that there's no theory to. People just go out and invent these things, design them and so forth. And I think that got him interested in this business of applying Boolean algebra to these things. And I think I had some influence on him. So I knew Claude quite well in those days--and later on at Bell Labs when I got into this cryptanalysis type of thing. He was already into that. But I don't know that I can say that-- Well, we just finished last year--1990-- Well, that's two years ago, isn't it. We had our fiftieth reunion, and of course we met a lot of friends again for the first time in fifty years. And of course some of the people I remember from those days, and they remembered me. I have one person who went to public school and high school and MIT with me and who lived right near, obviously, where I lived in Manhattan. But all through the years we had only slight acquaintanceship. So he's never-- He was a chemical engineer. So we've never really had much contact in that respect. On the other hand, people who graduated around the time I did from MIT and went to work at Bell Laboratories I knew quite well.

ASPRAY: Who were some of those people?

JOEL: Well, people like Stu Miller--I don't know if you've ever heard of Stu Miller. Stu Miller was a very famous--and died unfortunately last year--in fiber optics, development of fiber optic techniques in the research area, you know, long before it became a commercial thing--back in the late 'sixties, early 'seventies at Bell Labs. And before that he had worked on all kinds of other transmission research projects. And a fellow by name of McWeegan, who died rather early; he died in the 'fifties--

ASPRAY: What was his first name?

JOEL: McWeegan was.... Oh, gee, I should know it.

ASPRAY: That's okay.

JOEL: Bill. I think it's Bill McWeegan, but I'm not sure. And I can't recall them all right now, but there were a number of classmates who went to work at Bell Labs. Of course I kept up to date with those over the years.

ASPRAY: Let's come back and talk about this--the kind of education that MIT gave in electrical engineering at the time. Was it power-oriented? Could you do control engineering at all?

JOEL: Control engineering was just coming in. That was the big thing. Hazen was the guy--

ASPRAY: Oh, yes. Right.

JOEL: Hazen as well as-- Who was the other one? Anyway, when I started at MIT as a freshman, there wasn't really very much in communications. But communications was starting. As I say, Gillman had a course for undergraduates. He also did a graduate course, too. But a communications option started, I think, just about in 1936--maybe '34. The communications option only started in that area. And then one of the other things, of course, I do remember this. I think I tried, but did not succeed, in getting into the cooperative course. McWeegan and Miller, I believe, were both in the cooperative course that they ran. The cooperative course at MIT consisted of, spending, like, two semesters at MIT and then going out and working and--something of that kind. It still is in place today. And they had several options--So they had several options in power, and I think at that time they had the first one in communications--which was at Bell Laboratories. And I

tried to get into that and didn't succeed. I don't know why. I don't know what the problem was, but I guess my grades weren't high enough. I imagine for that you had to have straight A's or something. It was called 6A. [Chuckling] But really, I think grades were very important to get into the cooperative course. And I didn't get into it. I tried. But in any case, communications was just starting to become a more popular area than power at that time.

ASPRAY: And how many of your-- Was it a significant portion of the student population or just a very few people who shared that interest with you?

JOEL: Who studied communications?

ASPRAY: Who were interested in studying communications?

JOEL: No, there were a good number of people in communications. They were really interested in getting into radio and things of that kind. I wouldn't say any of them really shared the kind of interests I had--certainly nobody interested in switching. Switching at that time--as I look back on it--was an inventor's art. It was not the kind of thing that people with intellectual pursuits would say, you know, this is something--

ASPRAY: There's something to this.

JOEL: There's something to this. Yeah. And the people that I later met at Bell Laboratories when I started were all great guys, but they were all inventors. You know, they were almost the kind of guy you'd see in the back room putting things together this way and that way. The only difference was that they worked for a big company. In fact, you had to work for a big company like that--it wasn't that big in those days, but it was big relatively--you had to do that to do this kind of thing. Switching is not really--a big switching system--is not something you can

very easily put together on your own. It takes a lot of people and a lot of work. But the fellas that I knew-- Of course I had an unusual--when I started working there--very, very unusual situation. Because I came in knowing a helluva lot about the subject, you know, and they never saw anybody like that before, you know, in the whole time Bell Labs had been in existence. So that was very unusual.

ASPRAY: Let's try to wrap up your college education. What other stories or what other things can you tell me about that?

JOEL: Yeah. There's a lot of stories, a lot of things to talk about there. Because first of all my interest in-- By the way, in order to earn a little extra money and so forth in the Depression days, I remember working in a lunchroom--a lunch place--on the campus. And then I worked in the dormitory office. And that's very important because the dormitory office had a switchboard, and I ran the switchboard.

ASPRAY: Ah hah!

JOEL: And of course I enjoyed that. Doing all kinds of fancy things like connecting people together that didn't know each other and what not. [Laughter] To show what you could do with a switching system. But, yeah, it was very good, and it was a chance so that you met people. You knew a lot of people. All the people living in the dormitory would pass through the office there, and you'd get their laundry for them and what not. Charge them for various things. So it was very good. And send their telegrams for them. But at that same time I used this money that I got from some of this to get more patents. By the time I met my wife-to-be, which was--she says Easter 1938--then I started doing this thing in earnest. I mean I really went back and looked at all the switching patents and put 3x5 cards

on every one of them. And decided I'd buy certain ones that I thought were important enough and started accumulating a library of all these things. And learning about all the different things that people ever invented in switching.

ASPRAY: So you had time to spend on this?

JOEL: Oh, I spent a lot of time on that at school. Yeah. And of course I had to do my schoolwork. But that was my major hobby there. And I remember then I was quite knowledgeable already in some of this. So I used to have these drawings all over. And of course I think stories that people like to hear is that my first date with my wife, they had an open house--my wife-to-be--you could bring your lady friends up to your room. It was called "open house." And so she came up, and the first thing I did was I pulled out one of these patent drawings. And they're tremendous. I mean, they're like 50 or 60 sheets. And what I had done is pasted them together so that it was one great big roll of drawings. I had to lay it out on the floor for her. And I explained to her that--it took like an hour or so--but I went through all this business. I said, "It takes all that to give you dial tone in this latest type of switching system." [Chuckling] Which was the latest crossbar switching system. She claims I took her later to a crossbar office in New England Tel. I think it was a step-by-step office, but that's beside the point. [Chuckling] At any rate--

ASPRAY: Did she have a science--

JOEL: --she went home and told her father that I was crazy. [Laughter] But, I mean, I was into it that way. And I remember also the other thing I had in school. I had it on my wall next to my desk: the patent drawing of the coin district juncture of the panel system. Because people kept coming in my room all the time and saying, If you do this, can you get this call through for nothing? What will happen? And

they had all kinds of ways, you know, but the most common way was you'd tilt the-- You had a protractor on the bottom of the telephone booth, and you'd tilt it so many degrees and put pennies in it, and they'd sound like nickels or something. [Laughter] But they'd ask me all kinds of, you know-- Could you do this, that and the other so the wires wouldn't get you? And I had this diagram there to keep referring to it. It was a diagram of a circuit that was up on the wall that took care of this. [Chuckling] So I was doing that kind of stuff at the time.

ASPRAY: How did you meet your wife-to-be?

JOEL: Well, as I say, I worked in the dormitory office, and she came in with a girlfriend. The girlfriend had a date with somebody there. And asked to call up, you know, and I saw her. And I started talking to her and making eyes at her and what not. And then when he came downstairs, he introduced us. And then later on-- I said I'd be finished in a couple of hours or so, and I guess we went out that evening. And then later on we went out when we had open house. And one thing led to another.

ASPRAY: I see. Was she a student in the area?

JOEL: Well, she had been a student at Simmons, which is a ladies' college in the Boston area. But she had to drop that during the Depression. But the main thing was she-- Well, she lived in the area. She lived in Revere Beach, if you know where that is.

ASPRAY: Yes.

JOEL: And that was a great place to go to in those days because, you know, it was an amusement town and what not. And so I used to go out and visit her on the weekends. So I started accumulating this library of patents. And I guess as far a college goes-- Oh, the other thing that I touched on before, but I think it's

important, is that this Professor Tucker had contact, a lot of contacts--as professors will--and he accumulated some switches of various manufacturers. You know, from IT&T and some other people. They weren't a switching system. They were just odd switches. So I got the idea of putting together a case of these, putting them together in a glass case, and having buttons that people could go along the corridor and push the buttons and see them operate. And so I built that thing. I remember building that. And they used it in open house and places like that. Eventually it became a fixture in the Electrical Engineering Department in one of the halls where you could play around with these things. And then, as I say, I worked on the department PBX. They were always having problems of some kind. I'd try to keep it working. But that was fun. The computer of the day.

ASPRAY: Now during that time did you know you wanted a career with the Telephone Company?

JOEL: Well, my aim at that time was to have a career with Bell Laboratories. But that's a very, very interesting story in itself. In my mind there was no question. That's where I wanted to work. First of all, I knew all these patents and things, and could see that most of the things that were really of interest and real advances in switching seemed to be coming out of Bell Laboratories. So that's where I wanted to work. It turned out that one of my classmates--I can't remember what engineering he was studying; he was not electrical engineering--but I knew him through the dormitory. Well, no, he was a fraternity man, so I didn't know him--Some way I knew him. I don't think he was electrical. But it turned out his father was the chief patent attorney of Bell Laboratories. His name is Edgar Adams. He was Edgar Adams, Jr. And I knew that. But I didn't do anything about it. And I

had written Bell Laboratories--as most seniors would, you know, looking for a job--and I got the usual form letter back saying, "Sorry, we're not hiring this year." Of course we were coming out of the Depression, and there wasn't very much going on in the hiring. And I guess even the professor tried some people he knew, but that didn't do any good. But I talked to--I don't know whether I talked to him or whether he did this on his own; I don't remember that--but Ed Adams did talk to his father. He said that we've got this guy up here that really knows his- - You know, I've seen his study. He knows all this business about these switching systems. He knows all these patents and what not. I guess he thought maybe his father might be interested in the Patent Department or something. But his father apparently went to some people and said, Maybe you ought to look into this guy. May be something to this. [Laughter] In the meantime--there's a whole story there in itself--in the meantime, of course, it's getting to be near graduation, and I'm looking for a job. And so the next best is to go to the next--second--best company, which would be Automatic Electric, which were the people who were making the step-by-step systems. The successor to Stroger, the inventor of the first practical dial system, if you want to call it that. And they invited me out to Chicago to visit and for possible employment. I knew their patents, too, you know. I knew all the patents. So I knew what they had and who their attorneys were from the patents and who their inventors were and all that. And I knew a lot about them. By the way, at that time things started to get desperate looking for a job, so I also wrote to the General Signaling Companies because I was interested in railway signaling. To see if I could get a job doing railway signaling design because that was interesting. I don't think I got anything out of that, though. No positive indication.

But Automatic Electric was interested, and they paid for my way to go out to Chicago and to be interviewed at their old place on Van Buren Street, which looked like it had still been there in 1892 when he invented the stuff. Anyway, it was a real experience. And it was just one day, but toward the end of the day, I got a telephone call. And the telephone call was from the manager of my father's company store in Chicago. They had stores in Chicago--a lot of stores around the world, not particularly in the United States, but Paris, London, places like that. Anyway, he said, "I understand you're there looking for a job." He said, "I've been told to ask you not to do anything about it. If they make you an offer, don't accept it. But come to see me before you get back on the train to go back to Cambridge." And I did. I went right from the factory to his place. And he said that Bell Laboratories had called Professor Tucker and asked about me and whether they could see me. And he said, "You'd better get a hold of him in a hurry. He's out at Automatic Electric."

ASPRAY: Ah hah! [Laughter]

JOEL: And so I then got on a train for New York instead of going back to Cambridge. And I had a date then with Bell Laboratories, and they took me out. I spent a day with them. And so I got an offer from both of them. But the offer from Automatic Electric was much better than the offer from Bell Laboratories. I think Bell Laboratories was offering, like $100 a month and Automatic Electric $130 a month.

ASPRAY: Oh, so it was sizeable.

JOEL: A sizeable difference. And I told Bell Laboratories this. I said, "You know, this is where I really want to work. But I have a better offer." And they said, "Well, you

know, $100 is what we've been paying bachelor's, but you're going to get your master's degree. You have all your master's credits except for your thesis, and we understand you're going to write your thesis after you come to work. And the topic, I think, had been approved--the thesis topic has bee approved." In those days you had to do a thesis for your master's degree. And so they said, "Okay, we'll pay you as if you had a master's degree." And that was $130 a month. So that was it. So I started out with that.

ASPRAY: Let's go back for just a moment and talk about your master's thesis. What was the topic?

JOEL: Oh, yeah. Well, first of all, they had two things. In the master's program, there was a thing called a master's seminar, for which you had to do a piece--generally about history, by the way, I think. Well, it was something about your subject, you know, a subject you were most interested in, or very much interested in, and something about the background of the subject. It was not, you know, it didn't have to be an original work. For that I did a tremendous piece, which was the history of automatic switching. It was a huge thing, and it had pictures from many of these patents and pictures from all kinds of books that I could find and what not. And I had already accumulated, by the way, quite a library already of books on automatic telephony. So I used all this material, and I put together this huge thing. That was my seminar, and I gave the seminar and had slides and everything. It was a big deal. Then for my thesis I had picked a topic on the functional design of relay and switch circuits. In other words, saying, look, you can organize the way you design relay and switch circuits. It doesn't have to be every one's an invention. To take the, you know, bunch of requirements and sit

down and figure-- But you can have basic functions and put them together in various ways. And I tried to show how you could do that. It wasn't easy. I mean, there was no mathematics or anything you could apply before Shannon. Well, I shouldn't say it was before Shannon. It was after Shannon. But there wasn't much the Shannon thing could contribute except to the blocks. And I tried to show how to put the blocks together. Of course Caldwell never felt that this was a very sophisticated, intellectual exercise kind of thing. He would have preferred something much more esoteric than I had. [Chuckling] But nevertheless, after a while he finally accepted the thing, and I got the degree.

ASPRAY: Was he of much help?

JOEL: No, not particularly. I wouldn't say he contributed very much. I don't think he really liked it. I think he just sort of reluctantly agreed to do this. And the thing he really perked up on was after a while, you know, this resulted in a course that we taught at Bell Laboratories. And I started this, I started the whole idea of teaching switching. So we came up with a book, a famous book, which Keister, Ritchie, Washburn-- I don't know if you ever heard of it. But it's the design of relay and switch circuits. And I was the originator of this. I didn't participate in the writing of the book because I was off on other things by then. But nevertheless, Caldwell grabbed a hold of that. He liked that at that time then. We're talking now about 1946, '47. And he went out and wrote his own book. [Chuckling] But at the time, which was a lot earlier--we're talking about 1940, '41--he wasn't that much enthused about the whole idea of switching circuits could be formalized and so forth and so on. I guess he had been Claude Shannon's master's thesis advisor also.

ASPRAY: I didn't know that.

JOEL: I imagine so. I'm not sure, but I think so.

ASPRAY: Besides working on the--

JOEL: By the way, because of that I didn't get the degree the first year when I finished it. They didn't give me the degree until 1942 instead of '41. I graduated with a bachelor's in '40, my master's in '42. [Chuckling]

ASPRAY: Oh. In addition to the experience working on the Rockefeller differential analyzer, did you have any experience with computing while you were at MIT?

JOEL: No, no. In fact, the work I did on the differential analyzer was purely switching. And I didn't really fully appreciate what that was all about until much later. I did know, you know, that the integrators were sending these signals, but I really didn't understand the whole business of how you set of differential analyzers to solve differential equations. Which is fairly neat, you know. It's simple, and this thing gave it tremendous flexibility to do it with the electrical connections instead of physical connections. Anyway, a lot of things in your career, you have a contact with them at the time, and you don't appreciate the importance until later on. And that certainly was one of them.

ASPRAY: Anything else about your college era?

JOEL: Not really. No, you know, a lot of interesting lab work that I did that I enjoyed. The classes were fine. I liked mathematics courses and took a lot of extra courses like probability and things like that which were not-- Well, I guess I took-- Those were graduate courses. That's where I had Norbert Wiener, I guess, was in a graduate math course or something like that.

ASPRAY: He has a reputation for being a terrible teacher.

JOEL: Oh, he was. Yeah. But a great guy to talk to. He'd fill the board with stuff and then just walk out of the room. [Chuckling] But really in those days--and, I guess, pretty much today--you were on your own pretty much to learn. The teachers could guide you and could help you. And you could go see them and discuss things with them. But they really weren't teachers in the sense that-- Once in a while, you'd find a great teacher. Ernie Gillman stands out in my mind as a great--was a great teacher. [Chuckling] I remember the most important thing was he'd come up with these equations, you know. He'd go through all this business of equations for filters and what not. And he'd give you a problem, and you'd go home and you'd solve this problem. And it turns out that the problem required I don't know how many variances of capacitance to do this. And you'd come to him and you'd say, Well, this isn't practical. You'd never build a filter like that. He'd say, "I don't care. That doesn't make any difference. The theory's right." [Laughter] If it works good and that's where it comes out, that's where it comes out. He didn't care whether you could build such a thing.

ASPRAY: That raises a question in my mind. How practically oriented was MIT?

JOEL: Oh, very. I think so. Because I remember taking a power course where you had to sit down and you had to design this whole power line. Of course this was before the days of calculators, so you had slide rules that you could use. But, you know, they really had to calculate all the details of this power line and the losses and this, that and the other thing. It was pretty practical. On the other hand, a lot of the problems were always oriented toward solving something new that was different, not just going back over some ground that people had hashed over for years and

years. So there was always this-- You got a feeling all the time of being in a creative atmosphere.

ASPRAY: Problem-solving and design?

JOEL: Problem-solving, yeah. There are better ways anyhow. And that was good, I thought. And I think it set--at that time and even today--set MIT apart from some of the other kinds of places.

ASPRAY: Students were good?

JOEL: Oh, the students were great. Yeah, yeah. All the people that you came into contact with--both the faculty and the students--were always just top rate. Yeah. And even in those days a lot of foreign students. I can still remember Wiener going across the campus always talking in Chinese with the Chinese students. But there wasn't as many Asians as there are right now. But nevertheless there were a lot of foreign students always at MIT. In the graduate program mostly.

ASPRAY: All right, let's-- Do you want to take a break for a minute?

JOEL: No, no.

ASPRAY: Okay.

JOEL: Do you want some coffee or anything?

ASPRAY: I'm fine. Let's talk about your going to the Labs.

JOEL: Oh, yeah.

ASPRAY: What was it like? Where did you work?

JOEL: Oh, the Labs at the time I started working had only one location, which was 463 West Street in New York. It had been at one-time a Western Electric factory location, I guess, many, many years earlier. In 1925 the Bell Laboratories was

formed. Prior to that then it was the Engineering Department of the Western Electric Company.

ASPRAY: This is down sort of near where the Javits Center is?

JOEL: No, no. Further down. Between Broome and Banks Street.

ASPRAY: Oh. Uh huh.

JOEL: On West Street, right on the river. Of course in those days you'd look out, and the piers were there and you'd see the boats go back and forth. The boats actually docked right across the street from the Labs. Oh, it was a terrific place at that time. You can look back, and I have lots of memories of Bell Laboratories at West Street. And today it's called West Bend. It's an artists' colony. They sold it in 1963 or '64, something like that. But at that time it was the only Bell Labs location, and it consisted of less than 3,000 people. Probably at that time when I started working about 2500 people. So it's grown like ten fold [Chuckling] since then. And a great bunch of people, you know. There was a culture there. It was a mixture of all kinds of people. Most of the people, by the way, in the switching art in those days were not college people--not daytime college people. Many of them did go to college and got degrees at night. And anybody who got a degree at night at Bell Laboratories--who worked at Bell Laboratories in those days--was sort of looked down upon. For many, many years, a night degree did not have the same aura about it as a day degree. And many of these people, of course, started as technical aides and weren't engineers anyway until they became-- And it took a long time even after they got their night degree to become an engineer and be considered a member of technical staff. So it was interesting in that sense. But a great bunch of people. Of course they were still in the trauma of the Depression

when I started in 1940. I started in July 1940. We were still working--I think we had one half day off a week. So it was four and a half days a week or something like that. The story goes that during the Depression they were going to lay off a lot more people. And Roosevelt heard about this and didn't like the fact that they were taking this very important national contributor, Bell Laboratories, and reducing--getting rid of--some of the famous people they had there. The team that they had there. And so they opted to keep cutting back the days that people worked rather than trying to reduce the size too much.

ASPRAY: Before the war it had been a six-day workweek?

JOEL: At the time of the war we started a six-day workweek. It became six days, I remember that, very quickly. I don't remember just when. I don't think it was before the war.

ASPRAY: I guess what I meant to say was before the Depression and the cutback what had been.

JOEL: Oh, yeah. I think, yeah. I think you're right. Before the Depression I think it was six days. And we went to six days fairly quickly when the war came. But when I first started there we were still not fully back to the regular schedule.

ASPRAY: How were the Laboratories organized at the time?

JOEL: Well, as I remember it, there was a Research Department, and I don't know what they did there. [Chuckling] The only thing I did remember is they had a big chemical research area of some kind because they had tremendous chemical storerooms and places like that. The areas, like, were interested in--in archives and things--they had a big museum at that time, up on the other 11th floor filled with De Forest vacuum tubes and things like that. And, you know, the things that

had come out of Bell Laboratories' motion picture stuff. Nothing in switching, by the way. [Chuckling] They had, as I say, motion-picture stuff and phonograph record stuff. And then what else did they have? And then the library. And they had this one lady that was in charge of the library. She was a real character. I mean, everybody knew her. Her name was Lee Smith, and she ran that place like nobody's business. I mean, everybody knew her, and she'd get anything you wanted. And they had a terrific library. It was very, very, very good, very important to the proper operating of the Laboratory. Of course they had huge shops in those days because everything was mechanical. So we had to build lots of things. And excellent mechanics--excellent mechanical work. They had huge drafting rooms, you know, that filled the whole side of the building. Draftsman after draftsman. A hundred draftsman, maybe more. And then I remember the typing. Huge typing pools where these ladies would be doing nothing but typing all day long. And I remember even the messengers--the girl messengers--who stayed in the building, they would collate the copies for carbon paper and all that sort of thing. Correspondence files were big. And then the laboratories, of course, were tremendous. And the laboratories that I was interested in were just joy.

ASPRAY: Now, was the research function divided up by specialty areas?

JOEL: Oh, yeah. I think so, but I really don't know that much about the research area.

ASPRAY: Okay. Where were you placed?

JOEL: Well, that's another thing. Of course they didn't treat me any differently even though I had all this knowledge. [Chuckling] You know, I expected to be hired one day and the next day starting to design dial telephone systems. But they treated me like any other newcomer. And the first thing they do is to send you

down to the wiring shop where you learn how to wire. Make cables and wire them onto frames. Bell Laboratories did all their own building of their own experimental models. So the same thing applied to the switching equipment. You'd build your own frames and stuff. You wouldn't have them built at the Western Electric factory.

ASPRAY: Is this something you were already familiar with, had done this kind of handwork?

JOEL: Not really. I mean, how much did I do with soldering irons except, you know, when I tried to put these relays together that I'd worked on. But up to now I hadn't done much. But it was interesting to see how they put cables together. But I didn't feel I wanted to sit down there and do that for weeks and weeks, [Chuckling] but I was doing it. And I came to work-- When I was interviewed, I was interviewed by a man--several men--a fellow by the name of Matthies, who was under a vice president. He'd be the equivalent today of an executive director at Bell Laboratories. He took me to lunch with two of his underlings. A man by the name of Dow, who at that time was like a department head. And a man by the name of Scudder, who was at that time like a director. Not Dow's director, but another director. It turned out-- Matthies I knew by name because I knew he had some patents. Dow never had patents, as far as I know. And Scudder had a few very important ones. So they took me to a very nice, fine and fancy restaurant in New York. And then they sent me around the building to be interviewed by various people. But I do remember meeting them. And it was an interesting luncheon. They asked me all kinds of questions about what I knew about their things, and I'd tell them about their stuff. Later on, when other people in the building started

hearing about me, [Chuckling] they'd come up to me and I'd say, "Oh, I know you." You know, I knew this patent and that patent and so on and so forth. [Laughter] After I'd been introduced. And one friend in particular, Bill Keister, who is a very good friend of mine now, he loved to take me around the building and introduce me to this one and that one to see their reactions. [Laughter] But it was fun--for me at least.

ASPRAY: So how did you get out of the cable-wiring shop?

JOEL: Oh, that was tough. That was very tough. So this guy Dow--It turned out that Dow's responsibility was in charge of the laboratories: the building of the stuff--and he had the engineers working for him who tested it. In those days, the people who tested the designs of the dial systems and the various systems were not the same people who designed them. It was an independent force. They did their test-- They had them built and they had them tested. And then they'd send letters back and forth saying it didn't work--or why didn't it work. You know, what doesn't work. And it would be up to the designer to fix it. They couldn't fix it themselves. They had to have the designer send them an official drawing, which showed exactly how to fix it. So anyway, Dow-- First of all, these West Street buildings, in those days there was no air-conditioning. So the windows are open. Place is a mess. Incinerators blow smoke in there all day long, and the place is full of soot. You never could keep your desk clean. But at any rate, the day I came to work Dow-- I guess he had a feeling that I was going to be disappointed about not going to work designing switching systems. And he takes me over to the window, and he says, "You're going to go down there!" And he points down to a little building down below from the main building he was in, and he said, "That's

where you're going to go. You're going to go down there to work." And I said, "What am I going to do?" And he said, "You're going to build these frames." And I said, "Well, I guess I can put up with it for a while, but I don't want to do it very long." And I remember after I was down there a few days, he came down to see me. And I said, "I don't like this! I don't want to do anymore of this! I've learned enough of this." [Chuckling]

So after another week or so they moved me on to the next place where I learned all about relays. That was a shop where they built relays for special jobs. And they tested them, and they adjusted them. Which was a big deal in those days because most of the relays in those days had to be adjusted. They weren't self-adjusting when they were built. And so you'd learn all about the electrical requirements of relays. Which I really learned a lot there because it was different than I had ever had experience with. I knew you need relays and how basic and important they were to the switching systems, but here I really learned how to adjust them and things like that. Because those things get specified on the drawings eventually. So that was all right. That wasn't quite as bad. But I got tired of that, too, after a while after I'd tested a lot of these different kinds of relays. So then they sent me--I was there about two months, I guess--and now they sent me to a place where I did the first did engineering work where you actually designed relays. Where, you know, the engineers would say, I need a relay with so many contacts of such-and-such a type and work in this kind of a circuit and so forth. And you had to sit down and figure out how to put such a relay together. It was sort of a routine process, but it was interesting because everybody had something different. And I got some fairly interesting designs to do. I remember that. And in

fact, I guess, one of the picture I have someplace is a picture of me working on a breadboard on some kind where I was testing out one of my relay designs. [Chuckling] That was fine for a while, too, but I still wasn't designing switching systems. At any rate, of course, I was meeting a lot of people, and I was enjoying myself. I found my way around the buildings so I could see what's going on various things. I was very curious about what they were doing down in the crossbar laboratory and the new crossbar systems, and things of that kind which I'd never seen before now.

ASPRAY: And you were allowed to wander down there?

JOEL: Yeah. Nobody stopped me. And in those days you could; they didn't have passes or anything in those days. Nobody stopped me, and of course I started making friends in some of those places. Most of them were the wiremen and people like that in the wiring shop and the relay shop. But, you know, I met people, and it was good to go around. And of course I made friends like this guy Keister who took me around also and showed me. So this was my first contact with real, honest-to-goodness, live switching systems. And they had everything. It took me years to realize what I saw there, but I saw all the things that were in those patents. [Chuckling] So it was great. And of course the main thing in those days was crossbar. That was the big thing, and so people were designing crossbar systems of various kinds. So I had a chance to see them. I didn't really play with them, but I saw them at that time.

After a while--after I finished the relay design group, which was another couple of months--they finally gave me an assignment, again, in Dow's group. All of this was under Dow. They gave me an assignment in the laboratory, which is in the

natural course of things. I mean, normally the new engineer coming to work in those days, he didn't know anything about designing switching systems anyway. He didn't even know what a switching system was. And so everything--almost everything--was on-the-job training. So the natural thing would be to give him an assignment down in the testing laboratory. And so we went down to the-- So he gave me a job--yeah, I guess it was Scudder's group. Maybe Scudder was not the designer. No, I think it was in Scudder's group. Anyway, Scudder was responsible, I think, for the testing of crossbar systems. And these were big open places, you know. They weren't like today with the cubicles and so forth. Everybody had a desk, and there were five or ten guys in an office. And so I was given a job of testing out some circuits. You know, they'd assign them, and you'd go in the lab and you'd learn how to set up the circuit so that you could dial a number, and the call would go through those circuits, and you could check that they functioned the way they were supposed to. And find out why they didn't and what happened. It was interesting. I was really in my element now. All of a sudden I was really having a great time. And so I started--

So at any rate, now at last I had a chance to-- And by the way, now I had a chance also, not only to actually work with switching equipment for the first time, but also now I had a chance to meet the designers. Because, you know, you're working on the circuit, and it was designed by So-and-so. Oh, gosh, I know him from his patents. And now I could go up to his office upstairs and meet him and talk to him about his circuit and why it doesn't work. And one of the most interesting things was that these people had no idea what their circuits looked like downstairs. [Chuckling]

ASPRAY: Is that right?!

JOEL: Well, yeah. In other words, you'd build it. You'd have it built. They never paid much attention to the physical aspect of it because to them it was just a circuit. You know, a very big complicated circuit usually, but nevertheless, a circuit. But anyway, here I met them, and it was great to meet them and see what kind of guys they were and what it was like. By the way, no women anywhere here. There were never any women in the process except in the library, in the typing. A few drafts-ladies, I guess. By the way, the services were great, too, at Bell Laboratories. You know, not only the library service, but when you became a member of technical staff you had a button on your desk. And so anytime you wanted a new drawing out of the file, you just pushed the button and a messenger came. You told them what you wanted or if you needed sugar or something, they'd go get whatever you had to get. A pack of cigarettes or something. I mean, you know, whatever. [Chuckling] And then, of course, they had outside messengers, too, who would take things outside when you had to. Who would do this outside. But at any rate, you'd meet the designers this way. And I guess I spent a good year at that.

ASPRAY: At the testing?

JOEL: At the testing. So we're well into 1941.

ASPRAY: And what would you say you learned from working in the testing, mainly?

JOEL: Oh, tremendous--! I mean, now I really had a feel now for what these circuits that I only knew on paper, you know, were actually like. And you learn something about how--in those days--how important quality was. Your bosses wouldn't let you get away with anything. I mean, the circuit really had to work, and you really

had to prove that you put it through its paces. And it did the job the way it was supposed to. And did you remember this? And they even had checklists of all kinds you were supposed to check over. I remember on one thing that I wasn't directly involved in, but I know the designer who later became one of my bosses, he had a coin circuit of some kind which would turn and collect coins. And he had some kind of a relay circuit in there that, I guess-- By the way, one of the things you have to do when you're designing and testing--when you're testing--switching circuits, is to make sure they don't get too many clicks, or any clicks that are beyond a certain threshold. And this particular circuit kept--the people who were testing it in the lab--kept sending it back to him all the time: It doesn't work. Because it exceeded the threshold for clicks. And that's natural when you have coin return, coin collect. It would scan ___ click. At any rate, like all these designers --most of these designers--had at one time worked in the laboratory. This fellow was fairly young, so he knew his way around the laboratory as it was then. And he would come down. And finally he got so disgusted with getting this thing kicked back, you know, four or five times, he went down to the laboratory at lunchtime and started playing around with capacitors and this, that and the other thing. And he knew where his circuit was apparently, and started playing around with it. Then after he got something that he thought worked pretty well, then he'd go back and put it on the circuit drawing. Then send it down to be tested. [Chuckling] But that's the kind of atmosphere you were working in. He wasn't allowed to do that. He wasn't supposed to be able to play around with it. That was the tester's responsibility. But during this course, I really learned a lot of

practical things about switching because now, for the first time, I had hands-on experience with switching systems. And so it was a great opportunity.

I guess about that time-- So I worked on a lot of circuits during that year--I guess it was about a year--in the laboratory. It was all in crossbar, although I met people working in the panel lab and the step-by-step lab. It seems to me some of the circuits I did had connections in the other labs, too. And then I had occasion to see Dow and, I guess, Matthies. Maybe I was getting a raise, and they usually call you way up to the executive director's office in those days to give you a raise. And, you know, he was known to have black books and so forth with all the things about the people that worked for him. At any rate, I guess he was asking me how things were going, you know. And I'd tell him just like I'm telling you now. What I was doing and enjoying it. "But," I said, "I'm still not designing switching systems, and I still want to design switching systems. And some day I'd like to get out of here, you know, not too far down the line." Well, apparently just about that time they were forming a group which were not in the design place itself, but a group of designers and other topnotch people, being put together which was called a "browser" group. That was their name at that time for "forward-looking work." And this browser group was starting to look at-- You know, we've got all this, that and the other systems here that are under development and so forth. Not only in the central office end, but the PBX end. And they were supposed to sit down and, you know, study all this and say, what kind of better systems should we be working on? What future course should some switching systems take? What capabilities? And so forth. And I was asked to join this group--I was told to join this group. Which was terrific. I mean, these were

really top people. And they'd had lots of years and years of experience, and I was really [Chuckling] an office boy compared with these people. But I was really proud that I had been given this opportunity to work with these people. And, you know, the experience comes once in a lifetime.

Well, I started working there--I don't know, probably in September or October, and the war broke out in December. And by February things had already been switched around. Everybody in switching was working on something different. So I was assigned to a group that was working on various cryptographic systems because they were all using the electromechanical relays and, you know, the--It was natural that switching people would be working on this kind of thing. And I guess also it sort of went with the territory that here's a bright young engineer. They're the kind of people we're going to put on these new kind of things that we don't even understand--you know, the supervisors. It wasn't like the old business where you had years and years of experience in how to design switching systems. So the young people were put on this, and so we really got a good opportunity to work on something really brand new. So we were associated first of all with designing improved Teletype, cryptographic stuff.

ASPRAY: Now had Bell Labs done any work in this area before?

JOEL: Yes, the idea of an endless-code telegraph was started at Bell Labs not too long after the tape-reading Teletype had been invented.

ASPRAY: And this code being--?

JOEL: This was back in the early 'twenties. A fellow name of Birnam [sic] designed this.

ASPRAY: Oh, this is the one where you have--

JOEL: The Birnam Code.

ASPRAY: --a separate tape.

JOEL: An endless tape. And you'd send a copy at the other end, and each end has a copy, and, you know, it can't be broken. That was Birnam that designed that. He got a patent on that, I guess, about in the 'twenties somewhere. But I don't think Bell Labs had done any other work. Now, as you know, or may remember, in the 1939 World's Fair, Bell Labs had demonstrated the vocoder, so-called, which was an attempt to telegraph speech to another and to do about what Alexander tried to do way, way back. Actually to try to break speech down and define it into parts, and find ways of reproducing speech electrically. And generating speech. They had demonstrated this vocoder idea. That was the kind of thing that came out of research. But along came a need for a voice encryption system. And there were some well-known techniques, you know--not necessarily invented at Bell Labs--that people had been working on in the government cryptographic agency, which was called Arlington Hall. It was then National Security Agency or something like that. Arlington Hall. What was it called? NSA, wasn't it? Or is NSA a current--?

ASPRAY: Part of Communications Seesaw? Or-- I'm not sure. I know there was an Arlington Hall.

JOEL: There was Arlington Hall, and I've forgotten what the official name was. But anyway it was the National Security Agency or something. At any rate, they had been working on various speech synthesis things, speech encryption arrangements. Anyway, Bell Labs got one of these contracts from National Research Council to do this--to develop some speech. And right after that--very quickly after that--came the need for a foolproof speech system like the telegraph

endless key for Roosevelt and Churchill to talk back and forth. And so they married these two, and they developed this encryption scheme using the vocoder. And having, instead of an endless tape, a phonograph record with the digital key on it. So they produced duplicate phonograph records. And so that was a separate group. That's not the group we were in, but we were very closely allied with them. My boss reported to the same people as the head of that group reported to. And so we kept up to date with that, but we were continuing to develop less secure speech systems that would not last as long as that. I mean, that was supposedly the foolproof system. But we were developing speech keys, speech systems that would have less security, but it would be 12 hours or something. Something that was good enough for battle situations and what not, where you didn't have to have complete, forever type of security.

ASPRAY: And what would be the device of security there?

JOEL: Well, it would be applying some of these filtered types where you'd break up the speech into frequency bands and switch the frequency bands around, you know, that kind of stuff.

ASPRAY: I see.

JOEL: Which was well known in those days apparently. And so we were developing the relay circuits for doing this kind of stuff. And after a while we started developing some fairly complicated ones, and we got a contract--and I really took charge of that--was to try to say, How secure are these various systems? So I built labs full of relay and switch circuits that would try to find the basic keys in these systems and find out how secure they really were. How long would it take a knowledgeable person who already knew how the system worked to find the keys.

And so I had a whole bunch of people working for me. Unfortunately, we didn't have any computers to speak of, but we had some calculators. And so we had to do all this with telegraph equipment and things of that kind, which was, you know....

ASPRAY: Why was computational work required in this thing?

JOEL: You wanted to look at certain things every 22 segments, you know, and divide these into various modal, mathematical cycles, sub cycles and things of that kind. And so we were looking for the key. So I got involved in quite a bit of this. And in doing this, I sat at the feet of a great gentleman. His name was Nyquist, Harry Nyquist.

ASPRAY: Oh, Harry Nyquist. Yeah.

JOEL: Harry Nyquist. What a guy! I'll tell you.... I'd go down and tell him my problem with something, you know. I'm trying to do this. And by the way, he's one of the people from the Research Department. And, of course, we met all these people after a while. And I'd go down and tell him what my problem was. And he'd say, well, now, what about this? And he'd be writing. By the time he asked you all the right questions, usually your problem was solved. Or at least you got a helluva lot of ideas. And he'd have a memo written describing what you were talking about, [Chuckling] all right while you were doing it. And then one famous day--we're talking now about two or three years later--Alan Turing came. He visited the Labs, and we all had a chance to meet him. I just met him briefly one afternoon kind of thing.

ASPRAY: Why was he there?

JOEL: Well, he was there because he was working on this--what do you call it?--Colossus Machine in England and working on ciphers and codes and trying to break them, same as we were.

ASPRAY: Was your group familiar with what he was doing before he came?

JOEL: No, no. In fact, I didn't even learn anything from him at that time. Most of the things I've learned about him have come since he's dead. But I didn't know anything about him then [Chuckling] except that I was introduced to him, at that time, as being well known in this area from England. That was all. I don't think Harry Nyquist knew, even. He introduced us to him, but I don't think he knew very much about Turing either. But at that time we hadn't heard about the Turing machine and algorithms and all that. In fact, I don't remember Claude Shannon being there at that time, but I'm sure at that same time he did visit. By the way, one big thing that happened at Bell Labs during the first two years' part of the war, when I came to Bell Laboratories, they were looking ahead. Things started getting brighter. They were coming out of the Depression, so to speak. And they were talking about, you know, we're going to have to expand one of these days. We can't just stay in this old Western Electric building. So maybe we should buy another property nearby and expand and so forth. Well, across the street from Bell Laboratories on Bethune and West Street was a National Biscuit Company factory that made cookies. It wasn't too high; it was two or three stories high. Well, let me say, it had been making cookies. They had--not too long before I got there--Bell Labs took it over. Because they started making cookies up at 16th Street or something then. [Chuckling] My wife and I still talk about these things. We used to go up there and get a huge box of cookies. They had a great chocolate grahams.

Oh, boy! [Chuckling] At any rate, they took it over. And this famous guy Jack Morton built his tube shops there. He had all kinds of tube shops where they made tubes. And Bell Labs started saying, You know, this is not the end of this. We're going to have to keep expanding, the technology's expanding. And they said, what are we going to do?

Well, when I first came the popular thing was, we're going to tear down that building across the street, and we're going to build a skyscraper there. And that's going to be the future Bell Laboratories. Well, I don't know who it is--I never heard the story where the idea came from--but.... Of course we did have a place out in Whippany, you know, where they did a lot of work. And they had a place at Holmdel at that time, where they did the radio astronomy work and long-wave radio antennas and things. And they had work out at Whippany where they did the work on motion-pictures and radio altimeters and other kinds of things. Specialty products. But somehow I got the idea that, you know, maybe the next laboratory shouldn't be in the city. We should really build a really good place out in the country. And as a result they decided, about the end of 1940 or '41, to build Murray Hill. And Murray Hill was finished just slightly after the war started--the first building. And it was mainly for research, so most of us had no contact with it. But at least the research people had. And I think Claude was out there very early on because I didn't see much of Claude after the first year or so. I mean, when he started really working on information theory and work on cryptographic stuff, I never saw him. As I say, when Turing was there, I didn't see him. Maybe he had another date with him some other time. But anyway it was an interesting time.

So that was a tremendous break when they built the place out in Murray Hill. Couldn't compare with building a skyscraper across the street. Well, at any rate, where were we? So the cryptographic stuff got interesting. Well, I kept on doing that for a while. And out of that came some ideas for better devices to encrypt speech. The company applied for several patents on some of my work in this line. At the same time, well, several things happened. The group I was in got responsible for the cryptographic part of a new speech system that used digital speech--digitized speech. Everything was done with vacuum tubes. But they encoded the speech with a PCM kind of a thing. And we designed the key, the equipment for this. I designed some of the very basic ones, you know, and put my experience that I had had by then. And one of the things I got into was right away the synchronizing problem, which we didn't have before in digital speech. So I got a patent on that. I really think one of the first patents I had on the synchronizing of speech is really the same idea as what's known today as pulse stuffing. I don't know if you've ever heard of that. But to synchronize frames in T1 and T3 carrier, you stuff pulses in until you get the two ends to match up. Actually Mayo had the patent on that for T1, I think. But nevertheless, I think the idea that I used in this keying thing had that same idea in it somewhere. But the point is that I learned a helluva lot there because we had for the first time digitizing speech. I met some guys that could really throw digital circuits around like crazy, but they were all vacuum tube circuits. Terrific guys, though, they were really terrific. Just great designers. And of course I was still working with relays and switches. So I learned a lot about electronics there with them.

ASPRAY: Had you had much experience before at all with electronics?

JOEL: No, not very much.

ASPRAY: Did they teach you at MIT?

JOEL: Oh, at MIT I learned all the fundamentals. You know, I could design amplifiers and oscillators and that kind of thing. But not really inventing circuits. Here I had a chance-- I'd built a ring circuit of my own and some other things that I needed to do the job. And by the way, I got a patent--one of the patents that I got on some of the earlier jobs--was the very basic patent today of generating keys with prime numbers. Nothing ever came out of that. The patent wasn't issued by the Commerce Department until, like, 1973 or something.

ASPRAY: Can you explain that in a little more detail?

JOEL: Yeah. In other words, you can get long keys by having cycles and sub cycles, each sub cycle being a prime number, so that you don't get any repetition until you get to the multiplication of the whole thing. And apparently, you know, there hadn't been any patent on that subject before that. In fact, I don't think anybody had really thought about that seriously before 1942 or '43 or whenever it was. And so they applied for a patent for it. But we never got--the patent number was never issued. You know, they held a lot of these patents in secrecy for many, many years. And it was not until 1973 that a lot of them were released. In fact, I think I saw one of them that still hasn't been released. It's still under secrecy.
At any rate, that was one of the aspects of the work. And another aspect that I got into just about that time was to help a lone designer who was a very famous switching systems designer by the name of Sam Williams. He became one of the early presidents of the ACM.

ASPRAY: Oh, yes.

JOEL: I don't know exactly why or how, but he did become. Sam Williams was a very excellent designer. In many respects he did like I did. He got jobs in the company and worked his way up in the company, but never liked those kinds of jobs very much. Which is what happened to me, too, if you know something about my background. So, you know, I wanted the design work, and I guess he did, too. So even though he was like a director level, he designed all kinds of stuff. And I guess when they had this very special job that came in from Arlington Hall, he was given the assignment of designing this thing. It was a very secret, secret, top, top secret job. He needed some help along the way, and I did some work for him on it. Met him. And it was great to learn from him and meet him and know him. I don't know how much he understood of this either--and I didn't understand anything about it--but we had to build this thing according to their spec. Now in hindsight, now that I know all about the Purple Code and know all the stuff that Freedman did--I don't know if you know about Freedman--but now I understand that this thing was the thing that was going, one of the ways they were going to use, to break the Purple Code. And we built frame after frame of this stuff. You know, all I knew was a way of batting it around and I knew what the spec was, but I really didn't know what I was doing. Now I understand completely how it worked, you know, having worked on that. But at the time it was just one complete mystery, and all I was doing was just designing some circuits for them. And he needed the help. Also, Sam Williams-- Well, first of all, we had Stibitz.

ASPRAY: Did you know Stibitz?

JOEL: Yeah, yeah. Now Stibitz, back in '38, had designed this calculator, this--what do you call it?

ASPRAY: Complex numbers.

JOEL: Complex numbers, yeah. Complex numbers. And the person who actually helped them in a lot of the relay work was Sam Williams. And of course they set up this demonstration. By the way, a lot of that kind of stuff was the same thing I had in my laboratory. They had this demonstration up at Hanover with the Math Society and what not. And, you know, in my laboratory--this is sort of interesting about patents--in my laboratory, where I had the crypto-analysis work going on, I had to have a lot of ladies working at teletypes. We had five or six of these same kind of things that they had in Hanover, working into this one machine. It was the first application, I think, of a multiple-access computer, you know.

ASPRAY: What were these connected to?

JOEL: These were connected to the machine that I had that I was trying to solve the codes.

ASPRAY: I see.

JOEL: And they would put in all these problems, and it would come out with the various solutions to it. At any rate, I submitted this thing to the Patent Department, and they said, Oh, there's nothing to this. [Laughter] So I never got a patent on that. But I thought it was one of the interesting things. As I look back, I say, You know, that was a patent I should have gotten. [Chuckling] At any rate, they didn't think much of it. Now one of the jobs I got somewhere--and I've forgotten chronologically how it came about--but Sam Williams had worked with Stibitz and came up with an improved calculator that was really the first programmable calculator, where you could make decisions and skip past the tape and go to various sections of the tape, depending upon the conditions. So you had decision-

making in that, which you didn't have in the complex computer--it was just a complex calculator, that's all it was. It wasn't a computer at all. And Sam was working with Stibitz on this. I guess Stibitz got the patent on it; it was Stibitz's idea. Stibitz got the patent on it. But they had a lousy attorney assigned to it initially who really didn't understand it and didn't do a very good job of it. But somebody in the Patent Department said, You know, this is a lot more important than this. Let's get one of these young fellows in the switching area to rewrite this patent or at least do something to make it sound better. And they gave me the job, and I waxed enthusiastic about it. I thought this was great. And I rewrote that. It wasn't a big job. But I remember having that experience.

Now Sam Williams went along. We got a contract--Bell Labs got a contract--to build computers for the fire-control stuff for the government. And they put a fellow by the name of Ernest Andrews, E.G. Andrews, in charge of that. He was not a circuit designer, but he had been a supervisor at Bell Labs, and he got enthusiastic about this computing business. And they started building various computers to meet these fire-control spec requirements. And they started designing them so they were general purpose computers, so to speak, rather than just special purpose. In order to make them special purpose, Sam Williams got involved. You see, he was really the designer because Andrews wasn't. Then they had some people in there that were not-- They didn't have very many really good designers. Well, I shouldn't say that. They had some good circuit designers in there, but not overall systems kind of people. They were all old-time switching designers; that's what they were. At any rate, Sam Williams did this work, and he was the principal architect for many of these relay computers, which you probably

read about and know about. And Sam Williams, by the way, after working on this for a while decided that you could speed them up a heck of a lot if you just used vacuum tubes. And he learned a lot about vacuum tubes, multiple and multiple anode vacuum tubes of various kinds--you know, multiple-grid things and so on. And he put together--on paper he put together--a whole electronic computer about the same time Meggit Markley.

ASPRAY: As they designed theirs? Not as they built it?

JOEL: As they designed theirs, yeah. Well, we never built ours. But these two patents--their patent and Sam Williams' patent--got into interference in the Patent Office in the late 'forties and dragged on well through the 'fifties and, I think, well through the 'sixties. And finally AT&T just gave up on it. And let Remington Rand have the claims. But for years they fought over these. I had nothing to do with this, but this is just an aside because of Sam Williams. But Sam Williams was a great guy. While we're talking about people, another guy I met in the browser group was an idol of mine from the days I started studying patents. I used to study these patents, and I'd see all these patents with Warren W. Carpenter. And I said, Boy! He must be something. Well, it turned up that Warren W. Carpenter was assigned to this browser group, and he was not one of the regular circuit designers. He was not one of the guys that worked in the bullpen where they designed switching circuits. He was the kind of guy, all along, that just got ideas and kept getting patents on them. And he did a lot of work on his own. He'd go back home and build them. And he was the guy who invented the first AMA system, where they have this wide tape--I don't know if you ever saw 28-hole tape. There's no chad; it just punches through. He used a mechanism that came out of a switch that he built. He

did it all in his home because they wouldn't do it at Bell Laboratories. They wouldn't agree with his idea. And when the war was over, that was the best way we had of doing AMA. And so it was adopted. He also had his own idea of a panel switch, which was a high-speed panel switch that he tried to sell. He didn't do that in his basement. That required some real good mechanical design. That was done at the Laboratories, and he worked on that for years and never sold the idea. But he was a promoter of switching systems. Hey, that's me! That's what I want to do! [Chuckling] He was a promoter of switching systems from the word "go." And I met him and learned about him, and he was quite a guy. But that's what he did. So, you know, I got to know him. He was never assigned to war work. And that's why he was able to do his AMA stuff on the side at home during the war. I don't know whether he was a Nazi sympathizer. They had a lot of problems with Nazi sympathizers at that time. People like Llewellyn and--not Llewellyn--what's his name? Very famous guy. There were several famous people at Bell Labs that they had to sort of keep off on the side. At any rate, the point was that I met people like Sam Williams and some idols of mine in the patent work. Warren Carpenter.

So what happened next--

ASPRAY: Oh, let me ask one other question first.

JOEL: Yeah, go ahead.

ASPRAY: Out of the work on the moderately-secure system, what were the practical outcomes of that?

JOEL: Oh, those systems were built for things like tank radios--the little small things. We also built them for command headquarters. They used these so-called drum

machines--they had various Dutch names for them. Helgen [sic] machines. The drum machines that have the alphabets wired through each of five drums. And the way you control them-- Well, we developed some methods to control them very sophisticatedly with relay circuits. Rather than just have them themselves decide how they're going to move, we decided how they were going to move with a complicated relay circuit. Anyway, those were used at the command headquarters. So we developed a number of practical products that were made for this. Oh, and we applied it to voice. We applied it to voice. So all the stuff we did was voice, except the very early. So that was the main contribution of this group, that they actually designed some voice security systems.

ASPRAY: And this voice security system actually was put into use?

JOEL: Yeah, they were put into production and used in various places. They were cheap and dirty versions of the endless key kind of things. Many of them used--well, they all used--the vocoder because it wasn't until later when we started doing the digitized speech. That was toward the end of the war, and that was the last job I worked on, on that, was that digitized speech keyer. And the last thing I did. Well, what happened now was the war in Europe came to an end. The guy that I worked for his name was Al Bush; he was my supervisor. He had been a famous designer of crossbar systems back before the war. And he was highly considered. He was a very bright guy, and he was highly considered by the people there. And, oh, all during the war--well, I shouldn't say <u>all</u> during the war, but toward the end of the war in Europe--the Vice President, by name of Clark, A.B. Clark, was a visionary looking ahead at what the future was going to be for the Bell System in development of systems for transmission and switching. Because he had both

responsibilities. And he could see coming--and there were studies being made by the Systems Engineering people and so forth--of nationwide dialing. But by operators first and then maybe later by customers. Numbering plans and so forth. All that sort of thing was being thought about. And I wrote a memo, and I caught his attention about the idea of teaching switching. I guess he knew about me, but up to that time I don't think I'd had any contact with him. But when I wrote this thing, I guess, you know, again, I said, With the war coming we've got to teach people how to switch. We've got to get a new kind of people in here, college graduates. You know, treat this as a real technical subject and so forth and so on. It can be done, and there's a lot to be done. And that attracted his attention. So I met him, and I guess we got along pretty well. Some of the other people didn't like that, of course, because it was out of the line of organization.

But at any rate, the upshot was that Bush was assigned to work on the new dial system, which had been agreed upon, that they were going to design a new dial system for use in the suburbs. Because they felt that people were going to start moving to the suburbs. And rather than build step-by-step systems for the suburbs, which didn't have the ability for nationwide dialing and all that kind of stuff, they needed a new kind of a system, and that would be the No. 5 Crossbar. So Bush was designated-- Well, in fact, Bush actually developed, he designed, he planned the No. 5 Crossbar while he was still working on war work. And of course everybody bought this idea, including Clark. So when it came time for Bush to go off and start this project, you know, I was anxious to get on this project. He knew that. And with the war over in Europe, they assigned me to the

project, and I was assigned to the best part of the system--the marker, which is the brains of the whole system. I don't know if you know what the marker is.

ASPRAY: No.

JOEL: The marker is the central control part of a crossbar system. Every call goes through it. All decisions about what you've dialed and so forth are all carried out in the marker. And so I was assigned that. And, oh boy! This is a great opportunity now for my functional design of switching circuits and all that sort of thing. And so I started on the job. I was on it two or three months. And all of a sudden the draft board caught up with me and heard that I was not on war work anymore. And they said, Well, you know, there's still a war going on over in Japan and so forth and so on. And unless you get back on war work, we're going to draft you. So I lost my opportunity to design the marker. [Chuckling] Another good friend of mine worked on it, but he didn't like the ideas that I had. He didn't like my functional breakdown and what not. So they didn't do that. [Chuckling] At any rate, the upshot was that I got assigned back to--not back to--but I got assigned to Andrews' department, a place on the relay computers, because that was a war job. And I was given a job on the last big computer they designed--the Model 5 or 6 or whatever it was. To design their most complicated circuit, which had to do with logarithms, block-hunting on tapes--called BLT. Block-- The L was logarithms. T, I guess was Tape. I don't know. Anyway, it was an odd circuit. It was not a standard general-purpose circuit. Like it had memory and so forth. It was not a regular arithmetic unit or anything like that. Somebody else designed that. But I got this bastard circuit design, and I did it, the design on it. And that was part of that system. And then the war came to an end. And since I had been

designing computers, they said, Well, heck, we need computers for this AMA system that we're putting in with the No. 5 Crossbar in Philadelphia. The accounting center for it. And so I was immediately assigned to that. I designed a couple of circuits there. And, as you know, I got the biggest circuit they ever had and the biggest patent, I guess, for the circuit. And the guy ran out of time to write many more claims. I don't know, they had 400 and some odd claims. They just kept going and going and going on making claims. So that's how I got onto that work.

ASPRAY: Maybe you should step back for me and tell me about AMA and maybe about crossbars. A brief tutorial.

JOEL: Well, you know, for years switching systems had been designed--dial telephone systems-- First of all, of course, there's a whole technology that's involved in manual switching where the operators would handle calls, you know, with cords and plugs and jacks. You've seen those, I guess. That had a tremendous background for many, many years--all the way from 1879, three years after the telephone was invented, to even as late as 1950 something when I took over a group where we were still designing one more switchboard for some--I think it was a military switchboard. But at any rate-- So manual switching, of course, was the way in which switching started. But the dial system, of course, started eventually with dials--Initially had push buttons as a--you know--full board kind of thing about the early Strowger system. But eventually they had dials. And so as you dialed a digit, each digit you dialed went into some kind of a switch, and the switch did a job and advanced a call to the next switch, and eventually you'd get the call to the number you dialed. Those systems were limited in access, so-

called. Each of those switches could reach a hundred terminals, which meant not very much selectivity, so to speak. And the Bell System didn't like this, and the Bell System went out and designed switches that had accesses of 300 which they sent to Europe and 500 which stayed here, which were the panel system. It had the ability to select 1 out of 50, but it was on a big vertical panel instead of being on a cylinder, which was a step-by-step type of switch. So those ideas were great for their time, and they used-- But the panel switch used motors to drive these things. It had clutches and so forth and was very complicated. So the switches had this whole gross motion. Gross-motion switches. Switches that moved through large distances. Step-by-step went through inches. The panel switch went through inches. It also had the characteristic that the contacts were made of base metals, phosphor-bronze, things like that. And so therefore you'd get noise in the connection. The slightest vibration would cause a change in resistance, and you'd get noise. And people didn't like the fact that these big-motion switches required a lot of adjustments and a lot of maintenance and so forth. Even though the panel system with its 500 points freed this, control of the switch was no longer under the control of the dial, obviously, because the dial was a base 10 things, and this thing was a different number base. You had to have a translating thing. So that was a common circuit that did that. That invention was invented back in 1906. But in any case, they tried to get rid of the big motion by designing a large coordinate switch. A panel frame had 60 selectors, individual rods that went up and down, to select 1 out of 500--each could select. So the switch was really 60--there's 30 on each side--60 by 500. And so they built a coordinate switch that was 60 by 500 so you could operate a bar this way and a bar that way. Close the

contacts where they meet. And that would cut down on the motion. You wouldn't have the fancy motion. It would be an entirely different kind of a system. It couldn't be driven by a sequence of pulses anymore. It would have to be driven by some other kind of gadget, which is the marker. So those ideas started to accumulate in the early 'twenties, and they actually built a coordinate--that was called a coordinate--switch system. They actually built one of those. But that didn't solve the contact problem and so forth. But they did learn how to control something like this. And what happened was that Matthies and some of his engineers went over to Sweden in 1932--'29 I guess he went over. He saw the switch that they had developed over there, which was a unit switch, which was 10 by 10. And he said, you know, That's what we need. That's much better than this huge coordinate thing. Not only that, you can put regular relay contacts on it and get precious metals. You don't have to get base metal contacts anymore like you would on the huge coordinate switches. And so they came back and very quickly then developed the crossbar switch and the crossbar system, which was different from the Swedish because the Swedish system you just dialed into it and used the whole switch for one connection. Whereas we developed this coordinate idea with the marker in it, and you could get ten connections through a 10-by-10 switch. So it was a much different arrangement. We had a much more sophisticated control and so forth. And that was developed. And by 1937 they had a first installation in Brooklyn. And the switches that were first developed for that and tested in the Laboratories were the ones that went into the Rockefeller differential analyzer. [Chuckling]

ASPRAY: I see. Uh huh.

JOEL: At any rate-- That's all explained in my book, by the way. I don't think the RDA part is in there, but the part about the early offices and so forth are all in this book that I wrote on the history of science and engineering of the Bell System.

ASPRAY: Right.

JOEL: Mmmm hmmm. Yeah. At any rate, so that's roughly how the crossbar system came about. And of course it solved a lot of other problems that they'd had. Problems in big cities where even the accesses that you could get with a panel switch weren't adequate for large PBXes where you have a large number of trunks going into Con Edison or department stores and things like that. So it solved a lot of PBX hunting problems and gave some flexibility to operator dialing of various special long-distance calls. There wasn't too much. But later on, of course, after the war it was certainly the switch to use for expanding the system for eventually customer dialing.

ASPRAY: What difference did it make in terms of the scale of expansion?

JOEL: Well, not too much. You mean as far as making bigger systems? Larger offices?

ASPRAY: That's it exactly.

JOEL: Not too much. The panel system was ideally suited for very large cities. It was built for that purpose. The step-by-step system could grow into large systems, but it took an awful lot of space and was not very efficient--very inefficient on trunking. Because when you get into large cities, you've got a lot of calls, and you have a lot of trunk between offices. And to use them efficiently, you want switches that can access as many as possible. And the step-by-step system didn't do that. They had various artifacts to do it. They had things like rotary out-trunk selectors and all kinds of other things. But really, it didn't help. So you didn't

build step-by-step offices in New York City, for example. Of course London tried to do it, and London had to use the gadget that we used in the panel system to convert from the numbering plan that the customer dialed to control the switches more efficiently. We tried to sell London on the panel system and failed. But it went through Parliament and everything else. Very interesting story about that in one of the books that somebody wrote--a fellow by name of Robertson wrote. At any rate, the next thing that happened is that we developed the crossbar system then for the No. 5. They developed the No. 1-- The No. 1 system was the one that went in 1937. The No. 2 system they developed in the lab before the war, and then they dropped it. No. 3 was developed-- No. 3 was never really developed until after the war--much, much after the war. And No. 4 was the toll system, the toll crossbar system, which had the advantage that because they used relay-like contacts, you could have more than just two or three contacts. You could have enough contacts so you could have a path for transmission in each direction. Which fitted in much better with carrier transmission systems because those were built with separate paths in each direction. You know, that when you talk across the country then you don't talk on the pair of wires. It goes out on one pair of wires and comes back on another. The carrier systems were built that way. So the switching systems matched the transmission systems much better with the crossbar, four-wire switching, as it was called. The first office of that went into service just before 1942, just after the war. And it was the mainstay for the postwar development of the toll switching. And as I said, the No. 5 was for the suburbs. It was not originally intended for downtown offices, but later on they started killing us with kindness with so many features and neat things like that

that it became necessary to put No. 5 crossbars in downtown locations where they needed a lot of special capability that No. 5 had that No. 1 crossbar never could have. So anyway, that's a brief history of the various systems at least that the Bell System used. Now around the world there are hundreds of other apparatuses.

ASPRAY: Right. Okay.

JOEL: So, at any rate, the No. 5--I missed the opportunity to work on that directly--but I worked on the accounting center. Oh, the accounting, as I said, was the mention primarily of--what's his name?--Carpenter. He invented the whole system. From the making of the tape in the central office to the idea of how you would sort the tapes separately in the accounting center.

ASPRAY: Now how had accounting been done before?

JOEL: The only way accounting was done before--there were two ways. Well, one is in large cities, where you didn't want to charge for individual calls that were dialed, you'd have a meter. And so as you talked the meter would spin, and you would take photographs of the meters once a month and subtract them from the previous month's readings. And find out how many units you used. And that, by the way, is the basic way in which telephone calls are charged all over the world: pulse metering. And very few cities in the United States ever had it. Most of the cities in the United States, local calling is flat rate. You can make as many calls as you want--at least until we start developing more sophisticated systems. For the toll it was all operator-handled, so operators wrote tickets on every call. They wrote a ticket. They had a gadget that would stamp the time at the beginning and the time at the end. And then somebody would interpret that, and it would get into your bill.

ASPRAY: Were the bills at least sorted by some sort of equipment?

JOEL: We tried to build systems that would make IBM cards or Remington Rand cards--either one--for toll tickets, but they never were very successful. In fact even in the 'fifties we still were monkeying around with these gadgets where they'd use punched cards. In other words, once you pulled down the lever, what time it was for the beginning of the time called and the time at the end, you would punch the card with the time. She'd still have to write on it the number that was called. So until AMA came along, it was never automated. But there wasn't that much calling either. A call from New York to San Francisco, you know, might cost you 15, 20 dollars, so you didn't do it very often.

ASPRAY: Right.

JOEL: So, I mean, nowadays it's unbelievable the tremendous volume of calls in the networks compared with those days. But at any rate, we developed switching systems in those days to meet almost all the needs that you could visualize. So I came out of the war-- I worked on the--The immediate job I worked on was computers because I had been working on them during the war. Only this was quite a computer. It had to sort the tapes that came in from the offices by telephone number and all that. And then get all your telephone calls for a given customer together. And then process them. Then put them out on another tape, which you then compared and reprinted. So it did all that in one job. Prior to that we had developed separate machines for a lot of different stages, and this one machine did everything. That's why it was so big and complex.

ASPRAY: And why was it built inside rather than going outside to somebody else to build it?

JOEL: Well, because the technology that was being used was completer than anything outside. First of all, in the central office, it was natural that we would develop something that would work directly inside of our switching systems. So there was no technology that was available for that. I mean, we had no way of coupling up at that time. I shouldn't say we didn't have. I guess we could have coupled up with some kind of IBM machine, but we didn't even think of that. Other people did. General Telephone--Automatic Electric--did that. But most people went out-- You know, switching's always been an inventor's art. You never look at the other guy's stuff. You always go out and invent something. [Chuckling] And so it's continued that way in the accounting business. But really the accounting was a good idea. They punched a different kind of tape. There was no chad, so-called, no junk coming out of the tape. And you could put these tapes in huge rolls and send them around. It was before magnetic recording was-- We did a lot of the experimenting and tried to do it magnetic recording. So we did try other media besides punched tape--punched paper--but it never worked. I remember working on a job--one job--where we looked at wire, tried to record on wire, magnetic wire. That was no good. In fact, I did that back in the browser days I think we looked at that. And then later on we looked at ordinary mylar tape, and that wasn't perfected at that time that well. So we settled for a long time on the punched paper tape. It wasn't until magnetic tape became really reliable, and then you could build large, highly dense tapes, that it became important. I remember one time we lost a tape. Hearing about a lost tape in our system where we have the operators, you know, the TSPS-- I don't know if you've heard that yet. But later on you'll hear about TSPS that I developed. And that was the operator system

when you dial zero plus the number, the operator comes in. And that's all recorded on magnetic tape. And they lost one magnetic tape coming out of an office one day with $40,000 worth of revenue on it. So, a lot of compact information on that. At any rate, so punched paper tape was a good idea. It was Carpenter's idea, and it was eventually developed and adopted as far as the growing nationwide dialing plan of the Bell System.

ASPRAY: Now how long was this accounting system used?

JOEL: Unfortunately, not too long. IBM worked hard with us to take the tapes as they came out of the central office and immediately convert them to magnetic tape form. And that was all done in the early 'fifties. And I think they only built-- First of all, there was, I think, 150 revenue accounting offices in the United States, where they sent out bills. And I think at the time when we finally went to all IBM processing--or magnetic-tape processing, I should say--by that time we had only built, like, I don't know, something in the order of 60 or 70 of these computers that I designed. So we didn't have one in every center by that time. In any case, it rather rapidly, as it became so important, we went to magnetic tape. The only part that stayed paper tape was the central office, until electronic switching came along. Then later on we went back and put many computers into electromechanical offices and put magnetic tape in there in that way. But AMA was a very important step in getting-- And also unfortunately we put it in these offices like these suburban No. 5 crossbar offices. It got the customers in these suburban towns who called the main--into the city--which were toll calls, but they were cheap toll calls. Ten, fifteen cents. They got used to the idea of getting a bill every month that listed all these darn calls, and they won't give it up. So even as

of today, everyone of those calls is listed as a toll call, and you get a separate billing entry for them. We had hoped that the day would come that, you know, you would drop all that stuff. But it's never happened. At any rate, my first job after the war was on the AMA. And then I got assigned to another browser group.

ASPRAY: Before you tell me about that, you say you "got assigned." To what degree did you have choice about the assignments you got?

JOEL: Well, certainly in the early days, you know, before the war, as I said before, I didn't have any choice. I let it be known what I was interested in and what I'd be happy with, but nobody ever listened to you there. I guess they did in a way because if there was an opportunity and they thought it was a good opportunity, they would do it. But generally speaking, you know, it was from the top down. I was in a development department--or whatever kind of department it was--a regular engineering department. It was not a research thing. So I had very little choice of what work I could do. I shouldn't say that in the sense that I have several patents from those days on ideas that I got independent of my job. Ideas about switching. And I submitted those ideas to the Patent Department and got patents on them. That nothing to do with any day-to-day job of mine.

ASPRAY: What were they?

JOEL: Oh, I had a patent on a signaling system, some better way of signally using DC signals across the country. I had a patent on a way of improving the--simplifying--the panel system. [Chuckling] I had-- Oh, I don't know. I'd have to look back and look through the patents, but I have a number of patents of that kind.

ASPRAY: Were any of these of importance in one way or another to the company? Of great importance one way or another?

JOEL: Yeah. Some of my patents were used for bargaining purposes in connection with patent licensing. And some of them, you know, they just don't pursue them. But one of the patents I have, when touch tone--you know, when push button dialing first came out--one of the patents I got about that time was the idea-- I remember going around and seeing people used to put locks on the dials so that people couldn't originate calls from a dial telephone. So I got the idea that, well, now you have push buttons on there. You can put a regular combination lock idea on there. So you push a three-digit code in before you dial the number, and that unlocks it. So I got a patent on that, but people have done that since then. Actually nowadays you can do it with a lot simpler technology--half a chip or a tenth of a chip or something. [Chuckling]

ASPRAY: Right.

JOEL: In those days it took a lot of circuitry you wouldn't want to build into the bottom of the telephone. But in any case you get patents like that. I don't know how much value they are to the company.

ASPRAY: Anyway, I interrupted.

JOEL: That's all right. I'm trying to think now. I think right after I worked on this accounting center thing in 1946--'45, '46, part of '47, I guess--and then I was assigned to this browser group where we were-- But it was in the Engineering Department--it was not in the Development Department--Systems Engineering. Where we were looking at the plans for the future. You know, What should we be doing about this, that and the other thing? And that's where I got involved with operator services, starting to think about how you would improve operator services.

And then the fateful day came along--I guess it was in 1947--when they got us all up, all the members of the technical staff that they could fit in, up to the auditorium and told us about the transistor. And then they sent us back and said, What can you do with it? Then I started thinking, Boy, this is really the opportunity. Because for switching up to now anytime anybody's looked at using vacuum tubes for switching-- And of course I had an opportunity to do that after working on the voice encoding things that used digital transmission; I had the opportunity to look at tubes for switching. And the research people, by the way, had been looking at using tubes for switching. And there was an era there--if you read the book--there was an era where we used gas tubes in switching a lot. Even No. 5 crossbar used it. But other people went out and tried to build a whole switching system using gas tubes in crossbar switches and no--or very few--relays. But none of those were very satisfying. I mean, one gas tube could be the equivalent of one contact, when a relay can have ten contacts--sets of contacts--or 20 contacts. You need hundreds of them, you know, as you'd get a lot of gas tubing. So it wasn't very practical. But here we had a good device that didn't have--it was small--and it didn't have the heating and all the other problems of control. And it was just ideally suited--it seemed in my mind--it would be ideally suited for switching. And in a lot of other people's minds, too. But the question is, How are you going to use it? Well, this one gentleman, who was also a visionary, his name was Chester Brooks. And he had come to Bell Laboratories from New York Telephone Company. He'd been in the Traffic Department in New York Telephone Company. He was not an inventor as such, but he had ideas. And, as I say, he was sort of a visionary in many respects. And he had come to Bell

Laboratories after the war. He also could see the possibilities of trying to do things electronically in switching now that we had this. And also, you know, he had heard about computers and that they were now starting to use things like magnetic drums and what not. And Williams tube. Oh, he was enthused about the Williams tube. That was the thing, the Williams tube. Do you know the Williams tube?

ASPRAY: Electrostatic storage?

JOEL: Yeah. And so the Williams tube. Well, all they had to do was combine the Williams tube, 50 flip-flops made out of transistors, and we'll have a whole switching system.

ASPRAY: I see. [Chuckling]

JOEL: Anyway, that's the kind of guy he was. And he was really stimulating to talk to and to be with. And fortunately he knew me, and you know how it is in a company. You know a bunch of guys, and you know what they're capable of and their interests are and so forth. He got the ear of Kelley who at that time, I guess, was the President of Bell Labs. Of course A.B. Clark was still there. He knew me. And he got them to buy the idea of putting together a group to start really looking into electronic switching. The research people were still looking at electronic switching, too, and they were going off on their own. But they didn't understand switching. And he was a traffic guy, and he really understood switching, and I really understood switching. So he put together this group, so that I was a natural, I guess, to be selected to go into it. And of course I was anxious to go into it when I heard about it.

ASPRAY: Excuse me. When you say that the research group didn't really understand switching, what is it that they didn't understand?

JOEL: That's been a problem of mine all the years that I've dealt with it. [Chuckling] At least I think so. I'm sure you'd get a different story if you talk to them. But what's happened is that most people think that switching--oversimplify switching. In other words, their view of a switching system was to have anything that you could dial a number into that would set up a connection and--well, they allowed that, yeah, you could find out whether the line was busy or not and do something different--but if it wasn't busy, you'd set up a connection and you'd ring and you'd talk over it. And when the people were finished, you'd hang up. And that's, you know, only the very slightest beginning of what a switching system has to do. And until you understand the meshing of all these combinatorial factors of all the things that have to be done in a switching system to make a practical one, you really don't--

ASPRAY: What other kinds of things?

JOEL: Well, other kinds of things like when the customer doesn't dial all the numbers you expect or dials the wrong number. You know, all the things that can happen in that vein. Also, how do you deal with coin telephones? How do you deal with calls from PBX's and all the other kinds of things. And that list is now out of sight right now, the number of things we do inside of a switching system. And getting almost unmanageable, actually. We're at the stage where we've got all kinds of software problems because of all of the things we're trying to do on the switching system. No, I just said it sort of facetiously, because they've always taken a very simplistic view of switching. And that's good in the research, too, by the way if

you want to try to design a new switching device of some kind. And maybe some new architectures. They did think about some new architectures. They thought about some architectures where all the control of the switching system would be from the customer's device, and it would be a complicated device, for example, which is expensive. And then there's practical problems, you know, How do you turn on such a switching system when you have all the other kinds that are already around the country? And there's a lot of oversimplifying that they do there. But when you get it into an engineering group or, eventually, a development group, they have to think of all the factors. And that's what requires instead of ten guys designing a switching system, it requires 2,000 people to design a switching system. It's all the other things that have to go into it. At any rate, it was natural that the Engineering Department would set up a separate electronic switching effort at this time that wouldn't depend just solely on the fruits of research.

ASPRAY: So who else was with you on that?

JOEL: There was Ted Brooks. There was a fellow by the name of Benny Lewis. There was a fellow by the name of Henry--I don't remember what his first name was; Henry was his last name. There was--oh, gosh, I can see him now. He lived up here in Verona. George--I don't know. I can look it up. But anyway, there were only about six of us, seven of us, at that time. We're talking about the late 'forties now. About '48, '49. And we were just told to see what we could do, what thoughts we had about switching systems. And we went out into the wild blue yonder. One of the first things we studied and postulated about-- Of course almost all our switching systems started out using transistors as the cross-point device

instead of the crossbar switch with the contacts. And the control's much different. Since it's so fast, so high speed, we didn't need tens of markers. We only needed one so-called control for the whole system. That turned out to be a fallacy, but anyway-- We had our own simplification. But at least we could do all these things. We actually postulated a wire center. One of the very early studies that I remember--and I tell my classes about this--that in Queens, New York we'd have one switch that would serve 500,000 customers. The switch would be so fast and everything would be so small, you know, we could build this right in one little building out there to do the whole job for Queens. [Chuckling]

But nevertheless, we did a lot of work like that. And we studied it. You know, we didn't just study how the switch would be designed, but we would also study how the accounting would work and a lot of other aspects of it. Get rid of these tapes. So we studied a lot of aspects: remote switching so we'd have remote units. You know, many of the ideas that have come to fruition now were radical ideas back then. To show you how-- I was about the most technical guy in the group, I think. George wasn't. Benny Lewis was pretty technical. He was pretty good on transmission. But Chet Brooks, who was the head of the group, was really sharp. But whenever he came to the control part of the system, you know, he'd say, Well, we don't need all those hundreds of relays and so forth. We'll do it with 50 flip-flops. [Chuckling] I don't know what the heck he had in mind. I told him, you know, you can't do it with 50 flip-flops. I said, There's nothing the 50 flip-flops can do except maybe store 25 bits of information. [Laughter] I said, This is crazy. You know, how are you going to control them? Ah, you'll do 50-- When you really look back on his vision, maybe someday we'll have a system with 25 chips,

each with 10 million bits in it or something. But nevertheless, you know, that was really what he was thinking about. He wasn't really thinking about a-- But he didn't know what to call it, so he called it a flip-flop. So, you know, these are the kinds of visionaries you meet, and they're very good. They stimulate you. In those days I was really having a great time because--thinking about all these different kinds of things we might possibly do. I think I had, of all the people, more my feet on the ground. At least I wouldn't put out a memo on any of this stuff unless I felt you really could do it. He wouldn't hesitate. I mean, he put out all kinds of stuff. But all the memos I put out at that time really described electronic switching systems that could be built. Whether they could be practical or economic or not, we didn't know in those days yet.

But I did a lot of work like that and became, you know, well known. And later on it was used as a model and so forth. But that was a great opportunity. We were off and running then on electronic switching, and I was a pioneer--in Bell Laboratories at least--on that. Around the world there were other people thinking about it. A lot of people around the world--if you read the other book that we wrote, the Electronics and Computers and Telephone Switching--that book tells you about other people around the world who came off of radar work and other things during the war, you know, and looking for jobs. And they obviously came up with the idea that of all the things in communications that needed attention was switching. And why can't we apply all these great things that we know now about pulse technique and what not, why can't we apply all that to switching? And they did, and many of them started right down the line of time-division switching rather than space-division, which was what we were working on. So that was a

different approach by other people. But nevertheless, you know, it was a natural thing that we would start with and got new ideas on using the transistor and bulk memory, and that's what it was. So it was a great opportunity in those days because we were breaking new ground and were right in on the ground floor. Of course you don't think so much about it, though, when you're actually involved in it as you do when you look back on it.

ASPRAY: Do you want to go on? Or suggest another day?

JOEL: No, no!

ASPRAY: It's up to you.

JOEL: No, I can go on. You want to go on.

ASPRAY: Sure. I'm happy to. You're the one that's doing all the work.

JOEL: No, I'm not-- No problem. Anyway, that's what I was doing in the late 'forties. By the way, in that browser group was an engineer department just before this group was set up. I worked for a very interesting gentleman named by the name of Otto Friend, who was an old-time relay-system engineer in switching for the AT&T departments that came up to Bell Laboratories in the late 'thirties. I learned a lot from him about how to write good memos. You know, the usual kinds of things. You always have some mentor, some guy like, and he was very good at that. And by the way, all during this period I spent--where was it?--I guess just between the time I worked, I left the war work, on computers and started to work on the AMA computer, there was a period of about six months when I started this school where we taught switching. And where I had almost all the ideas on how you were going to put this course together to teach new young people, who were now coming into the Bell Labs in droves, how we were going to teach them what

switching was all about. And, as I say, I had the backing of A.B. Clark, the Vice President. And he put a gentleman in charge of that by the name of Nazar. And he was a very aggressive kind of guy. He was all steamed up. But I was the guy with the ideas. Nobody has ever said that I wasn't the one who started the school and had the ideas, but they all ran off with the glory on most of that stuff. Keister, Ritchie and Washburn wrote the book, and Nazar became something or other after a while. But I got out of it. Teaching wasn't for me. I mean, one--I think I taught twice--the first time was very exciting because we were putting the whole thing together and learning from our mistakes. And the second time we fixed it up. After that I didn't feel like doing anymore teaching. So that's when I got out and did the work on the computer. But these other fellows carried it on and made a big thing out of it. Actually Ritchie went up to MIT as a visiting professor and taught there. And he got Sam Caldwell interested in it, in a lot of this stuff. And that's when Sam started getting interested in writing a book. Of course he had other people up there. Hoffman was interested in some of those kinds of things. In the early 'fifties when we finally got over into later stuff in switching, we committed a bunch of real good theoreticians and people like that in switching. Something independent. Washburn, who was one of the other authors of this book, did some of that. We had a great team. The whole idea of starting the school was mine. And I have a feeling that as a result of our success--and we had a lot of success, I think, in teaching switching; because people came out of that school-- First of all, most of them became later on very important people in Bell Labs. Not only that, but they all really understood switching. And they could put the work immediately into designing switching systems, which was unheard of before the

war. Before the war all they had was these very good inventors who could put these things together. But they didn't know how to take college fellows and really put them into switching. And, you know, I was always interested in that. I always was interested in saying, you know, We've got to make switching into a profession.

It was during that time, for example, that I got involved in IEEE--AIEE--and we formed the Switching Committee of IEEE, to get people to present papers. Up to that time, the only time any switching papers ever appeared in IEEE--AIEE--Transactions were when we had one paper on the No. 1 crossbar system, and it was written by the bosses. It wasn't written by the people who designed it, but by the boss. And it was that way all along. The panel system--there's one paper on the panel system. There were a few articles in Bell Labs Records, but not very much detail. In fact, there was very little detail in any of these things. In other words, in those days anybody like myself would be frustrated in trying to find out professionally how these systems worked. That--there's two things. That dissemination of information about switching always bothered me. And I was always interested in seeing more done to get people interested in it and knowledgeable about it and leave a record of what they did. And the second thing was to treat it more scientifically. Try to find if there wasn't a better way of dealing with it than an art--because that's all it was when I started with it--and, unfortunately, that has never panned out. It's still an art. There's very little science in trying to put together a switching system--unfortunately. So I don't think that part's been achieved yet.

ASPRAY: And anyone who came in as an employee in the company who went to the switching area, would go through this course?

JOEL: Yes. Oh, especially then because we were hiring in a big way then. And I was going to say, the success of that course, in my opinion, was the reason Kelley, who was then the President, decided that we would have a continuing education/technology program in every discipline--not just switching--and set up what was known as Kelley College, for which all the young fellows that came in took not just switching but took many, many other courses. But we started with the switching before the Kelley College. And I have a feeling that the success of our teaching of the switching rubbed off and said, You know, maybe ought to do this for everything. And they did, and they did a terrific job. I mean, you got all the best people at Bell Labs to put together courses in all their disciplines. And anyhow it was a tremendous thing after that and stayed that way.

ASPRAY: You were just actually getting started telling me about the electronic switching.

JOEL: Oh, did I? All right. Well, so we worked on this with Chet Brooks and that group for a good two years or so--maybe even three. All during this time, by the way, the research people were not idle. They were doing some good work on developing transistor cross points, magnetic drum memories and a lot of other things that would be needed if you--And they had some very fundamental ideas, too. For example, they got the idea of scanning lines looking at the lines periodically and gathering information about whether your receiver was off the hook and so forth, and dial pulses, all by scanning. Converting the control into a time-division thing instead of just transmission as a time-division. At any rate, they had some good people and good ideas, and we learned a lot from them as

well. But all during that time we were developing our own ideas of how a system ought to look. And how it could be applied. See, Chet was great on looking at the actual field conditions and trying to match the field situation with the actual-- Which the research people don't give a darn about. They don't worry about the real-life reality of how the actual deployment might be. And he was.

We finally got to a point in this study work where we'd studied the stuff enough and with a lot of optimistic figures, we said that, you know, we think we can do this. We think we can build a system that would be competitive with existing technology. And that we ought to move on with the idea and start a exploratory development--as they called it in those days. So we wanted money-- This would require now money, not just from AT&T, which is the one that had been funding the exploratory kind of work, I mean, the systems engineering type of work that we were doing, but would fund the real work that eventually would involve production of equipment by the Western Electric Company. So Chet wrote a famous memo of some kind outlining his thoughts as to how far this thing could really go. And really, I guess, again sold the idea. I mean, he'd originally sold the-- He had a lot of opposition. By then they had a lot of opposition. By then these people knew we were working on this stuff. See, when he first sold the idea that he put together a group to look at electronic switching, you know, they said, oh, well, another group looking at electronic switching. Because people had already developed, as I said, a gas tube switching system and so forth. So this was just another group. But now he's asking for big money to start actually building something that would eventually go into the field, go into service. And now, you know, all our opposition came out of the woodwork. All the existing

electromechanical switching systems designers said, Ah, you can't do it. You can't possibly do all the things we do in the switching systems, you know. And what do you people know about switching? [Chuckling] All the usual things.

ASPRAY: Right.

JOEL: So we ran into a lot of opposition. But nevertheless, he got the backing of the top brass at AT&T and at Bell Labs and got money to--and asked for the establishment of--an Exploratory Development Department. Now he personally never got into the development end at all. As I say, he's not really that kind of an engineer. He was more of a traffic man. And I don't think he really wanted to get into proving that you could do it with 50 flip-flops. [Laughter] But I did. I mean, I wanted to get my hands on the actual switch and get it moving. So when the time came, I was happy to have been made a supervisor in this work. They had started a department. They set up a department. They made Bill Keister the department head, I believe. Yeah. He was made the department head. And I was made a supervisor in charge of the architecture for the system--like the principal architect. And then they had other groups that were designing the various parts--the memory and the scanning and the control and so forth and so on. I guess one reason Keister was promoted to a department head was he had taken over the school all this time. He was teaching switching. And he was promoted then from being the supervisor of the school to this job. I think Nazar might have had it, but Nazar died, though.

So Keister took over as the head of this exploratory work. And so we started. We got some money. This was 1952. We decided that we weren't going to do this work in New York. We were going to do it in Whippany. I forget why that

decision was made. I don't remember that I can really construct--except maybe there was space there. But we wanted to get out of New York; I know that. So we set up this department which had about--I don't know--maybe 30 people in it. And there must have been four supervisors. There was Washburn and myself. And, oh, we brought in a young fellow--actually he was one class beyond me at MIT, he was the class of 41, but had been in transmission all this time. Fellow named Ketchledge--Ray Ketchledge. He was brought in as supervisor. He may have already been a supervisor in the transmission area. And one other guy. I can't remember. So there were about four of us reporting to Keister on doing exploratory work on the subsystems, you might say, of an electronic switching system. And hopefully, you know, under the guidance of Chet Brooks who was still over in the systems engineering area, trying to tell us what the architecture of the switch should look like even though he didn't know much about it. But we used to have some wingdings of disagreement with him all the time because he was trying to tell us what to do and, you know, you just couldn't do these things. Just wouldn't work. [Chuckling] Nevertheless, he had his own vision of how to put switching systems together. So we worked, anyway, and demonstrated during the next two years some of the major components that this system would have. Not a system, just some of the components. And I guess we made enough of an impression during those two years on the top brass that they decided that--again, with Brooks's pushing --to go ahead with the development of a system. I mean, he kept saying, We're going to develop this system. We're going to actually now not worry just about putting it in one place-- which they'd already picked, by the way;

it was going to be Morris, Illinois. We went out to Morris, Illinois and told them they were going to have the first of this brand new era of switching systems.

ASPRAY: Why there?

JOEL: Well, many of the studies we had made had been in California. I remember Rossita[?] and some other places. Anyway, Chet didn't get along too well-- He thought he had a lot of friends out there, but when he got out there and started telling them what we were going to do, they didn't seem to like it. So he never got along very well with the Pacific Tel people, but he did have some friends in the Illinois Bell that he did get along real well with, including the president, whose name was Kahler. And so I guess Chet, someway or another-- He was a great talker. He talked this Kahler into the idea--Hey, wouldn't you like to have the first of a brand new type of switching? [Chuckling] And so they studied this Morris community and decided that was the place to have it--which is 60 miles out of Chicago, down near Joliet. At any rate-- Oh, there was another aspect to this. Now I don't know whether this ever had anything to do with it. But Morris was slated to be one of the first places to--<u>the</u> first place; maybe not just in Illinois but maybe in the whole area of the country or something--to have a nuclear power plant. [Chuckling] I don't know to what extent these two things had some relation to one another. I never did figure that out. But in any case, we sold the idea that we would put the first electronic switching system into Morris. And it would no longer just be an experiment, but it would be a prototype, and we were going to get the Western Electric Company all geared up to make this thing. And the Western Electric would make all the parts and so forth. Which was different than you would do if it was just an experiment. You know, we were really starting to

get the big wheels moving on this thing. And most of this I attribute to Chet Brooks. I mean, he had some other brass that was on his side pushing it. But nevertheless, he succeeded. It always takes somebody like this in almost every big project. Somebody who can sell it. And we were all salesmen, but he was the top salesman.

ASPRAY: Now how would the senior management of the company view this? Was this looked on as an important part of the future? Were their minds someplace else and they weren't paying much attention to it? Or--

JOEL: Oh, no, no, no! In fact, the record is replete with very important broad statements by the President of AT&T about how important this work is and that it is going to be the future. And it's going to represent a complete change in the way we do switching. And it's going to make a big, big difference in the future. No, they were really behind it. In fact, they expected more out of it than it was. I think. But they were really sold a bill of goods. By the way, at the same time that Chet sold--Chet Brooks--sold this originally, the idea of exploring electronic switching when the transistor was first invented, there were other people at high levels in Bell Labs who wrote similar memos about: Now's the time we ought to be doing something about switching. You know, moving into new technology with switching, getting away from electromechanical. So there were other people thinking along that line. But Chet was the one who was pushing so hard that he wanted to set up a group to do the whole thing. The other people were just, you know, writing memos about it.

ASPRAY: What were the limitations on transistors at the time? I mean, they weren't reliable. You couldn't manufacture them and so on.

JOEL: They were awful! They were awful. And in fact, one of the things that came out of this first two years of our exploratory work was that. By golly! Some of this stuff we had in the lab was so poor, so unreliable, so unpredictable, that we should get some smaller project moving first. And indeed, in my group we started two different projects that had nothing to do with directly applying to having a completely electronic switching system. We settled on electronic remote concentrators that we could apply to electromechanical systems.

ASPRAY: What is a remote concentrator?

JOEL: Well, a remote concentrator is: The idea is you have an apartment building, for example, or a housing development. Instead of running a pair of wires from every house or every apartment to the central office and there picking up the first point in the switch, have the first point in the switch out here, you know, near the development or out at the apartment building. It had been a dream of switching people for years, but they had no technology that would do it well. Because it was too big, and it was too much influenced by the environment and so forth. Here we had transistor things that we could do maybe a lot better. So we sold-- I actually had a lot to do with selling that idea. Chet also sold that idea. Of a remote electronic concentrator on existing systems. And we also sold the idea-- At that time we were starting to get into all sorts of problems with the translation in electromechanical switching systems as customers were starting to dial 10-digit numbers. And we had to improve those systems so that they could handle the 10-digit numbers. And instead of going in and doing it all electromechanically, why not do it with some electronics. And so we came up with an idea which we called an electronic drum sender--what was it called?--MDAS, Magnetic Drum

Auxiliary Sender. And that was able to be attached to an existing electromechanical office to deal with the 10-digit dialing and all that. And we had that project moving as an exploratory project. So we had several smaller projects moving as a means of testing out and trying out the transistor circuits and so forth, to see whether we really could get them reliable and, you know, we could depend upon for a whole switching system. So we were doing a real--I think--a good job in covering our bases. What happened was that after a while, both those things became a drag, and we dropped them. We ran into all the usual arguments. In fact, we learned a lot about things from the arguments because obviously the people in the electromechanical areas said, Hell! We can design our own 10-digit dialing. We don't need your electronics. Your electronics has this, that and the other. They found all kinds of reasons why it was no good. And so I learned a lot about, you know, how to argue with them. Which we needed to know when the chips were finally down on electronic switching systems against electromechanical switching systems. And we had to argue again the whole thing. So it was great! It was an interesting time because we had a chance then to try out the new technology on some things that we were going to take out to the field. And one of them we actually took out to the field was the remote concentrator. And then all of a sudden Chet got a more brilliant idea. He didn't just want a box. He wanted to distribute the box over the whole neighborhood. He had some new kind of a distributor remote concentrator. [Chuckling] And we had to drop that one. In the meantime, we had a lot of experience with it, though. We actually put three of them in service. At any rate, we had a lot of arguments with them.

ASPRAY: But this never became a widely distributed technology?

JOEL: No, never at all. In fact, again, we did so much to prove the idea that remote concentrators were good that the electromechanical people went out and designed an electromechanical remote concentrator that was a helluva lot cheaper than the electronic one. They sold that.

ASPRAY: And they were put into--

JOEL: And they were put into production and service. [Chuckling] Well, we had great times. But anyway, in '54 the chips were really put down. That they said, Look, all right, we're going to go ahead and really move into electronics. We'd better get the factories running. Learn how these techniques-- What they're like to build, these different things. And you people are going to go out and actually design a system that's going to go into Illinois. And a complete system, now, not just the parts like we were playing around with before. And we had proved ourselves, you know, with these concentrators and the MDAS job and some other things. So I guess I was put in charge-- Oh, then they made me a department head--I guess all of us became department heads--that had been supervisors of that department and given different responsibilities. Of course mine was naturally the whole system architecture and, you know, the main control of the system and so forth. Ketchledge had the network part and the memories. And Keister had the trunk circuits and some other parts. The four of us all became department heads. And they brought in a new guy--a real codger, he was a really drippy guy. He came from the apparatus area. He had made a name for himself as the co-inventor of the gun director that shot down all the V-1's. His name was Lovell. He and another fellow by the name of Parkinson had invented this famous gun director--

ASPRAY: Oh, yes. Right.

JOEL: --that was driven by one of our radars. And he was very, very smart. He was a physicist. A real brilliant guy. And they decided to bring him over to the switching area. Now he'd never had arguments with Chet before. He had never met any of us--he didn't know any of us at all. Maybe Keister he knew--I don't know--because they were both Southerners, and they got along real well together. [Chuckling] At any rate, he became the director, the head of the whole business. So we had a great--really good--team together. And he learned a lot about arguing with Chet. [Chuckling] But he was a real codger, a real great guy. And he could take everything in his stride, and he had a lot of good common horse sense. It was good to put him in there. Somebody had really a good idea to put him in there; I don't know who. So that was the team, and so we started out. Within the first year in my part of the system--Well, actually it was more than my part of it. Ketchledge had got busy and gotten memories going, and he had a real terrific memory, which was using the idea of a Flying Spot Store. You've probably heard of a Flying Spot Method of reading films.

ASPRAY: It sounds familiar, but I can't place it.

JOEL: What it used to be was for kinescoping and things like that, you would scan a frame of film with a cathode-ray tube. And then you'd get the signals out, and you'd transmit them. Well, they came up with the idea of a Flying Spot Memory where you could scan stationary things. And by having multiple lenses, you could have a whole things you could have light in-- And we actually had a 37-bit word. We had 37 slides that this one tube was looking at, simultaneously getting a 37-bit word out. The thing that they had invented very early in the game was a servo arrangement so that as the beam looked at one, they'd have some other slides that

would have the positioning. Have the spots on it so you'd know exactly where the spots were. You could bring that thing on a random axis and place it any place you wanted to in less than a microsecond. It was terrific. And the more that he worked on it, the more capacity it had. So originally when all we were going to store in there was the telephone line numbers and some things like that, they after a while had a store that had tremendous capability.

In the meantime, my guys were trying to develop the control circuits, and what they were doing was the same kind of thing we did when we designed markers: to try to take these transistors and build flip-flops and all the other things you needed, just like you had relays, to process the call. And they were getting into more and more damned trouble because it was hard--hard as hell--to build these long complicated and-and-or circuit type of, you know, tremendously complicated and-and-or gate array of transistors and diodes. In the meantime, Keister wrote a memo about storing the logic of the system in the memory. That's all he said. He had tables and whatnot to look up the memory and tell you how to process telephone calls. It was a good idea. One of my guys, a fellow by name of Arthur Budlong, one night, you know--he knew we were having all these problems--and he sat down and he said, You know, like, these computer people are writing and storing programs. It's true that they don't work in real time and it takes a lot of memory and so forth, but suppose we wrote a program to do all this instead of using this logic? We'll just build a circuit that'll read the results, put it into memory, take it out of memory. Which is a similar kind of thing that Keister had in a broad way. And he wrote a program and so forth. And then we started looking at the stuff that was being designed on the Flying Spot Store and said,

Gosh, this is ideal. We've got plenty of space in there to store programs. We don't just have to store telephone numbers. The two ideas worked away. Within a period of--I don't know--three or four months, we came up with this idea of switching logic in the memory, as we called it, taking the logic and building "and" and "or" gates. In fact, that was my contribution. The point was that very quickly we all agreed that this seemed to be a heck of a lot better idea than what we were working on for the control. So we started down that road. It turns out that in retrospect now, looking back, that that was more important than all the business we did on electronic switching about, you know, how we were going to set up the paths through the cross points, and what kind of cross points we were going to use, and what kind of memories we were going to use. The most important thing was the idea that we were able to put all the logic on how we were going to process telephone calls into memory--in a memory--and use a program to carry it out. And we've learned how--we had to learn how; the learning process started then--how to do this in real time. How to be able to keep up with the demand for telephone calls as they were pouring into the system. Which was something different than the computer people ever had to do. So that was the real contribution, I think, at that time.

ASPRAY: So this was 'fifty--

JOEL: 'Fifty-four, 'fifty-five.

ASPRAY: Okay. So, for example, this was the same time that the Sage computer was being built--

JOEL: Yeah, right.

ASPRAY: --for processing radar signals. Do you know enough that you can compare the demand--real-time demands--of the two?

JOEL: Oh, yeah. Ours was much more than the radar bogeys or whatever you call it that were coming in. Because we were talking about a switching system and, of course, in Chet's view we're talking about a switching system of--well, maybe not a half million lines, but-- [Chuckling] Well, at least we want to go up a step; we don't want to, you know-- The current switching systems at that time, electromechanical, were at least 20,000 lines and maybe more in a few cases. We wanted to at least go to 50,000 lines. So we were talking about that many possible-- In a busy hour, in the busiest time of the day, it's not unusual to have 5,000 attempts at a time, you know, all coming in simultaneously. You have to process all of those. No, it's a real challenge. It's, I think, more of a challenge-- Of course there's not as much information to be processed about each unit as all the other things you have about these things that the Sage has to process. So they're a little bit different in that respect. But nevertheless, it's the same kind of a challenge.

So that was the real nut of the-- I wouldn't say that anybody recognized it as being that important at that time. I mean, we just said, that's the way to go, and we went that way. And we did, of course, start talking about it that way as being important, that all you have to do is change the memory, and you can make the system do something different. We didn't tell them how hard it was going to be change the memory. And how many people it took to write the program or anything like that. [Chuckling] In fact, we didn't know ourselves at that time. But nevertheless, I mean, I didn't have a very big group, and we turned 100,000 words out for the

Morris program within two years or something. We had six or seven people; that's about all. [Chuckling] So it was quite a feat and kind of a real change. It was a challenge, too. We had problems, and Ketch had problems with his memories of various kinds. And the network. Everything from time to time, always a problem would come up that was basic to the whole darned--the success of--the job. And we were out there selling this stuff like crazy, telling them how great it was going to be when you get it. And we were sitting back and saying: We don't know whether we're ever going to solve these problems, you know, some of them were so tough. And yet we always came through with not only a solution--like the stored program control--but a better solution than we'd ever expect. It was just one of these things that everything we seemed to touch got better when we sat down to work on it and, you know, had found it was a difficult thing to solve. So, by 19--whatever that date is on there; I think it's '57, '58--we had that office working in the pre-Morris, as we called it, laboratory where we had one of everything, and we put it together. I tell the story in the book--I don't know if you saw it--but there's a story in the book about the supervisor that worked for me in charge of putting the system together, the laboratory system together. He had all these plans--he and his people had all these plans--about how they were going to test it out and so forth when they'd get the first program and the first of everything working together. And instead this famous day came along in March, I think it was, of '57, and he says: "Well, dial! Dial! Dial the number and see if the call goes through!" [Chuckling] That wasn't what was on the schedule, you know. They were going to go through a whole bunch of steps very, very carefully. Very carefully programmed steps that they were going to take to make sure that

everything was right. Instead he says: Well, let's dial the number and see if the call goes through. And sure enough, it did. And that was the first call ever established through Stored Program Control. So I got a box on that in the history book. But that was a big event so of course we had people demonstrating.

Then out of that and, you know, my desire to-- Well, first of all, the patent licensing people of Western Electric Company wanted to make a big deal of this with all our licensees to show them, Look at all this stuff you're going to get as part of our license package. My desire, of course, to see that people in the future who want to study switching don't have a problem of finding out what happened in switching. We held the first of the international switching symposia, if you want to call it that, in 1957, where we had the world people come and also Bell System people. We did it twice. Once for all the people from the Bell System to come--or a certain cross section of them--and one for all the people from around the world, licensees, to come, to see our pre-Morris and to see how it worked and to see what we'd accomplished in switching. Then what do we think future switching looks like? We got tremendous response to that. Everybody couldn't believe that they were seeing. And how can we ever do that? And so forth. As a result of that, by the way, every three years since then we've held an international switching symposium. The first two were held at Bell Labs in 1960 and 1957. But after that we started going around the world. This year it's going to be in Yokohama. Last time it was in Sweden, in 1990. Sometime it's every two years or every two and a half years. So I'm considered "the father of the International Switching Symposium." There's a chart back here on the wall that proclaims that. [Chuckling] But this is good because things have changed a lot, you see, since the

days I started in switching, when nobody knew what the heck was going on. And here now these people want to hear about what's going on. You've got comrades from all over the world. I gave a talk in Sweden in 1990, one of the introductory talks of the whole symposium. There were 3500 people in the auditorium and, I don't know, another 500 outside some place else--they couldn't fit them in--at the opening session. And I said, "As I look over this room, I just can't believe it. Here you've got 3500 people interested in switching. The days when I started in switching, there wouldn't be this many people in the whole world--in fact, there wouldn't be even a tenth of this in the whole world--interested in switching and know what's switching is all about. And now you've got this many people in one place." Unbelievable what's happened and, you know, I'm glad that I had something to do with it. So it was a great time.

Anyway, we had this big symposium in '57, and by 1960, of course, we'd built the office. The office was built by Western Electric. It was not built at Bell Laboratories. They installed all the parts in production lines, and they learned how to build them in production lines and all that. And to show you just how [Chuckling] we much we like to fool the bosses, we came along in-- We'd no sooner gotten the pre-Morris working, demonstrated, and said, now we're going to go ahead with Morris-- And by the way, we were starting to ask for big money now. [Chuckling]

ASPRAY: Can you give me a figure?

JOEL: I don't know, but the first Morris when we started, I think was $10 million, which was a lot of money for those days. And pretty soon it escalated to, like, $15 million, and they couldn't believe their ears because this was a lot of money in

that time. Especially for a new switching system. Before we were finished, we spent well over $100 million--before we cut over the first line in Morris. But in the meantime, the worst part of it was that by then the technology was moving so fast that by 1958, '59, we'd already decided that the Morris technology was great and we were going to go ahead and put the office in and learn from the field and get some experience with it. But it is not going to be the system we're going to eventually put in production because the technology's changing already. And we know we can build lot better and different memories and network parts and so forth. By the way, for Morris we required special telephone sets, which never would fly with the telephone companies. They would never buy the idea that the telephone man that comes around to your house has to have two varieties of every telephone--one to work on electronic switching and one to work on electromechanical switching. So a lot of crazy ideas like that that we didn't sell. So we solved these problems by going ahead with the newer version of the switching system. In fact, nothing was retained except the principle of stored program control. A whole new set of technology, which I worked on. I was the architect of that system, too. And we started in earnest in 1959 to develop that system. And that became the No. 1 ESS--the first ESS--which went into large-scale production. As I say, we had a symposium on that in 1960. And in '63 we cut over the first one in Succasunna. We just took it out of service in Succasunna last--a couple of weeks ago. I don't know if you saw it in the papers.

ASPRAY: No, I didn't notice.

JOEL: Yeah, Succasunna was cut over. That was the first No. 1 ESS. So what else.... So we started designing that system and put all that into production. Of course now

we're spending money like it was-- But I think by then we'd pretty well convinced all the top brass that this really was a viable thing, and it was going to really revolutionize. They started believing some of our advertising, you know, how flexible stored program control was going to be.

ASPRAY: Tell me, in hindsight just what were the advantages? How does one measure the advantage of the electronic switching system?

JOEL: Well, I think there's no question you can measure-- I mean, we had a long list of things that we said were going to be the advantages when you get it. We had a lot of problems with this when it came to the FCC investigation of the Bell System. But there's certainly no question that one of the first things on the list was the space savings--they were tremendous. I mean, when the Telephone Company started really installing electronic switching--and I don't care if you're jut talking about No. 1 ESS, let alone many of the other generations that have come since then--that they started having real estate for sale all over the city. It took so much less space. There's no question about it. Now some of the other things, you know, it was never half cost. But it was a lot cheaper to maintain because these systems you couldn't maintain them with a pair of pliers and all the other things you needed for electromechanical systems. And you had very sophisticated stuff built into the system that led the craft people to the trouble. Told them, you know, pull this package out and put another package in its place, and the system will be back in service. You know, they couldn't do that before. So it took a lower-paid, less trained, less skilled--

ASPRAY: Less skill requirements for that.

JOEL: Yeah. I used to go around the country lecturing about nurses and doctors. We needed nurses now instead of just doctors. Sure, we needed some doctors, but even that we'd mechanized. We had arrangements built in around the country so that all the trouble reports came in and were automatically put in databases. And whenever something happened, boy, immediately we'd go to the data base and say, Oh, they had a thing just like that somewhere else, and this is exactly how you fix it. It was very easy to do all that. So the maintenance and the space. The flexibility was there. There's no question that the software could easily be changed, and we did it many times, changed the software to make the system function differently or add new features. The problem was it took a heck of a lot of people, you know, design people to do it.

ASPRAY: So what would be a typical kind of change that could be accommodated by this system?

JOEL: Well, one of the changes we liked to talk about in those days was the coin situation. When the 911 situations came up on coin phones, it became a big problem. Because up to that time, you couldn't dial a number in a coin phone without putting the nickel in--or dime or whatever it was then. And we had to deal with the fact that you had to start arranging coin phones so that you could process calls without coins but then decide later on whether you needed a coin before you completed a call. But we just went in then and made a few changes in the software to do that. To do that in an electromechanical system would require a heck of a lot of circuits to be changed--and not just one circuit, but those circuits are replicated throughout the office, and you have hundreds of them to change. But we just went in and changed the program. So, you know, that's just one

example, but there are many, many examples. The problem we had to learn was you lease the software, you don't sell it. You had to learn how to deal with the fact that every office didn't need all the software. There are a lot of problems in software we haven't solved yet. As I said earlier--remember I told you earlier? -- that the switching system has to do so many things, and that's growing to the point where we're almost getting bogged down in it, and it just keeps growing. And you very seldom get rid of it. You don't get rid of very much. You get rid of some things over time, but not a lot. At any rate, I think, looking at all the objectives we had, even now the costs are way down. They weren't initially. I mean, initially there was a real struggle to prove in on a first-cost basis, an electronic office against an electromechanical, in which the costs have been beaten down over generations. And we hadn't beaten them down. Now that we've beaten them down over generations--we've gone through generations of electronic systems--the costs are down, too, now. I mean, nowadays you go out to a factory--they're made in automated factories and whatnot. But initially they weren't that way at all. Think of poor Tom Flowers saying, you know, at the cost of transistors in those days, how can we build a system?

So at any rate, the ESS really proved itself in as a tremendous accomplishment, and it gave the Telephone Company something. I mean, even today as they install the latest of technology, which is time-division and digital stuff. Many people attribute things-- You know, we're installing the latest thing. It has this, that and the other thing. The things it has are the things that No. 1 ESS had, not something just attributable to time-division digital exclusively. It's the stored program control that they frequently attribute their great gains to, and not because it's time-

division digital. And it's the same thing with the space and all. Of course they're even less space now with the time-division--even less than the original. The service was better. The number of customer complaints was down. We could find troubles in anticipation of customers' complaints. We could do a lot of things that were better. We could give faster service--as change telephone numbers faster and things like that. A lot of things were improved. We completely changed the way telephone companies did business. And also the billing part of it. It's just so many things that improved as a result of using electronic switching. And, you know, when I started in the business, although I saved patents-- In those days I remember I had books of patents of electronics applied to switching. There was nothing in the cards those days that would look like they were practical. The most frequent thing you saw back in the 'thirties, patents on the use of cathode-ray tubes with targets in them that would act like a rotary switch of some kind. And they wouldn't have hundreds of targets either. They couldn't get that many in the glass. So that there was very little in the way of practical electronic switching. And I think that we accomplished something by showing how to do it. We took a lot of ideas from other people, too. I mean, sure. As I say, the research people had some good ideas. But we persevered, and we turned every difficulty, it seemed like, into another advantage. [Chuckling] One way or another. And I imagine that this is true in any good new project that's breaking new ground in technology. That frequently the solutions to the problems you have make it something worthwhile. Make it even better than you thought it was going to be.

Anyway, it was a great era. That was the 'fifties, the late 'fifties. And I was lucky to be at the right place at the right time, which is important, too. It turned out that

throughout that period, as I look back on it, for some strange reason I was about the only one in that Lovell laboratory that developed ESS that really knew switching. You see, all the people that worked for me all came in after the war. We trained them all in our school. All of us except Ketchledge, who came about the time I did--and he was a transmission guy and didn't know switching-- [Change to Side B of Tape] Okay? Can you hear me? Is everything all right now?

ASPRAY: Yeah, it is now.

JOEL: Okay. So if you put yourself back at that time when we started this, the people were either people we trained, brand new people-- Nobody came over from the electromechanical business except a couple of mechanical designers, people who design equipment frames and things like that, not electrical designers, not systems designers. The people who design frameworks and packages and all that kind of stuff. I had a couple of those people who came over from the electromechanical side of the business. But none of the electromechanical circuit designers or systems designers came. First of all, many of them sort of boycotted us. They didn't believe us and thought we were going to take their jobs away from them.

MRS. JOEL: Can I get anything for anybody? [pause]

JOEL: So, you know, the people aspect is very interesting when you put yourself back at that time. And I really, right from the very beginning, I knew that I was about the only guy that knew anything about switching systems. And this is we're talking, like, 15 years after I started working there. Which was different than the previous generation of people. And all the people working for us, even my supervisors, were all brand-new people, all postwar people. Most of them had never worked on electromechanical systems either. Or they worked on some small trivial part of

it, and, anyway, never put a system together. Neither had I. I mean, in my mind I had for years. And I knew all the systems they had, but I missed that opportunity to work on No. 5 and then never worked on anything else. But I was really the principal system architect from, you know, a detail point of view. And the same thing on No. 1 ESS. I got out all the details. I told them exactly how every black box was going to work and everything was going to do its job before I left the job. Because I left the job in 1960, I guess it was there--'60 or '61; I've forgotten now. I left the job before the first Succasunna cut over. I left the job after we had laid out the plans for the No. 1 ESS, gotten the initial money for the development. Again, the big disappointment of the brass because, I mean, we started out with $50 million, and it went up to $500 million, and it was the most expensive project they ever had. They couldn't get over what the cost was. But nevertheless, they backed us, and they got the money. And I think overall the Bell System, you know, was benefited tremendously by it. In fact, it's only when you look back and you think of the amount of money that was spent that you really get scared. [Chuckling] At the time you're spending it, you have a lot of arguments about it. But nevertheless, you know eventually you're probably going to get it. And having gotten this far, you're not going to stop the project.

Now there's another aspect to the project that is worth talking about at this time. That up until we got committed to developing No. 1 ESS, there was a competition from the PBX area. PBX people were also looking at electronic switching. They had postulated various things. And in fact, in order to sell my remote concentrator job that I had back in the exploratory days--remember I mentioned that--

ASPRAY: Yes.

JOEL: --in order to sell that I told them they ought to use that as their PBX. And I went out and even told them that they could adapt this idea of having several of these remote concentrators and one central PBX controller. And it sunk in eventually. Eventually they came around to that idea, except that the remote concentrators, instead of being what we call space-division, where you have individual cross points out there to operate, to set up the connections, they went to time-division, which is the current idea. Only it was not digital. It was just plain time-division. And so they had the idea of a switch, a system of PBXs, where these time-division units--remote units--would all be controlled by one central control. Which of course they adopted from our stored program control. And so by 1958, '59 they were ready to go ahead with this project. And of course the bosses kept asking, Should our central office be time-division instead of space-division? Because they were working. And we said, no. And I think it was the right decision because we eventually were able to point to England and show what a fiasco they had trying to design a large system like a central office with time-division. See, a PBX is a lot smaller, so it's a lot more practical. Anyway, it was the right decision, but there was this argument going on all along. And eventually they went ahead and developed their system and put it into production and actually beat us to it. They put their first system in--in service--in 1963 down in New Brunswick. It was called the 101 ESS. It used the stored program control unit that we developed for the No. 1 ESS. Or something like it. It used the same memories and everything. So they beat us to it by two years. And by the way, when we first set up getting the money for the No. 1 ESS development in 1959--it may have been '58, but I think it was '59--when we first told them we were going

to cut it over in the middle of 1965, and we did. So we never missed a scheduled date on that. Which was very unusual for a half billion dollar project. So it was really something. So we really accomplished a lot. But the point was that we always had these other people in our hair with the time-division versus the space-division, PBX and so forth, and them beating us to the punch with getting the first stored program control system in service. But nevertheless it was our basic idea. So that was something that also went on along in parallel, and it was always a running argument as to whether we should have done time division. And I don't think even looking back today--even though today it's time-division, but it's digital (that makes a big difference)--and I don't think we would ever have succeeded the other way.

So anyway that gets us up to really the time when I got off the project.

ASPRAY: Is this an appropriate breaking point, do you think?

JOEL: Yeah, it would be a good time to break--

ASPRAY: Okay.

JOEL: --because after this I got off and went other ways and got off this particular thing. But up to this time the No. 1 ESS is well on its way, and Ketchledge is pretty much the prima dona of this thing. They decide to move the-- First of all, Bush had been the executive director over Lovell all this period. And Bush not only had responsibility for the electronic, but the electromechanical switching. And by this time they started to decide that they ought to have a separate executive director for electronic. So they brought another guy in and took it all away from Bush. And so that's how I sort of got off of this thing, because Bush brought me with him to his new assignment. Which frequently happens. So that's a good place to

stop. But at any rate, the new man came in; he became-- And Lovell retired, and Ketchledge took his place. So Ketchledge got a promotion out of this. Which I never got. Well, I became a director. Well, that's all he-- He became a director at that time. Later on I became a director when Bush took over on the other stuff.

ASPRAY: Okay.

JOEL: Okay, good.

ASPRAY: It's the 18th of February 1992. This is the second interview with Amos Joel in his home. Let me just check to see that this is taping. [pause] Okay, why don't we continue the story of your career then.

JOEL: Okay. Well, as I say, we'd just finished talking about the role I played in planning the No. 1 ESS, the first electronic production system, which was the successor to the Morris trial which was the first electronic switching system with stored program control. And about that time--it was in 1961--that I was promoted to become a director at Bell Laboratories in charge of local switching systems development. And what that consisted of was primarily all systems besides electronic and crossbar because crossbar systems were still a very large development effort in Bell Laboratories. Because that was a continuing thing whereas the electronic systems were just in their infancy. So there were several laboratories devoted to crossbars. [pause] There were a lot left over, for example, for step-by-step system and manual boards--I think I mentioned ones--and what we called common systems. For example, this laboratory had responsibility for designing all the adjuncts that had to go into existing systems for Touch Tone, which was just being developed at that time. Also this laboratory had whatever

was left over to be done in the panel system, which was still in existence in many locations in the country. And so for example adding Touch Tone to even a system as old as the panel. So we had a lot of miscellaneous kinds of activities in the switching development, in the switching area. We were responsible for all those developments. And it was a laboratory with about 160, 180 people, something in that order. Most of which was, at that time, back in New York at 463 West Street, which was the original location of Bell Laboratories. The electronic switching had, in the meantime, moved out first to Whippany and then was going to move in 1961 to Holmdel. And I was expecting to go. But because I got this promotion, I went back to New York. And my friends all moved down to Holmdel. My group in New York had been planned also to be moved to Holmdel. And we had, in fact, because we had all these old switching systems--having responsibility for all this old equipment--we had a special laboratory built for us in Holmdel where we had high ceilings. It was in what was then the first floor at the bottom, the lowest floor. That had been planned as part of the building when they built the building that we have this special laboratory for this group that I was going to bring down to Holmdel from New York. Because the old-fashioned, the old electromechanical switching all had high frames. And this was a demonstration laboratory. We had one of everything, including even No. 5 crossbar, in that laboratory. And it was a very useful thing at that time for all the people in Holmdel who wanted to make sure that their equipment worked with the existing equipment that was in the field. So it turned out to be a very good idea.

ASPRAY: Excuse me for just a minute. You say you were appointed to director level. What level was that in the company?

JOEL: In Bell Laboratories it's the third level down--fourth level down. There's president--well, there's executive vice president and vice president--and then there's executive director, then director. I don't know. In a company like Bell Laboratories at the time when they had, like, 15,000 employees, they'd have about 125 directors, something like that.

ASPRAY: Okay.

JOEL: So usually a director had at that time responsibility for anywhere from a hundred--depending upon what kind of a laboratory it was--a hundred to two or three hundred people in the laboratory. And oh, this group had responsibility for switchboards and, as I say, for a lot of other things. Moving over there, I felt because I was primarily, you know, from the electronics--I loved this new stuff that we had been working on on electronics--I felt it sort of an obligation to say, Well, gee, maybe I can move this laboratory into electronics and get away from all this electromechanical stuff. You know, what can I do with this? What can we come up with? It turned out that we were able to. Of course we had the electronics in the Touch Tone and that sort of thing, but that was minor. I was thinking in terms of electronic switching systems of various kinds. And there were some projects on the books where some electronics had been introduced, but they weren't very big projects. Some of them were fairly far along. For example, this laboratory had been committed to putting common control--centralized control--into the step-by-step system, which is a very primitive original dial telephone system in order to deal with various problems in some large cities. It was a modest project, but we tried to put electronic controls in for the common control, but we couldn't sell it to anybody at that time. Everybody wanted to meet

the schedules and didn't want to spend a lot of money on the development. And they knew how to do this and do it well. And all these people I was bringing down there from West Street were not electronic-minded kind of people. They were all old-timers who had worked on electromechanical-- In fact, I lost a lot of them because they were just too old to come down; they retired. Which is good because then when I got down to Holmdel, we were able to hire a lot of new people who were electronic-minded. And it turned out to be very good in the long run. So that group did its job and moved on with various improvements in electromechanical systems that they were responsible for. Until we came up to a point where we had to introduce operator dialing into the step-by-step system that we were responsible for. There was a version of the step-by-step system that was used that had centralized AMA recording in it. You remember the automatic message recording?

ASPRAY: Mmmm hmmm. Yes.

JOEL: Had that in it. And one of my department heads, a fellow by the name of Dick Jaeger, who, by the way, has been a director in IEEE--I got him started actually in IEEE--he and I put our heads together and said, you know, we both had this idea that we'd like to get some of these young people involved more in electronic switching than the old electromechanical switching. And so we came up with this idea of a stored program control operator system. The outgrowth of that was the so-called Traffic Service Positions System, which was an electronic switching system using stored program control taken from the--actually we used the control taken initially--from what was a version of the No. 1 ESS. Only we couldn't use exactly the same technology because there were some problems in connection

with frequently changing tariff tables and some other things that we had to do. And we used a different kind of memory. In fact, we broke ground by using a new kind of memory known as the "twister." The permanent magnet twister was used in the No. 1 ESS, but we used a piggyback twister, which was one that you could electrically write. Whereas the one in the No. 1 ESS you had to have a special machine that made magnetic cards that were used as the permanent memory in that system. In any case, we came up with this basic idea of an operator system that could be used universally. Whereas up to that time each laboratory working on electromechanical switching was trying to design one for their own system. If it was a No. 5 crossbar, they were out designing one. For a No. 4 crossbar, they were out designing an operator system. Each was getting a different operator system to work with the future dialing plan of the country, which involved dialing zero plus the number for operator-assisted calls.

So we came up with this idea that you could have a universal system of electronic switching as the main way of doing operator services. And after a lot of hard battles, you might say--with just because of the ingrained nature of most of these other people wanting to go ahead with their projects which involved the use of electromechanical switching--we finally convinced everybody that this was a darned good idea. So we started down the track of taking this new young laboratory, with relatively young people now--almost all new people--and switching them over to developing the Traffic Service Positions System. Now along with that-- And we did; we started that project and moved ahead so that by-- Of course we didn't get approval for this thing until about 1964; I've forgotten what the date was of the patent, but somewhere in that area, the mid-'sixties. And

we had the first TSPS, as we called it, that was cut over in Morristown in fact, in 1969. In the meantime, I also had in my laboratories some people working for years trying to improve the directory assistance. And we tried and we tried to find ways of improving this service by using microfilm and microfiche and all kinds of other techniques of getting quicker access to directory information. None of which worked out very well. None of which could pay for the equipment that you needed. And computers, of course, were then starting to come in, and we started looking at computers and did all kinds of simulations of computer-operated directory assistance. That work got started in this laboratory, and eventually--Well, it was not something that Bell Labs developed. We came up--Bell Labs did--but not in my shop, in what's called the Human Factors Area of Bell Laboratories. The people there--one particular person--came up with the idea of making it very easy to type information into a computer, just a very minimal amount of information and coming up with a rather restrictive list of stuff from the directory on the video screen in front of an operator. And that's the method used even to this day where you don't type out the full name and address of somebody before you get the telephone number. But you just type out the first letter of the street address and the first letter of the name--the last name--and like-- We call it a combination of details of three or four characters. And you restrict it fairly quickly to maybe a list of six or ten items. And it's easy then for the operator with a light pen to pick out which one it is and that's the one that gets announced to you.

ASPRAY: I see.

JOEL: Well, anyway, we were involved in trying to make this kind of thing work. We didn't get very far with it, I don't think, because eventually outsiders like IBM and others developed the actual computers and the databases and things of that kind. But we did develop the interfaces that had to work with the existing switching systems.

ASPRAY: Was AT&T doing most of its computer business with IBM at this time?

JOEL: Not really. Well, I shouldn't say that. I guess in the accounting area, in the controller's area of the telephone companies--not AT&T itself, but the telephone companies, which were of course, were subsidiaries of AT&T--they were working mostly with IBM people, with IBM computers. In fact, one of the projects we had in that group was to convert AMA paper tape into IBM magnetic tape. And we worked closely with IBM people on that. I might also say this was an era where IBM was having some success with electronic computers, of course, the 701s and the 709s and so forth. And they were looking around for better fields to conquer, and they thought they could develop electronic switching systems. Around just about the time we came out with the first electronic switching system in 1965, they came to the top management at AT&T and tried to sell them on the idea that they could do a better job of developing the memories and all the other things you needed for in an electronic switching system. That we should use their equipment and so forth. But that never was thought of very seriously by AT&T or Bell Labs management, and nothing ever became of it. It did arise later on in some legal action but not seriously.

At any rate, the other thing we were working on in this laboratory-- Of course the main thing we were working on was the TSPS, the Traffic Service Positions

System. That was a big winner. I mean, they were going to make this and use this all over the country, and it was going to be the main way of getting operator services in the foreseeable future at that time. The other thing we were working on, though--had been working on for some time--was to try to mechanize some way the so-called intercept problem. When a telephone number is changed and they take it out of service, they can't immediately reassign it to somebody else because the people who know that number might be calling the old party. And so we had a practice for years of intercepting those numbers. And an operator would answer, and you would tell the operator what number you were calling, and she would look up in a book and find out what the new number was that you had transferred to. Of course this took a lot of operators--required quite a number of operators. We were looking for a better way of doing it. Well, we had devised the basic equipment for the operators to have access to computerized records, things of that kind. But IBM and another company had tried to come up with a system where the operator would key in the information you gave her. In other words, you'd say, Well, look, I'm calling 555-1212, or whatever number it was, and she would key that number in and then the machine will look it up in the computer and find out what the new number is. So that's a semi-automatic way. Well, I came up with the idea of using something we already had in our switching systems. We already had a method they had built in--in fact, by the way, this was one other responsibility of this laboratory that I took over when I went to New York--that one of their basic products that they were starting to work on just at that time, which was electronic, by the way. It was Automatic Number Identification. Prior to that time, whenever you made a call, the operator would

ask you for your number, and she would write it down on a ticket. Or for AMA we had operators who would punch this information up in a keyset, and it would go into the AMA record that way. That was called Operator Number Identification, if you will. But it wasn't always very good because in a place--in fact, one of the best examples we used to use was in Newark, people would give the Bamberger's Department Store number instead of their own number. And Bamberger's would end up with a big long list of toll calls, which they didn't make. [Chuckling] So we had worked on Automatic Number Identification. In fact, that became a very big product. We actually developed three different methods, depending upon the size of the office whether you did it one way or another. And of course eventually all the electromechanical switching systems were rearranged to include Automatic Number Identification. And that's why in the scheme of things this laboratory that I had was called the Common Systems Laboratory because Automatic Number Identification is common to all the systems, you see. Same way with switchboards, which is common to all the systems. So that's why I had that responsibility. At any rate, I said, Look, we already have a way in the office of finding out numbers, you know, the number that was called--the number that was calling. So I said, Why can't we turn this around and make it so that we use it also when the number is called.

ASPRAY: When it's called. Sure.

JOEL: So I got a basic patent on that and described it to various people. And we eventually went in and arranged these various switching systems--the electromechanical switching systems--so that they could do this. Of course the electronic systems you could do this from scratch, and the same way with

Automatic Number Identification. You can do that from scratch with the electronic systems. But the electromechanical systems, you had to build equipment to do it.

ASPRAY: Was it a difficult problem?

JOEL: Very difficult, yeah. Yeah. You mean to turn this thing around--

ASPRAY: Yeah.

JOEL: --so it identified the call? No. The same equipment was there. I mean, after all, the call lands on the terminal, the same terminal that you identify when you send a call out from it. So it's just a matter of saying, look, when this calls up on intercept, you then send out this signal to look for the identification of this line and send that. The main thing is that you had to develop a little thing to send it out over the intercept line to the central bureau where the computer was located. Where previously operators had punched this information into the computer, now it was coming in over the same line that the announcement was going to come back on. And we did that. And it became a very successful-- Well, successful in the sense that we did have an automatic intercept system in service also again about 1969--'70 I guess it was. And of course you didn't need very many of them. Like the whole state of New Jersey only has two systems like that even today. So there were only about 30 or 40. It's interesting that this is a kind of a product that since divestiture you couldn't justify. Nobody could afford to spend the millions that it cost to develop this system because you couldn't make the money on the product. You make the money on saving the operators. But the telephone companies, you know, normally today wouldn't have the money today to invest--

wouldn't be allowed to invest--in developments like this. So, you know, it's a different world today.

ASPRAY: Do you think that means that certain kinds of advances are just not going to come true?

JOEL: Oh, that's true. Yeah, there's no question about it. Certain things that you couldn't afford to do under a monopoly situation, which may be not benefit one part of the business but could benefit another part, you can't easily transfer today when you don't have that monopoly power. So that was another invention of mine, and that was something that really got the-- In fact, it was a great improvement in the service, too, because this thing told you exactly what number you reached, not the number you thought you'd called. And frequently people would get their calls intercepted only because they had dialed the wrong number. So, as you know when you make these calls and you get this operator, when you get this announcement that comes back to you, it says: "The number you have reached is" so-and-so. Not the number you have dialed because you could easily make a mistake. You know, there are still problems with this. It doesn't solve all the problems. For example, the partnership of Jones & Riley breaks up, and they have now two new numbers, it can't give you the two numbers. You have to go through an operator and tell her which one you want. [Chuckling] But it does solve most of the problems, and so it's cut way down. The number of intercept bureaus and operators is very, very small today--if it existed at all. So that solved that part of the operator problem. Then we were gradually making some progress here in dealing with the future operator needs of the telephone system.

ASPRAY: Do you have any sense of--can you quantify--savings in operators?

JOEL: Well, we estimated at the time that the savings in the TSPS alone to the Bell System was over a billion dollars in, you know, over a 10-, 15-year period. Something like that. It was a tremendous savings. But it wasn't all due to the TSPS. It was due to the fact that the customers were now dialing their own operator-assisted long-distance calls. Whereas previously they would dial zero, and the operator would have to do everything. You know, write the tickets, and keep track of the accounting, and all the rest of the calls. Which they didn't have to do anymore. Now you dial the number, and then the operator would come in only at the appropriate time to make sure the party you were calling would accept the charges or whatever it was that was involved in the call. Take the credit card number. And we did some wonderful things with credit cards in the system. We could have access to a database, and we could-- In fact, we even built right into the system the ten or something hot credit card numbers, and immediately it would show up as soon as somebody gave that number. But we could do it for large numbers of credit cards. We can do a lot of things now that we could never even have possibly thought about before. And all this due to the fact that we decided to do it with electronic switching and not continue with electromechanical the way some people had wanted to do it at the time. So having come over from the electronic switching area into this, I brought those kinds of ideas and concepts with me. So it was a good plug.

But something happened around this time and changed my whole career.

ASPRAY: Before you go to this new--because this looks like a transition--

JOEL: Yeah, it is. Yeah.

ASPRAY: You've told me what your group did. What did you do on a day-to-day basis?

JOEL: Well, that's a good thing to go into this transition. As you can see, my main interests, even then, were to invent things. To develop new ideas. To try to figure out new things to do with this new technology and, in fact, with whatever technology there was being used in switching. So I was full of ideas and got a lot of patents on things that never materialized into projects like the ones I've just described to you. But that was the things I liked to do. Unfortunately, day to day I did have to do a lot of personnel--you know, hiring (we didn't do any firing), moving people, classifying them. Worrying about budgets. You know, how much money could we get for the next year to do what we wanted to do? And all these other kinds of administrative things that come along. Now Bell Labs had up to that time had no Fellow Program like IBM has. And I guess about that time IBM started their Fellow Program. We're talking about 1967, '68--somewhere around there. But we didn't have anything like that at Bell Labs. But I just had a feeling that this was not-- I didn't want to continue worrying about budgets and personnel problems and all that kind of thing for the rest of my career there because I was still full of ideas and things I wanted to do. So I went to my boss--I went to the vice president, actually--and told them how I felt about it. And so he said, Well, all right, why don't you just, you know, we'll fill in behind you and get somebody else to take over your laboratory. And you just become a director without portfolio, so to speak. I don't know whether we called it initially a consultant, or not, but eventually we called it a consultant--I was considered a consultant. But the idea was that I would not have to worry about any of these things, and I could do what I wanted. Of course I had no help, I was just on my own.

But also about that time I, you know, I had been always interested in what other people were doing in electronic switching. And of course I started the International Switching Symposium, as I mentioned before, so I kept going to those as much as I could. Of course during this period when I was busy on this administrative job, I couldn't get much time to go to the meetings of that. But now I could go to the meetings and mix with my friends from other countries that had been doing the same kinds of things I had when electronic switching started. And so I started doing that kind of thing. And of course I had been keeping up to date with what was going on around the world in switching and around the U.S., too, for that matter. And more and more, you know, people kept relying on me as the source of information on this. There wasn't anybody else at Bell Labs. In fact, it was unusual for Bell Labs to worry about what other people were doing. They usually felt, Well, we were the leaders; we're not going to worry about them. Especially our problems in the U.S. are different than problems in other countries, so why worry about what they're going? But I didn't feel that way because there was a lot of new technology coming out of these other places. And a lot of people were having experience even copying our technology, and I was interested to see what they were doing with it. So it was a real opportunity, and in part it was because I was now without portfolio and also partly because I had this great interest in what was going on in electronic switching. And so it was a great opportunity, and I was able then to start working on new ideas. And I had a lot of new things I worked on. And of course the most important one in that era was the-- Oh, by the way, I was now free to look at what other people were doing around Bell Laboratories. You know, no longer confined to my day-to-day worry about

this, that and the other things in connection with our own projects. But I had a much broader view of what was going on in Bell Laboratories and frequently called upon to use that--give talks and things. But the main idea was that I knew that the people were starting to think about this cellular concept on mobile radio. I realized when I saw the work they were doing, you know, on the radio waves, that sooner or later it would involve some switching. So I started working with some of those people and saying, you know, what I thought it should have for switching. Wrote memos and so forth on it. And went to their meetings which I was free to do. I was free to go to almost any kind of meeting that was going on at Bell Labs, which was sort of unusual in itself. And I, as a result, came up with the first ideas as to how you'd build the switching part of the cellular mobile system. And eventually I got the first basic patent on that, which I think was issued in 1972, or something like that. At any rate, so that was just one of the projects that I was involved in. But, as I say, people kept coming to me all the time with problems --you know, interesting things to look at, technical things. And also to find out what other people were doing in the field of electronic switching.

ASPRAY: Did you have a patron in the company that allowed you to do this?

JOEL: Well, my vice president at that time. His name was W.H.C.--William H. C. -- Higgins. He had taken over the vice presidency of this electronic switching area. In fact, the whole area. He had been at just about the time I left electronic switching, he became the Executive Director of Electronic Switching. And during the time that I was working on TSPS and all those other things as the director of that laboratory, he was somewhere in there promoted to vice president of all of the switching work. And so I didn't know him that well. He had come in from

military work. He was not a switching man. But he had looked through all the earlier basic problems we'd had with electronic switching. And by the way, I was able to spend time as a gadfly [Chuckling] and tell the electronic switching people what I thought they ought to do with some of their problems that they were having and how they ought to solve them. I don't know as they listened to me very much, but this was one of the advantages I had now. I had really a great job, I thought. Anyway, he sort of protected me and allowed me to do all this.

ASPRAY: Were there other people by this time in the company who had this kind of position?

JOEL: No. In fact, even for the remaining time that I was at Bell Labs, which was I guess 17 years, 16 years, something like that, I don't think anybody at that level was a consultant. There were supervisors that I know of who were sort of put on the shelf as consultants. But they didn't operate the same as I did. I mean, I was really an operator in some respects, [Chuckling] you know. I took advantage of things. But that was what I liked to do. I liked to work that way, and I like to be free to look into all kinds of things that I thought I had some ideas on. And sometimes they were good, and most of the time they were bad. But at least, you know, that was great. I got some patents out of some of those things.

ASPRAY: What were some of the other positive results?

JOEL: Oh, I used to tell people how I thought they ought to design processes for electronic switching systems. Well, there were other projects. I remember one project in particular. I had it in my craw that you shouldn't, when somebody makes a call to this intercept system and they get a new number, that their call-- we ought to give them the option of letting the call go right through automatically

to the new number. Of course in some cases people wouldn't want to because it's a toll call, you know, and they don't want to make the toll call that's involved. That was one of the things that-- I also--what was the other one? Well, the directory assistance, same thing. When you looked up things in directory, I always wanted to say, Well, look, after they got the number and we've got the number off the computer and you'd announced it to the customer, why not give the customer the option of letting the call go to that number that they looked up. Of course they may not in all cases, but in many cases that's just what they want. Right now--just within the last two years or so--that sort of service is starting to be introduced in some places. It's taken all that time. But anyway, these are the kind of ideas that I liked to play around with.

ASPRAY: I see.

JOEL: Oh, I worked on-- At that time, for example, signaling was the big thing. People were very active in trials around the world, as Bell Labs was, on what is known as common channel signaling, where you no longer send signals over the individual paths over which you set up connections. But you set up separate signaling networks and pass the signals about the telephone calls over data links. And that became--has become--the primary way of doing signaling. But at that time it was for international purposes primarily. And we had people who were very active in studying this for eventual introduction into the AT&T network, which they started in 1976 to do. And so I was always interested in the signaling and trying to get ideas as to how you might improve this process. I don't know that I can point to any contribution I ever made there--inventive contribution--but I was always interested in that type of thing. But then we come to another phase. I was having

my fun for four or five years doing this sort of thing, and all of a sudden AT&T gets hit with an investigation by the FCC.

ASPRAY: What year was this?

JOEL: I believe it was 1971 or '72. It took place over Christmas. A very famous situation, where I guess the FCC said they weren't going to do anything, and Congress was out of session. And when they came back they raised hell because the FCC did not pursue this investigation, and they had to change their mind. I forget exactly; it was some kind of situation like that. But eventually FCC ordered a full-scale investigation of Bell System practices and the monopoly. The same kinds of things that had been brought up in 1938 and 1953, each of which had resulted in a consent decree. So now they were going to go after us again and say, you know, aren't you impeding progress and this, that and the other thing. And it turned out that they picked on electronic switching as one of their big issues, you know. You took too long to develop the No. 1 ESS. You spent too much money. And so forth and so on. And so it was natural when they look around, they say, Oh, here's Amos. He's not doing anything. We're going to [Chuckling] put him to work worrying about what has to be done to work with the lawyers and the other people involved in this process. You know, I'm not the only one, but at least I know where all the bodies were hidden. I'd worked on all this stuff. [Chuckling] And so it was quite natural that I was chosen to be very active in this area. Not 100 percent of my time, but a large percentage of my time. And in fact it got to the point where within a few months that I recognized I needed a lot of help. So they started assigning some people to me again. But just a limited number of people.

At any rate-- And I worked-- Of course I got help from all the various organizations. So we pursued all the various matters that they kept bringing up. They brought up a lot of switching items, some of which dealt with electromechanical switching. They didn't all deal with electronics. And this went on for several years--I guess until '75, '76, something like that. And then that turned into the anti-trust case by the Justice Department. So therefore I just had to continue working on all their accusations, which were almost the reverse. [Chuckling] Why didn't you introduce digital switching faster? And all that sort of thing. Why did you have to introduce all this space-division switching so early? Anyway, I was involved in it again in helping get information together for that, although it was much broader--the technology was broader and a lot of things. But there was still a big section of switching. It's been claimed by some people, if I hadn't worked on these two things over the last ten years or more of my career, think how many more patents I might have gotten. Which is probably true because I did spend a good deal of time on this. And I still have lots of ideas that I wished I could have pursued and didn't have the time to. At any rate I still kept up my interest in evaluating what was going on in switching around the world. In fact, even more so now because sometimes we contrasted what we did with what other people did in things of that kind. And I put out some books, as I think I said. I put out two books in the IEEE Press Book Series about what people were doing around the world in electronic switching.

So that was the main thrust of my career at the end of my career, you might say, until I retired in 1983, which was just at the time they announced that AT&T had agreed to divest themselves of the Bell operating companies beginning in 1984.

Now I retired in March of 1983. So I retired before divestiture took place. But it had been announced in January. That was when the agreement had been reached, in January of 1983. So I got out just about the time the old Bell System monopoly was broken up.

ASPRAY: Was the decision yours to leave at that time? And did it have to do with divestiture?

JOEL: No, no, no.

ASPRAY: This was standard practice?

JOEL: Yeah, it was standard practice. In 1983 I was 65 years old. And so therefore their practice was that people at director level or higher had to retire at age 65, and they could require them to retire at age 65 under the then-existing laws about age discrimination on retirement and so forth. Presumably you were supposed to be a policy-maker. Certainly the kind of job I had, I was no policy-maker by any means. In other words, if I had been a regular director of a laboratory, yes, maybe I was. As an ordinary director sitting off on the side as a consultant, I certainly was not a policy-maker. But it didn't make much difference because I had arranged at that time when I retired to come back as a consultant. By the way, one of the things that I got involved in all through this period was that since I had this broad knowledge about switching and, you know, knew all that was going on in the switching area, I was frequently asked by the vice president to coordinate this, that and the other project. [Chuckling] Because I was the only one that was in a position to be able to go down to this place and that place and the other place and say, you know, Get me all this kind of information I can put together so that the vice president can give a speech somewhere or something of that kind. So I

did a lot of that kind of thing--speech writing and helping them put talks together and put visuals together. You know, it takes a lot of reference sometimes. And I had a little bit of help on that. I had a couple of people working for me all during that period. But that was another responsibility that came out of this. It was handy for the higher-level people to have somebody like me that they could call upon that knew the business, that knew what switching was all about. Especially when they didn't know themselves. I mean, they didn't come up in the switching area. At least Higgins was the only one that had. Later, after Higgins, we had a fellow by name of [Don] Fleckenstein who was the vice president. Now he started back with us in Whippany. In fact, he took over that remote concentrator job that I worked on back there. So that he was one of our own, you might say. One of the first ones that became vice president who was one of our own. But even he needed help once in a while, and I could give it to him. Anyway, I continued along with this. As I say, on the anti-trust suit, I worked up right to the very end, and that was announced just about the time I retired.

ASPRAY: After you retired, was there somebody in the company that had the same kind of knowledge that you had who could fill some of those functions that you filled?

JOEL: Not in the same way. The people that I had reporting to me--even when I was still a consultant--they continued on. One of them continued to help the vice president put together stuff. He was the kind of person who, in effect, I'd trained so that he could do some of this kind of thing. He knew where the sources were that I used to use and all that. And by the way, I put out, starting in 1976 I think it was, I started to put out a book that was very useful within the company about all the switching systems around the world: what they were (including our own, but all

the others). It was called Non-Bell Switching Breeds. The idea was to put on a page or two all about all the things you could know about the various products that other companies were making. Of course at that time they weren't considered competitors. In fact, we had patent licensing agreements with most of them. And we had access to information from them. It was very good, and I used to keep track of all this, put it all together from a technical point of view. Not only technical but also deployment--you know, how many systems they had put out and where the first ones were and, you know, all that kind of stuff. And people found this book very, very useful, and it was distributed widely in the company. And I kept reissuing that book up until the very day I retired, that last edition I put out. And that was all on the database I built up over time. It was very useful. And these other people who worked with me continued to use that and keep it up to date. Until divestiture came. Then it was a whole different situation.

ASPRAY: Tell me about your career after retirement.

JOEL: Oh, after retirement? Well, after I retired, as I say, the first two years, AT&T felt that I could still be of considerable use to them in various respects, particularly since I knew a lot about the international situation. And about a year or two [earlier?] they had started AT&T International, a new company, who were looking abroad to see what the business opportunities were going to be. Part of this came out of divestiture; part of it was foresightedness, you might say, what they felt the need to do. In fact, we had already started working on projects for Puerto Rico and Iran and a number of other projects before divestiture. So they had started the company AT&T International, which looked at the whole international situation. And they felt I could be of some help to them, so I was

half paid for by them and half paid for by Bell Laboratories. And they had a commitment that they had to pay me for a certain number of days a year. For the most part the people at AT&T International really didn't know how to use my talents. They weren't used to using professionals at that time. Of course Bell Labs there were opportunities, and I was doing a lot of work for Bell Labs because there were a lot of people who still knew me there--always knew me there--and continued to use my services as if I was still an employee. So I had no problem working with Bell Labs people. But the other people were sort of bean counters. I remember particularly one thing where I was asked to help in some foreign country. They were offering my services, but they wanted to get paid. And it would have been a good idea for them to have absorbed that. They'd have had to pay me anyway. To absorb that just as goodwill. But they hadn't learned that kind of thing yet. A lot to be learned about how to do international--work in the international field. So they expected this other telephone administration to pay me--pay for my services. Pay them. So they were a little bit inept at that. They had a lot of so-called bean counters there who were looking at every hour you spent. [Chuckling] So it didn't work out very well for that.

About two years later--in fact, two years later--we agreed to continue with a contract because there were a lot of people still looking for my services at Bell Labs, but it wasn't any longer an exclusive contract. And I started then offering my services to anybody that wanted them. There were a lot of opportunities. I didn't advertise or anything, but people heard about it. And I did work for IBM and for Continental Telephone. By that time Bell core had been established for the seven Bell operating companies. Also down the line a little ways, it got to the

point where some of the telephone companies were working on ideas that they didn't want Bell core to know about it. [Chuckling] And they were looking for somebody like myself to help them on that and evaluate what they were doing and things of that kind. Or where they would hire outsiders to do development work for them, and they wanted somebody to check on the development they were doing with these. And then they didn't want Bell core to know about it at that time. So there was some of that. And I did work at Bell core--primarily teaching. Now teaching is something-- As you remember, I started the training of switching people way back. So I always liked to lecture, and I always had various ideas about courses. During the early 1970s when I was, you know, a consultant, I set up a course called "What's New in Switching?" that was very popular. I used to have guests come in from all the various organizations that I knew and tell about what they were doing to a class, and we'd keep it up to date. It was very, very well received. But what we were doing was primarily within Bell Laboratories. In fact, I also started at that time a thing that's become very popular and continues to this day, which is known as the Holmdel Technical Talks. One noontime every month the auditorium is open for people to come to hear a lecture on some latest technology thing that's going on in the company. And that still continues, but I started that back then. So there's been a lot of things of that kind going on.

ASPRAY: You told me off tape you'd also worked for some venture capital people?

JOEL: Well, both in-company and out-of-company, people would have new ideas, and they'd want them evaluated, either by people wanting to put money into the project or the company itself, whether the company wanted to put money into some project. It's not unusual, apparently, in a lot of companies where groups go

off and come up with ideas, and then they try to sell it to their management. And their management says, Well, we don't know how to evaluate this, but we'll call in somebody who can. I did that several times, and I also worked for venture capitalists who had similar people coming to them with way-out ideas, usually, that they wanted to evaluate, to see whether it was worthwhile putting their money into. And I also did a lot of work--a lot, I mean, you know, five or six times--with people, lawyers, law groups, come to me where they were involved in patent suits of various kinds. Usually patent suits. Although I guess there was one lawsuit that was not a patent lawsuit. But there were several lawsuits that I was involved in. The most memorable one was a case where the Home Shopping Network sued General Telephone, claiming that they didn't give them good telephone service and that's why their stock went down. And they couldn't tell their stockholders they were going to make so much money because the telephone service was poor. So I was deposed in that case, and I was going to help them out. And I worked on a number of different things like that.

And then I did teaching. Did some teaching at IBM; I did some teaching at Bellcore. Gave lectures around the country for various occasions. And around that time we started to give a course at the University of Maryland and UCLA. This course was put together by a man by the name of Jack McDonald who, I guess, just before that worked for Continental Tel as a-- Well, worked for a company called Vidar, which was later bought up by Continental Tel. But he started the idea of having a course on digital switching. And he asked if I would join him and do some of the teaching. And he would do some, and then we got some other people. So there were about five of us started teaching this course at these two

universities. And from the notes of that course we put out a book--he put out a book of which he's the editor. We've gone through now--We have a second edition that came out a couple of years ago. So we taught that course quite often in quite a number of places--oh, at least ten times. So I was busy with that. Then I gave individual lectures at various places around the country--companies that had a need to hear what was switching all about, just wanted to know the fundamentals or people wanted to know about the latest technologies in switching. Whatever it was that they wanted to know something about switching, I'd be happy to be able to talk about it. And the same thing in Bellcore. They had me training in switching that they didn't want to use their own people for. And in fact I did some work for one company who had a contract with Bellcore. So at the same time I was teaching at Bellcore, I was also working for another company that was also teaching in Bellcore.

So I did all kinds of work during this nine years since I retired. I've been doing a lot of things. And then around this time I started writing a book with a Frenchman by the name of Robert Chapuis, which we finally called the book-- He had written a book called A Hundred Years of Switching, mostly about electromechanical switching. He was a very good researcher, and he did an awful lot of work. He worked for the CCITT, which is the international body of telephone and telegraph. So he'd done a lot of research on his own and written a history of electromechanical switching which he called A Hundred Years of Switching, and manual switching--not very much on that. He asked me to write the preface of the book, which I did. I'm sure if I'd written the book there were a lot of other things I'd like to have put in it, but unfortunately I wasn't the author of that. But he then

came up with the idea that maybe he and I should write a book together about the history of electronic switching. Which we did. We started about 1983, just about the time I retired, and it took us a long time to get it out. Let me say that if you ever work with a foreign person as a co-author, both of you should have fax machines. He didn't have a fax machine. We did trade diskettes back and forth all the time. Well, I could have done that with him. So at any rate, we finally published this book called Electronics, Computers and Telephone Switching that was put out by North Haarlem Elsevier in 1990. So that was another effort that I went through during this nine-year period since I've retired.

Let's see, where does that bring me? Well, I continue to this day-- Oh, just recently, within the last year or so, I put together a brand new course on switching which I call "Switching and Networks in Perspective," which tries to look ahead. There's a lot of new things going on in switching, like photonic switching. And the things that are popular right now are frame relaying and SMDS, which is Switched Multi--Mega-Bit--Digital Service. There are many things going on, you know, broadband ISDN, ISDN itself. All of which sort of portend something about what the future might be and taking my experience over a long time, trying to project that as to what this means in terms of the future. So I've been putting a course together, and I did that last year and taught it three times. I'm looking forward to revising it right now and doing it again this year. But combining so much nowadays--particularly in the United States and eventually around the world--involves not just the technology itself. You see, through my career I was able whatever we wanted to do with the technology we could do it. We just had to prove to our bosses it was the best thing for the whole Bell System. And in most

cases it was, and we could make money at it. It was just a question: Can this project--spending this much development money--make more money for the Bell System than some other project? But they were all good projects to work on, and they were decisions that we could make ourselves. Now, of course, it's so much political and so much competition and other factors involved that it's no longer your own-- You know, your decision is influenced by so many outside factors. So I'm trying to get that into the course, to say, you know, What is the future of photonic switching? It's a wonderful thing from a technology point of view, and I can have a lot of fun describing all the various things going on in photonic switching. And there are great strides being made, and I can see lots of other things that people might eventually come up with. But the question is, you know, how does this fit into the future? What might it portend? So that's the kind of course that I'm trying to put together. One that brings all these other factors in. Because it's no longer a world where just the technology and the decisions about the technology you can make yourself. And that's gone very, very well. I'm very pleased with the way that's been accepted. And the people running the course say they keep getting calls every day and want to know when it's going to be given again. [Chuckling]

ASPRAY: That's nice.

JOEL: Yeah.

ASPRAY: Let me go to one short topic after another, and I'll ask you to comment. We'll go as long or as short as you want to define these things.

JOEL: No, I don't care. Sure.

ASPRAY: One of the things that I'm keen on asking you about is your affiliation with IEEE and its predecessors--IRE, I guess, in your case probably.

JOEL: No, AIEE.

ASPRAY: You were in AIEE?

JOEL: Yeah, I was never in IRE. IRE was primarily radio people.

ASPRAY: Right, okay. Can you tell me about your membership, your activity? I know you were president of--

JOEL: Well, I don't know whether I mentioned it before, but I think I did. When I went to college and I learned about transmission and learned, you know, starting with things like Heavyside and Maxwell and going all through more practical things--I can still remember the book, K.S. Johnson on telephone transmission--and so forth, all these things in transmission had been reduced to an engineering basis. They weren't science, you might say. I guess Maxwell and Heaviside were sort of science, but there was some mathematical basis on which you could evaluate things. You could predict, you could set limits, you could do all kinds of things. And I felt, you know, and all the other things I was learning in college, all were in that boat. And here switching was not. And I always said, Gosh, that's what we need. We need some way of putting things into switching where we can measure switching. Measure its complexity, measure something about it. Measure the combinatorics that are involved. And that was always in the back of my head: How can we do something like that? And I really am ashamed to say that although, you know, I've worked a lifetime in switching and I believe I have a lot of training--I'm sure there are people with even more skills than I have in mathematics and other things could perhaps have done more--I still don't see what

I'd like to see in switching. And that is something other than a cost evaluation of something as the only way you can compare switching systems. I mean, we can go off and write a lot of prose about it--and I do as part of my evaluation of profits for vendors and things--to say this switching system is better than that one on my judgment for this, that and the other reason. But that doesn't mean a darned thing. Wouldn't it be nice if we had some mathematical way of saying that kind of a design is better than this kind of a design. But we're not in that boat. And I've always, through my whole career, wanted to do that.

Well, I certainly felt that we should do something professionally as much as we could in the switching area. I was always--ever since I was a kid--discouraged by the fact that you couldn't find information about switching. There was very little--places that you could look it up. As you know, I went and looked at patents. I got a lot of bum steers there, but I learned a helluva lot about switching. The point is that the few papers that I said that were written on switching were written by the bosses and one per system, and that was about it. And so, you know, you can put into one binder almost all the papers written up to 1938 on switching that appeared in AIEE Transactions. Or transactions of any other professional society. So I liked to see a change in that. And I therefore in about 1946, '47 when we started working on postwar developments--and there were a lot of them, lot of new switching developments going on--I was very much interested in seeing us start a-- Well, it wasn't called a society or professional group, but it was a committee at that time in switching as part of the communications area of AIEE. And we did, we started one. I won't say that I was the prime motivator. I was just one of the people who was excited about the possibility and went to all the

meetings, and eventually became chairman of the committee, of course, and so forth. But I was very much interested in that. And also I was always interested in professional activities, you know, because I thought that was a good way to exchange views on these kinds of things. And you especially needed it in switching because about the only way you could exchange views was to talk to other people working in the field.

ASPRAY: Were there people in many other companies in the U.S. besides AT&T?

JOEL: Yeah. Well, as I mentioned, I had this job offer from General Tel--what became General Tel. Automatic Electric. But yeah. Of course that changed over the years. There were always people involved in designing switching systems in these other manufacturing companies. And, you know, throughout the history of the telephone, there were very, very many companies manufacturing switchboards and, later, automatic systems. Many of them fell by the wayside, but there were lots and lots of patents and lots and lots of ideas as to how to build a better switching system. And a few survived. Many survived, actually. If you look at the field right after World War II, there were 20 or 30 different varieties of switching systems out. They were being used mostly by the independent telephone companies. And so there were a lot of people--relatively. I don't say there were a lot, but there were people. In fact, I like to remember the phrase I used at the ISS in 1990 in Stockholm. I was asked to give one of the keynote opening addresses, and I did. And I just couldn't get over the fact that at that meeting there were 3500 people in this huge auditorium--in fact there was some overflow somewhere else with video monitors. But I started the talk off by saying, "You know, I just can't get over the size of this audience." I said, "When I started in switching--and I was

always anxious to talk to people in switching--there weren't this many people in the world interested in the subject." I'm sure of that. I mean, I can tell you all the manufacturers there were in the world at that time, and there were quite a number. But each one of them had, what, 10, 20, 30 people, maybe, designing switching systems. And even Bell Laboratories when I first started there, there weren't that many people designing switching systems. Today in the electronic switching area alone we have over two thousand people. So, you know, it's a big, big change. So, in any case, it's certainly changed, and there are certainly a lot more people interested in the subject because it's a very interesting subject to a lot of people. And we have managed to have generations of people trained, at least, in understanding logic circuits, you know, things of that kind, that are an outgrowth of switching. And, you know, have formal courses in universities on things like that. Unfortunately, we've had very, very little in the way of courses in switching itself. And that's just primarily because we can't get professors interested in the subject because we cannot measure it. And until we can put down complicated equations about some aspects of switching, we're not going to get very many professors interested in that sort of thing. If we do, they're mostly likely to come from industry into teaching. And occasionally now, a guy like Mischa Schwartz at Columbia--which is well-known in the teaching of communications--he worked with us on a couple of consulting jobs that I was involved with. He learned a lot about switching working on them. And so therefore he has recently in some books that he put out, you know, has a chapter in there about some switching system that he worked on--several switching systems he learned about. But I don't know how much he tells in his courses. He prefers to go back to talk about his

communications theory and networks because in networks you can put down a lot of traffic equations and things like that. Queuing and all of that. But you can't do it for switching, not at all. At any rate-- But over a whole lifetime, I have not seen the kind of--not professionalism--it's just not seeing the scientific-- Turned into a science or turned into a true engineering subject. Nevertheless, since the AIEE Switching Committee was formed in 1947, I think it was, I would say they have sponsored at meeting after meeting--and nowadays it's two or three meetings a year, like GlobeCom and ICC--they have sponsored three or four sessions at everyone of these on switching topics, and hundreds of papers have been given, and people have exchanged lots of viewpoints. Not only there, but in the committee meetings themselves. And we're making very, very slow progress. But some things have happened. We have the International Switching Symposium, which is very prestigious. For 1992 there's going to be a meeting in Yokohama this year--the end of October. For that meeting we've received 600 papers to date, and we only put on, like, 150 papers. So you can see there's a great demand of people wanting to give papers on switching. And this is strictly switching, this meeting.

ASPRAY: How important was--and how important is today--those AIEE or IEEE opportunities to communicate? You just mentioned a non-IEEE group.

JOEL: Yeah. Well, that meeting is a floating meeting. It runs around the world, and the local professional society puts it on. So we've had it here twice. We've had it here-- Well, we had it more than twice. We had the early ones when we first started here at Bell Laboratories. And then we had one in Cambridge, Massachusetts in 1972, and we had one in Phoenix, Arizona in 1987. So we've had two of them in

the U.S. But otherwise other professional societies around the world have run the others. So it's a floating thing. I think it's done a lot. I mean, I'm really amazed. I go to a committee meeting now, which is held as part of ICC or GlobeCom or both actually--they have a committee meeting at each one--where they discuss what the papers that they're going to put together are offering from the various companies for the future meetings. But nevertheless, you know, it's great to see these people. It's one of the only times you see these people getting together and talking about switching as such. Of course there are many standards meetings. That's a different body, and those people are all pushing various company viewpoints. Whereas here they're discussing, you know, What would be a good topic to hear about in switching? First. And then they decide what their company might be able to contribute. Whereas in these standards things it's more, you know, What is our company's position with respect to the standards that are being discussed here?

ASPRAY: I see. Did you get actively involved in standards?

JOEL: No. My only activity related to that has to do with nomenclature. For years I was a bug on nomenclature, saying, you know, we ought to define things better in switching. We ought to give good names to things. We have a lot of very poor names that are given to things in switching. If you let people go free, they come up with some of the worst things that really don't adequately describe. So I've tried to change that, and we did have a very strong Nomenclature Committee in IEEE and in AIEE before it, trying to bring about industry names for things. It was somewhat successful. And I also was head of the Nomenclature Committee

in Bell Laboratories. [Chuckling] So I had it both ways. In any case, that's another aspect of the kind of thing.

By the way, in addition to ISS, which is this floating international meeting on switching, there's others that have sprung up. One on software for electronic switching systems. Separate meeting just for that alone. And that's held, like, every three years in various places around the world. And there's the International Traffic Congress which started in the 1950s which is basically switching. Most of the traffic you can have is really for the switching systems. And that's grown to be very, very prestigious. Almost more prestigious than ISS because it's highly academic. There's a lot of professors and people like that who are involved in that. So at any rate, my feeling is that I've always hoped that this could become a real academic-type of science kind of thing, and it hasn't. But there's been progress in, you know, in things that have been very pleasing. It has gotten it out of the mystique, you might say. Switching is no longer a mystery. There are plenty of people around the world, who know what switching's about, and the principles are well pronounced and people understand them. Most of them. I mean, I could tell--ask--a lot of people today what's the difference between distributor-controlled and distributed switching, and they wouldn't have any idea. To them distributed is distributed, and that's the end of it. But I make a distinction between these things, you know, there's fine lines. But as far as the general knowledge, around the world there's certainly a lot of people who know what the heck's going on in switching.

And you asked about the other companies. That's been one of the things that's been very interesting because all the companies around the world have always

done as much as they can to interchange information--not from a patent-licensing point of view, but just to have meetings to learn what the other fellow's doing. I have never been disappointed in going into other companies, and I find that from the executives all the way down, the people can tell you about what's going on in switching--in the world, I mean, not just their own company. Bell Labs has been one of the few places where it's the other way. And it's been very, very hard, and we're just only succeeding in the last few years to get the executives and other people so that they're at least somewhat knowledgeable in what the competition is doing and what they're about. And also the engineers. The engineers in these other companies all know--they can all tell you about--AT&T's No. 5 ESS. They can all tell you what it is and how it works. But go into AT&T's 2,000 people I mentioned that are working on electronic switching and ask how many of those can tell you about the IT&T 1240 system. Very, very few. There are more today than there was when I retired. It's changed a lot, and it's changing more and more every day. But it's taken an awful lot to do that. But this was always true. I mean, if you go back to before electronic switching started, you could find lots of people who could tell you about how the No. 5 crossbar worked in Automatic Electric Company. But, well, of course, we didn't have to look too much at the step-by-step equipment that they turned out, though. I guess we didn't have to worry about it. But go over and find out how many people in the United States in 1947 could tell you about the new German system that was then just starting to be developed because they lost everything during the war. Very few people. But their people knew what we were doing. And the Swedes knew what the Germans were doing and so forth.

ASPRAY: One last question about IEEE affiliation: I noticed that you were the editor of IEEE Frontiers and Communications series. Can you tell me about that?

JOEL: [Chuckling] Yeah. That's sort of a fiasco. [Chuckling] We started out about six years ago--five, six years ago--in the Communications Society to put out a series of books. We had a very successful publication called Selected Areas of Telecommunications, JSAC, Journal on Selected Areas of Communications. And it's a very, very good publication. Each issue has editors who zero in on a particular topic, either invite papers or get papers together, and it's been very successful. The thought was that many of these issues are very--it would be a good idea if we could archive them and really have them put out in nice form, like a book or something. And so that was the basic idea for this Frontiers series. Could we eventually get to the point where the editors of these JSAC issues could say, Well, we know we're going to put out a book eventually on this subject, and so after we get the journal out then we'll concentrate on getting the book out? Well, so far it's been very hard to get anybody interested in this sort of thing. We've put out about three books, I think it is. It's been very discouraging to try to get the editors interested right from the beginning. I mean, they're so busy just getting their papers together and making sure they meet their deadlines, that they could care less about what's going to happen to it after it gets out. So it hasn't really worked out. And also you question, if people really want these publications, they have them, they keep them. They don't have to have them with hard-binding and so forth. The idea was that we'd write bridging material, you know, and do a much better job perhaps in bringing this stuff together than was done in the JSAC issues, but it didn't work out that way. And so right now I sort

of consider that a sort of defunct activity. Unless somebody comes up with some better ideas.

ASPRAY: Okay.

JOEL: I wanted to mention one other thing while we're talking about--

ASPRAY: Sure.

JOEL: --IEEE activities. I not only was very active in the Switching Committee from the standpoint of technical things, but I was also interested locally in what was happening with professional people in the New York area where I was located for a good number of years. And so I became active in the New York section. That was interesting because there we had a cross section of engineers in all kinds of disciplines, not just communications. And the meetings I had been going to--AIEE meetings--were all communications meetings. But here I had a chance to mix with power engineers and lighting engineers and all kinds of others. It was very good fun, and we met a lot of interesting people and got to know them over the years. And eventually became chairman of the New York section. So I'm both a chairman of the New York section and eventually I became president of the Communications Society. I guess the second president. We changed over from what had been the group to a society. At any rate, so I'm both a section president--chairman--as well as a society president. And I still go-- The New York section still has a meeting every year where they honor their fellows, and I still like to go to their meetings. I still see a lot of friends there. So that's one of the advantages of professional work.

ASPRAY: Can you tell me what your duties were as president of the Communications Society? What kinds of issues came up? What kind of direction did you take it in?

JOEL: Well, the Communications Society was quite new when I took it over. Of course I had been going through the ranks, you know, in earlier jobs in what was then the Communications Group, I guess it was called. And so I had been in charge of technical activities and meetings and conferences. Most of this work we were doing in those days in the Society was to get our bylaws straightened out, and getting our manuals--various kinds of manuals of practice, and things of that kind. Getting our-- We've always had problems with publications. There's always been the question of how many pages of publications can you put out within your budget? And whether or not--to what extent--the authors and their affiliations should pay for some of this? And academic versus industry papers, problems of that kind. Lot of budget problems. And also the direction. We spent a lot of time--today as then--looking at, What technology should we be setting up committees for and looking at to stimulate conference papers and sessions in various disciplines? Or even should we have special workshops and so forth? During the early period of the Communications Society we were setting up these procedures for working this out, having workshops and how we'd pay for them, and that kind of thing. Of course for a long time we got bogged down with so many things at our Board of Governors meetings, which were held like twice a year, that--and it's a big committee with so many different people involved--that it took so long to get through the meetings that eventually we, right from the time I was president, we set up an Operating Committee which met more often. A small group where we could discuss policy things and then bring them before the Board of Governors. Let's see, what else did we do? I guess that's all. Even today they've

streamlined the Board of Governors. They have to. There are so many issues; there are so many things that have to brought up on the agenda.

ASPRAY: As president do you feel that you left your mark in some way or other?

JOEL: Not particularly. No, I don't think anybody remembers anything I did as president. [Chuckling] I guess you remember the first president, maybe, more than anybody else--of the Society--because that was a big change. And that was Dick Kirby. Dick Kirby went on to become the head of CCIR in Switzerland. Good friend of mine. Well, you don't remember-- I mean, I know who all the presidents were in there, but I don't know that I can say that each one of them--[Chuckling]--what they contributed.

ASPRAY: Okay. Let me turn to a different question then. Throughout your career at Bell Labs, do you feel that there was some sort of engineering style that characterized your personal work? Historians are interested today in understanding how people approach and attack problems. What would you say your engineering style was?

JOEL: I think, as I mentioned earlier, I seem to be motivated--I've always been motivated--by wanting to invent, wanting to create something new. I always wanted to do something different. I've never been satisfied, you know-- Somebody would describe something to me, and I'd say, Well, would I do it that way? Or how would I do it? That's the way I like to--used to like to--think about things. [Chuckling] It would grate on some people, you know, because they'd say, That's not my responsibility. Frequently you got into arguments about that, you know. Somebody's working on some new processor for an electronic switching system, and I'd say, Well, I think you ought to do this, that and the other thing. And, It's none of your business, it's mine. This is my project; I'll do it the way I

want to do it. But, you know, that was always my approach. I always tried to say, How would I do it? And I liked to think that I'm sort of an inventor. Well, I guess I can be considered an inventor. I got over 70 patents so I certainly must be an inventor. But, you know, that's my first thought.

ASPRAY: Did you have a stock of tools that you used over and over again?

JOEL: No, I had no tools. I had no one approach or anything that would kick me off. Ideas come to you in all different ways and different conditions. But in switching it's usually combinations of things that trigger you off. You think about--and I think this is why it's so important for people to know about history--because sometimes just thinking about the history of something, you say, Hey, he did that way back, you know, a century ago maybe--or something like that. Using that with modern technology may not be a bad idea today. But I think history's a very important thing. Of course, as you know, having written about a lot of history myself, I really feel history is important. And I stress that even in my classes that people should always look back. Because it's not really re-inventing the wheel that you worry about, but people do tend to get certain things from re-looking at old ideas with new technology. It can make a big difference. In other words, it may not just be the wheel, but, you know, getting a rubber tire on it and a few of those things that make it really worthwhile to have a wheel. [Chuckling]

ASPRAY: Well, maybe this is the point to ask you about Volume 3 in the Technical History Series. We've hardly touched on that at all. How did you get involved in that?

JOEL: Oh. Yes, that's right, we didn't talk about that. Well, Bell Laboratories with the approach of 1976, which was the centenary of the telephone, decided that a good way for us to recognize this centenary would be to put out a set of books that

would talk about the history of telecommunications as seen by Bell Laboratories and AT&T--but primarily Bell Laboratories. And so they commissioned the idea of a set of books. It got off to a flying start by saying, Look, up to the time that Bell Laboratories was formed, which is 1925--that's just about fifty years--and so therefore we'll knock off the first fifty years by putting out one volume on the first fifty years. And hire or get one of our people to spend full time at this who is well-known as a writer and so forth. And so they got Mort Fagan--I don't know if you know Mort.

ASPRAY: I don't him.

JOEL: Anyway, Mort Fagan to write this book on the first fifty years. And he wrote, so-called, The Early Days. And he tried to cover all the period before then--with the help of people around the Laboratories--and I spent a great deal of time with him on what I thought was important in the switching part. And he's got most of that in there. I think he went too far, myself, in connection with some of the panel stuff because it really was beyond 1925. He and I had a lot of disagreement on that. But nevertheless, that was it. And so then they planned the series from there on to be really the next fifty years that took place between 1925 and 1976. And so they broke down the work more or less along the disciplines that are common to the telephone plan. The transmission, the switching. And they recognized very early on that, you know, the Bell Labs had contributed a great deal to national goals and things like that. Such things like the work of BellCom, which was the company that they set up to help with the space program. With Sam Deere [sic] which they helped with the nuclear armaments. And many other things that we worked on during World War II. You know, the gun director and the various

radar systems and all kinds of things. And going back, radio altimeters. You know, a lot of things. And I guess even I don't know how much we have in that volume, but in the 'twenties--from 1925 on--we have the period of the phonograph records and the sound on film, all of which Bell Labs was a big contributor and first to do most of that stuff. Even early television--not with the tube but with a revolving disc. [Chuckling]

At any rate, the point is that they broke down the work into these volumes. I don't know how many times, though, this was revised. But it was certainly recognized that one volume would have to be switching, and the obvious person to do that--to at least head up the project--would be myself. Because first of all I was already off onto the side, you know, and doing this kind of thing for the vice presidents and for myself and so forth. So it was very natural to do it. And also, I had the background. I had worked-- I knew all these people; I knew all the patents. In fact, I still-- That's one of the things that interests me. I still remember people back-- First of all, their names when I first saw them on patents. And then when I first met then at Bell Laboratories starting in 1940. And that was sort of a thrill in the sense that first of all, even to think of them today, to think I knew those people. There aren't very many people around who can do that in their professions. To say, you know, I remember the people who worked before me a couple of generations ago. But I remember these people. I remember them by name, and I remember what they contributed. At any rate, so it was sort of natural that I would do this volume, and I did. Of course I had a lot of help. I had people who would write some of this stuff in the volume, some of the chapters. But certainly I put together the whole idea, how to organize it and whatnot. So it was

the third volume in the series. The transmission volume came out quite late. Again, because the guy they assigned to that had been an executive director, but then he retired. So when he retired he could do it, but he couldn't do that until he retired about the same time I did. So that volume got out a lot later. Also, I had a lot of struggle in that book because I didn't want to stop at 1976. 'Seventy-six was a good stopping point from several standpoints at Bell Laboratories. We finally got our first time-division digital switch in service in Chicago--the No. 4 ESS. And we started with our common channel signaling, which is the basis of the signaling network. And we had a lot of other new products coming on stream about that time. By the time I got the volume out, which was 1983, I believe, there were a lot of things that had happened in the meantime in those six years. So there's sprinklings of things in there that are beyond 1976, which I was glad I was able to get in. But I wasn't able to put in all the things I wanted to put in.

I have written an epilogue, but I never published it. I haven't written it completely. I've really outlined an epilogue. I've got a lot of stuff up to divestiture--up to '83. Things I didn't get in the volume that I-- You know, a lot of details, which probably nobody's interested in. But I would like to have written that and now write beyond the divestiture what's happened. The technology people are after me for this course. Want to know what I'm going to do about that--if I'm going to write a book on that. I don't know. I don't think so because the stuff I put in this course that I'm working on now changes from day to day. I mean, right now the FCC just put out a document last year on what they think should be the rules for Caller I.D. You know, where you get the number of the people calling you. Well, you've got 30 states that have approved it, and, I don't

know, 18 states that don't want to have anything to do with it. So you don't know what the future of this thing's going to be. It's going to be a struggle between the states and the FCC for a long time. So you can't say what the future of this kind of thing is going to be. So I don't know whether I'm going to write a book on that or not. I might give this course outside of AT&T. My contract allows me to do that, provided I take out of the course those things that are proprietary. There isn't much anyhow that's proprietary.

ASPRAY: How was Volume 3 received?

JOEL: I never got very much feedback from it. You know, it was looked upon, well, you know, this is the next volume in the series. I really never got any comments on Volume 3. Nobody's ever walked up to me and said, Hey, that was a great volume, and I enjoyed reading it, and so on. I don't think I've ever had anybody say that. I've had people ask me for copies, you know, that sort of thing. You know, it's just one more volume in the series. [Chuckling]

ASPRAY: Well, I found it very helpful.

JOEL: Is that right?

ASPRAY: Yeah, yeah.

JOEL: In what respect?

ASPRAY: Oh, just to understand what was going on.

JOEL: See, I think maybe people look at the volume, and I think there may be too much detail in it. Which is my tendency in writing. I tend to put too much in. In fact, I bet you I had in there about those early crossbar switches going up to the Rockefeller differential analyzer. I don't know.

ASPRAY: I don't remember that part.

JOEL: I don't remember it either, but I wouldn't be surprised that kind of detail's in there. But there's a lot of-- No, I guess I wouldn't put that in because that wasn't strictly Bell System. But at any rate, there's a lot of that kind of detail in there. I remember there's a little paragraph and a picture even about the so-called "call announcer" which was used in the very early systems where we had to bridge calls between dial systems and manual systems which were still in big deployment throughout the metropolitan areas. It was not all of a sudden everything became dial systems in one day. So to go between one and the other, we eventually automated the announcing from the dial system side to the operator side--announcing the number to the operator. Rather than displaying it on a set of numbers in front of her. We did that for some time, and we developed it using the motion-picture technology. [Chuckling] We developed two things. Nowadays you do that on a half a chip or something. [Chuckling]

ASPRAY: All right. Okay. I know you've talked in telling me about your career about how you consciously chose to make an opportunity to continue your engineering work and not do management. But can you talk about the engineering versus management tension at the company? Did other people find it in their career path and so on?

JOEL: Well, you know, when I was at Bell Laboratories--during my career at Bell Laboratories--it was a benevolent company, very benevolent. There wasn't that much stress between the management and the members of technical staff. I take it that's what you mean by the engineers, the members of technical staff.

ASPRAY: No, that's not. I guess I asked the question incorrectly. I mean, a career path for a promising engineer is to do engineering for a while but then to go into management.

JOEL: If you want to make more money, that's what you had to do. Not a lot more money, but there was a difference.

ASPRAY: But in so many American companies today, you end up in management rather than doing engineering. Whereas supposedly the Japanese model has a parallel tier of engineers.

JOEL: Yeah, so does IBM to a lesser degree. The way I look at it is this: At Bell Laboratories everybody, including up to department heads and, I assume, beyond department heads (I was never privy to beyond that, but department heads reported to directors), everybody was rated on merit. And the idea was to try to make their salary commensurate with their merit. Because they didn't all start necessarily--they'd had different positions. So you had to go through a 90º from where they started to where they all come up with on the ladder somewhere. Now that process includes department heads and supervisors and so forth. Nowadays they even have a class known as Distinguished Members of Technical Staff, which is a first step in this business of trying to recognize people who will not become managers but who have made more in the way of contributions than their peers. And so I would say that they're all included in this. So people who naturally rise in this ladder, are naturally chosen to be promoted to higher jobs. That's inherent in the process, as I say, except for more recently when they went to this Distinguished Member of Technical Staff. So therefore for those who are considered better people, they all tended to be considered as the best suited for

management, which, you know, is not true. And people mostly around the world recognize that, but Bell Labs never really spent any effort trying to--you know, the top management at Bell Labs--never tried to spend a lot of effort trying to resolve this thing. I'm sure they all were aware of it, but their idea was that if somebody was good technically, he could become a good manager. We can train him to become a good manager. We can send him to charm school, they used to call it, and various things like that to make him a good manager. Which may or may not be true. It may not satisfy the individual either, which was in my case. But I don't know that there's any easy solution to this. Eventually the person who doesn't go into management doesn't get treated as well pay-wise--eventually. Because I never got another promotion after that. I spent 16 years as a consultant--director level. I assume I got, you know, the average director's pay for all that period. There was inflation all during that period so I got that, and I maybe got a little merit--I don't know. I'm sure, you know, if I'd gone on--if I'd stayed in the other job--I probably would have become an executive director, maybe a vice president. Who the heck knows? But at least I would have gotten perhaps better pay than I did staying just as a director-level person. I don't know. I assume that you always hit your head up against this. I don't think that there's any pure technical person that really gets paid commensurate with pure management people. Just as we said, it's my opinion, that's all it is. I don't know that it represents any policy of anybody. It's just natural that that's the way things work out.

ASPRAY: What can you tell me about your time as a manager of groups of technical people? Did you have a managing philosophy?

JOEL: No, I guess the closest I come to that is that you're looking for reflections of yourself, and therefore I tended to push and to compliment and so forth people who had new ideas, good ideas, things that I liked, you know, in the way of ideas, that sort of thing. Of course I had to recognize people who were good plodders, too. Who turned out a lot of work in a short time and so forth and met their schedules and all the other things. But I guess I tended to more aggrandize the kind of people who had better ideas.

ASPRAY: Was there a Labs' way of managing, in a sense? Were you inculcated with some sort of principles?

JOEL: Well, not exactly, no. No, I think-- First of all, one thing I like about Bell Labs--they've always done it, and I hope that it continues although they're lots of signs of its cracking now--and that is that there's a culture at Bell Laboratories which is very, very fine and much better than any company that I've known and visited, am familiar with, including the big ones like IBM. That is, there's a certain culture. First of all, there's a very great freedom of interchange of information. Now that's changed a lot since competition is involved now. There's competition within the company. And there's secrecy within the company and so forth because of this, and it's having an impact. But nevertheless, there's always been a great freedom of interchange of information. Nobody--You came over and asked somebody about his process or whatever, he'd say none of your business. You'd never run into that. You could always get people interested in talking to you about their jobs. So as a manager, you try to stimulate that culture. You wanted to see your people get the best continuing education, for example. So you did a lot to support the educational activities of the company by contributing teachers and things like

that. You wouldn't hesitate to do it because that's important. In fact, we recognize it. It was always part of the company philosophy: You hire the best people you can. Obviously in switching you're not going to go out and hire people who can sit down and design No. 5 ESS for you. So you're going to hire the best people you can. Their philosophy has always been at Bell Labs that by hiring the best, they will all eventually find a niche which will be--they'll be able to carry on in whatever discipline you put them--assign them--to. That they're not going to come into the company already with expertise in the things you need. And also that you have to continue to educate them while they're there because the technology changes so rapidly you can't just keep them the way they came from college and expect them to contribute over a career of 30 to 40 years or whatever. So therefore you must be able to continue their education. That's why I'm teaching right now, I guess. But nevertheless, that's part of the basic philosophy. Nowadays everybody has something of their career tied in with their education, by their supervision. And there are very few restrictions on that. So therefore, you know, there's been a philosophy at Bell Labs, and the managers sort of grow up with it and continue it.

ASPRAY: I was re-reading your Kyoto Prize Lecture this morning.

JOEL: Oh, yeah. [Chuckling] I take it most of the stuff I've been telling you is in agreement with what's in that.

ASPRAY: It's in agreement. There's a section in there labeled "Hype."

JOEL: Oh, yeah, yeah.

ASPRAY: Could you tell me about sort of product announcements and marketing and how they related to technical people?

JOEL: Oh, yeah. That's a favorite topic of mine. I just wrote a letter, in fact, to a friend of mine who wrote an article about that in some magazine called Network Management. What's happened is there's never been a period like this. Well, I shouldn't say never. The period about 1910 to 1918, in that era, maybe a little earlier, there was a period when the independent manufacturers of equipment--not Western Electric particularly, although I imagine they were guilty in their own way [Chuckling]; but the other manufacturers--were out there, you know, extolling the virtues of their latest manual switchboards. And if they happened to have an automatic one, they were doing the same for that. But even as I look back now on the stuff that was published, it wasn't that bad as it is now in terms of the fact that people--ad writers--are dishonest, don't want to know the facts--don't bother me with the facts. This is the way I want to tell the story because I want to sell this product, make our product look different than everybody else's product and so what.... Well, since the divestiture and the introduction of this great amount of competition in the selling of switching equipment, there's so much hype involved now. People struggle to say that they were the first with something or other in the field. And as a historian, I know damned well they weren't any more first than anybody else. That they've found some little niche that they want to say that made them first.

ASPRAY: Put enough qualifiers on anything, and you can be first.

JOEL: Exactly. Yeah. But the hype is very bad. It's unfortunate that even the engineers are succumbing to that, too. This thing I'm working on right now, this ATM, asynchronous transfer mode. I'm writing a IEEE--presently working editor of an IEEE Press book on it and doing a lot of research in this area. This is a technical

approach to broad-band ISDN which is being hyped. I mean, it's not just being sold on the merits. Very few people are getting up there and telling you what all the technical problems are. They're all out there telling you, Wouldn't it be nice if we had this thing? And what it's going to do for us. But nobody's telling you about all the problems. Very few people. And even there I found a case where a guy at Bell Laboratories submitted to his management a paper that was going to tell about these kinds of things, and he wasn't allowed to publish it. So, you know, there's all that kind of stuff going on in a big way now. This is not something new; I mean, this goes on in lots of other industries. But as a pioneer, you might say, in switching, I'm sort of disappointed to see it coming into switching. You know, I like to see switching take on the aura of a lot of professionalism and all the other stuff. And this is jumping past professionalism and going to the other extreme of stuff that has nothing to do with the technical aspects and the technical quality of something. So it's something that, I guess, comes with the territory nowadays. But the main thing I like to do when I talk about this in class is to make people aware that they should be looking for this. That they shouldn't just buy-- Just because the academicians and a lot of other people have put out 200 papers on ATM it's the answer to the future. That's what I'm worried about.

ASPRAY: Could you talk briefly about patents? What role did they play in the company for the technical staff? Were you encouraged to patent? What was the procedure for patenting?

JOEL: That's interesting. First of all, you know that the day you come to work at Bell Laboratories, they used to give you a dollar for all future patents. They don't even give you the dollar today, I understand. I don't know what it is you sign today.

But you sign something, they don't have to give you anything for signing it. But in my day--I don't know where the dollar is. I didn't save it. [Chuckling] I got so little pay I guess I had to spend it. I remember we used to talk--my wife and I--I wouldn't consider getting married unless I was making $150 a month or so. It took a long-- Uh, no--until I got on the monthly payroll. That's what it was. I wanted to get on the monthly payroll, and until I got on the monthly payroll I wasn't going to get married. And that was a struggle, but I finally got on the monthly payroll. Otherwise every week the guy would come and give you the money in an envelope. [Chuckling] But the point is that as far as patents go, I never felt in Bell Laboratories there was a real push on patents. I've seen other companies where the first thing you should think about is, I've got a new idea. How do I get a patent? Should I get a patent on it? And shouldn't I start pushing to get a patent? None of that goes on at Bell Laboratories. Never in my day, and I don't think even today. Until you get down to some critical time when you're putting out a product and you want to make sure you're adequately covered and you're not infringing and so forth and so on, the patent doesn't become an issue. As a director of a laboratory, you have to make sure that when you are to that point on a product that you certainly inform the Patent Department that you're going that far, that you're going ahead with this, and what is the patent situation? And they might write back and say, Well, who invented this thing you're putting out? What have you got to show for it? And so forth. But there's not a lot going on where everybody that's working is looking to say, Well, what can I get a patent on? The only time that happened--and that wasn't really with respect to patents--was when the transistor was invented. We all got together in the auditorium, and they said,

Go out and do what you can with this. But they didn't say, you know, Go out and get patents on it. They just said, Go out and see what you can do with this, to apply it to your discipline.

ASPRAY: Was the writing of patents-- Was it a way of getting credit within the company?

JOEL: Well, not really. I don't think so. You know, even today--First of all, there was always the problem of finding time to work with the Patent Department to help them get their patent out. That took time away from the job in some cases, and people were sometimes reluctant to do that, and you had to get after them. I don't think that patents played a big part in the evaluation of people. I mean, you couldn't point to one person and say, Well, he's got 25 patents and this guy has none. Therefore, you know, he ought to get a higher place on the merit ladder than somebody else or something. It was more down to what can the person as a whole do? Not just whether he can get patents. And I don't think in my career even, even though I had all these patents that very much ever came of all the patents that I've had. Until just recently I got this notice that AT&T's going to give me a Patent Recognition Award, whatever that is.

ASPRAY: Oh!

JOEL: Did I tell you about that?

ASPRAY: No.

JOEL: Oh, yeah. Starting this May, right after I get the IEEE Medal of Honor, the same week, I'm going to get an award from the Chairman of the Board of AT&T. I guess what they have done, starting last year, they pick out, like, 20 people that they want to give Patent Recognition Awards to. I don't know whether that zeroes in on a particular patent, which in my case I think it may be the cellular mobile

patent. Or whether it's for broadly all your patent contributions. Or whatnot. And I'm surprised because I didn't know they were going after retirees. I thought, you know, it was primarily for-- But I'm very pleasantly surprised by this. So there's going to be some kind of an awards ceremony, and the Chairman of the Board of AT&T is going to give out these plaques or something.

ASPRAY: Well, that's very nice. I have sitting in front of me what you sent me of resume, and it lists here some of the key patents in your opinion. I'd like to hand you that, and can you just talk about some of those. What the contribution was?

JOEL: Well, I think some way or another we've talked about most of these--I hope--because they're very important ones. I guess one of them we haven't. But to start off with the first one on here, is this AMA assembler computer. Now that's the first civilian job I worked on after the war. And as I've mentioned, it was a very large patent and a large system. It took all the records from the central office that were on tape in a random order and brought them together so that there was eventually put out by the computer the charges on the calls. And the calls were sorted by line number. So that it did all that in one fell swoop. So that's the assembler computer. And as I say, they built about 150 of those or something like that. then eventually the electronic computer technology took over. Traffic Service Position System, I think, is the one of all that has saved the Bell System the most money because that was a huge--at one time we had about 150, 200 of those installations in service around the Bell System. Today there's none left. We started in 1969. They reached their peak about the time I retired. And since I retired, they've come out with a newer system, using the latest, the No. 5 ESS, instead of the technology of No. 1 ESS. Called the Operator Position System. So

that's no longer of the importance that it was. By the way, associated with that system I got another patent that's listed here where I showed how you can remote the operators from the switch, from where the switch is. Originally, the TSPS was located between your local office, where you make your calls, and the first toll office, where the call goes into the toll network. The operators could be in various groups nearby that location. And I worked out a scheme so that we could concentrate the traffic from several of these and bring them hundreds of miles away. So one of the first installations I know of was in Texas, and I think that the traffic was coming from Dallas and Houston and places like that. But the operators were, like, 200 miles away, almost to the--I don't know--to the Oklahoma border or someplace. And we were able to do that. In fact, there was a lot of times when operators were no longer anywhere near where the traffic was. And that was because of this remote TSPS arrangement that I had. Then the dual-access trunks was the basic cellular mobile radio patent--cellular switching patent--that I had. In order to serve cellular calls, I developed this idea that dual-access trunks--the title is here--that it had the ability to switch you from cell to cell through these dual-access trunks.

We didn't talk about this particular one. I have a patent that was first used--I guess the office was first cut over in Phoenix in the early 1980s--but they put it eventually into all the TSPS's, so that not only could you normally dial a call and have it charged to you in the usual way on your bill every month, but you could also make a call from a coin telephone and that could be any kind of a call that required more than the initial deposit. So that you could make a call across the United States, it would cost a dollar and a half, and it would go through the TSPS

system, and the TSPS system would rate the call. And it would say, All right, this call is going to cost a dollar and a quarter for the first five minutes or whatever. And arrange so that automatically it told the customer how much to put in and counted the coins as they were being deposited. And did it all without any operator, so we didn't need any operators for the calls. Now this shows you how inventions happen. I invented a similar scheme with older technology back in 1946. I got a patent on it. At that time we were interested in calls to the suburbs out of New York--coin calls out of New York--and tried to find some way to automate them so these 15-cent, 10-cent calls from coin phones, where the basic charge was a nickel, could be handled automatically. And I got a patent on that. But this patent--this one on using TSPS--is basic because what it does is put into every coin phone that when you deposit the coins, the coins send out signals that are machine-detectable. I mean, prior to that the only way you could tell was the operator could listen to see whether it was a quarter or a nickel or a dime by the sound. Now we put gadgets in there that automatically, you know, oscillators that automatically sent out signals that went to this equipment that could count the coins as you were depositing them. So that's part of my patent. That's basic to my patent.

ASPRAY: I see.

JOEL: And that was used in a large way. In fact, all the coin calls now in the Bell System and AT&T are handled that way. I see there are two patents on that, and I imagine one has to do with the telephone and the other has to do with the equipment in the TSPS to do it. Give out the announcements and all that. By the way, that required a whole new-- It shows you what you get into. That kind of an

invention requires-- You see, you have to have a lot of knowledge about the system. You know, some outsider can't come along and invent something like this. This required a whole new kind of database. Because up to this point, all the calls that were rated in that system were either rated, you know, in the accounting office-- When you made a call and you made a credit card call or you made a call and charged to a third party or a collect call or whatever kind of call you made, it went on the tape--in this case magnetic tape--and it would be processed in the accounting center. And we'd figure out how much the charges were because it was an operator-handled call. And we'd have a charge for the operator-handled calls. However, when you bring coin phone calls in there, you've got to do it in real time. So we had to put a new kind of database in the system. And it had to be a database you could change readily. Because it isn't-- Here's the way it was--and I guess maybe it still is to some extent--the AT&T in their great wisdom all of a sudden decides that as of midnight a month from now, they're going to change all the coin rates. And we've got to go within a month and go to these 155 sites and change the tables in all these machines. And you've got to find a way of doing that. And these patents include all that kind of stuff.

And then there's one of them here on this automatic identification for automatic intercept that I've described to you, so that you know what number you reached and not what number you think you reached. And do it automatically you don't have to have any operators. By the way, you'd be interested to know that since I retired, I guess I did have two ideas. One of them is still pending in the Patent Department, but one of them I've already gotten a patent on, on photonic switching. Switching with light beams. So I continue to get patents. And there are

people at AT&T and Bell Labs that still think I'm going to come up with some more ideas. [Chuckling]

ASPRAY: For the scholar who wants to go back and look at your career and would like some guidance on your publications, could you pick out maybe a half dozen of your publications from this list and say that these are the important--most important--ones to look at?

JOEL: Well, you're talking about importance from the technology or importance of seeing the variety of the things that I did or what?

ASPRAY: Well, I think probably the importance of the technology is what these would be read for.

JOEL: Well, it's hard to say. These are all publications. I know that No. 6 here, the "Communications Switching Systems as Real-Time Computers," I know that that's importance because it's been brought up in several lawsuits. Because I predicted it in that paper, the growth of the stored program control idea and the importance it's going to be. And that was in 1957. In '56 I wrote this important article, the No. 5, that describes the first stored program control calls going through a system and how they went and so forth in the pre-Morris laboratory. And, you know, if you're interested in broad kinds of things, then even No. 7, "Telephone Switching: An Old Field With a New Future," where I'm talking about what the future of electronics might be. That's in January 1958. Well, there's so many of them here. There's two articles here about Morris, "An Experimental Switching System Using New Electronic Techniques," September 1958. Oh, I wouldn't say encyclopedia articles. I wouldn't include them. Here's one, No. 13, "On Permutation Switching Networks." Shows my interest in

switching fabrics, as they're now called; they're now called switching fabrics. But I had a great interest in that and have done a lot of work with that. My interest in history is shown in No. 17, "Twenty-Five Years of Switching System Innovation." Of course what the Traffic Service Positions System is about--the two of us that are joint inventors of that-- is in No. 18. No. 20 is a favorite topic of mine also. It deals with the classification and unification of switching system functions. And attempt, again, to formalize stuff about switching, which is, you know, a favorite topic. And occasionally I see this referred to by other people, trying to nibble at this problem. So it gives me a lot of satisfaction when I see somebody quoting [Chuckling]--referring to--this. Again, I wrote another thing about networks--nodal networks--as No. 21. Twenty-two, again, points out the fact that the stored program control idea was more important than the electronic switching idea. That paper I gave in Munich in 1974--22. Of course we celebrated the history of Bell Labs again under the 50th Anniversary issue--No. 23.

One thing that's interesting in looking over this thing, you see a lot of these encyclopedia things. In fact, I just turned in a thing the other day to an encyclopedia reference volume about ATM switching. The interesting thing is that as a child, I wished I had all these encyclopedias I could have looked at, to find somebody who was knowledgeable about the subject, you know, to write about it. There wasn't anything like that when I was a kid. And boy, maybe I would never have been interested in switching if I'd read enough of these articles. [Chuckling] Well, of course, the books like the Press books, they've sold fairly well. I think they've sold about 8,000 copies of each of them. They're pretty well used. And by the way, I mentioned to you that I was involved in lawsuits, and one

of them was a patent interference recently that came out. The jury ruled against AT&T. But in that trial, our witness was asked--was shown--a table from one of these IEEE Press books. And this is the Vice President of AT&T was the witness, and they said, "You know of a Mr. Amos Joel?" "Oh, yeah, he's world famous" and so forth and so on. You know, they built it up to big fare-thee-well. "Well, he has this table." And he gave him the table from one of these IEEE Press books and said, "See, doesn't this show that you've been infringing--?" and this, that and the other thing. And the Vice President looked at it very carefully. He hadn't seen the table before. But he saw all my notes. I had a lot of legends down on the thing. He looked at the legends. And the legends said all these other systems were field trials. Ours was the only real system that was in production. [Laughter] And he let the guy have it right then and there. He said, "Oh, Mr. Joel says right here that these are all field trials." [Chuckling] But that gives you an idea of the kind of stuff I used to do, you know. I spent a lot of time on that, and nobody else did. A good general article was the one that appeared in IEEE Proceedings in September '77. That's it for one article. And another history article under 30. Seems like I've done a lot more writing toward the end of my career than the beginning, doesn't it? [Chuckling] Does that mean anything? [Laughter]

ASPRAY: I think that's common.

JOEL: Yeah? More recently, of course, we have the history books of the--Bell books. And the Chapuis book. I thought that the work I did in this No. 48, this Ingles Handbook--McGraw-Hill Handbook on Electronic Communications--I wrote a chapter in that. I thought that was a pretty good chapter, myself. Never heard anybody else say so, but I thought it was pretty good. And of course the

McDonald books on digital switching, which I always like to preface with the fact that I personally don't agree with the title because I don't believe there is such a thing as digital switching. It's a misnomer. That's why I'm so fussy about nomenclature. But there is no such thing as digital switching. There's a switching of digital signals, but from a switching principles point of view--and I like to emphasize switching principles--there's only space division and time division. There's also the possibility of frequency division, but I can prove that that's not a very viable thing. But there is no such thing as digital switching because you can have both space and time division of digital signals. But people won't recognize that. They just brush it aside and say, The latest thing is digital switching. Anyway, those are not too important, I don't think.

ASPRAY: Okay. Thank you. We haven't talked at very much length, anyway, about your awards.

JOEL: Oh, yeah.

ASPRAY: Now, I have a list of them right here of some of right here in front of me.

JOEL: [Chuckling] Well, those are replicas. If I can get a replica, I have them mounted and appear here on the table. But if I can't get a replica, for example, of the Kyoto Prize of some others, I don't have them here. And I have over on the other side right near you-- My daughter doesn't want to be necessarily outshone by me, so whenever she gets an Emmy, she sends me a plaque to commemorate her Emmy that she wants to put next to her father's awards. [Chuckling]

ASPRAY: How nice!

JOEL: She hopes to get an Emmy again this year.

ASPRAY: Uh huh. I didn't have any idea.

JOEL: She's a set decorator for "The Young and Restless" soap opera.

ASPRAY: Are there any stories you want to tell? Or any comments you want to make about any of the prizes?

JOEL: Well, you know, I certainly appreciate receiving all these proofs of recognition. And I guess you're most surprised when you get the first one. [Chuckling] They seem to build after a while. And of course I was very surprised about the Kyoto thing. I just never expected to get that. In fact, I didn't even know what it was really [Chuckling] 'til I got it and heard more about it. But, yeah, it's interesting that some of them zero in on specific things, like the-- New Jersey keeps-- I guess we got an award for--a patent award of some kind--because of the invention of the TSPS and how it's important to the industry and so forth. Those are sort of interesting. I like those awards because, you know, they really recognize you for something specific. The Kyoto was a broad thing about your whole career, contributions as a person. So, I guess, was the Medal of Honor of the IEEE. Same kind of thing. The Alexander Graham Bell Award, which I shared with two others, was really zeroing in on something important. That was the ESS itself. By the way, it's interesting that that prize we got, of course, for our contribution to making ESS viable-- But they took pictures of us. And we had pictures in the various books, the same picture of the three of us. I guess we had it also in the Chapuis book. And the interesting thing is that the place where we took the pictures was Succasunna in New Jersey where the first No. 1 ESS was put in service, May 30, 1965. It was just taken out of service a month ago in Succasunna and replaced with a No. 5 ESS. And that frame that we're standing next to has been shipped to the Smithsonian. They're going to use it for something; I don't

know what. I don't know if they know the whole story or not, but that's part of the story that goes with the medal. We had the picture of the three of us taken there.

ASPRAY: The Curator of Electricity at the Smithsonian sits on our Board, so I'll make sure he knows the story. Finn--Barney.

JOEL: Oh, yeah, I know. I know Barney.

ASPRAY: Barney.

JOEL: Yeah, I know Barney very well. I don't know whether he's familiar with what we did. [Chuckling] In fact, I'm sorry-- You know, as you get involved in various things, there are many things you look back on your career and you say you wished you'd had more time to spend on some things. And that was one of them. There was a time when I guess Barney Finn asked if I could help in-- They were going to revise the whole area there in the Telecommunications, which they did. I wanted to do something more about electronic switching. I would have liked to have gotten into it, but to get into it would have required more than just the technology. They wanted the social implications and all the other things, and I would have liked to have tried my hand at that. But I never had time to do that, and I'm sorry I didn't. Because, you know, I look back and see that kind of thing that went on with the early switching systems--dial systems--where it had big social implications. I mean, for the first time in many communities people were able to get telephone service 24 hours a day, which they couldn't get before that. Things of that kind, which were very interesting. I am sure we could relate similar stories. I can still remember today working-- We worked on Morris, and we cut it over in November 1960. And we put on a big show out there for the AIEE and local townspeople and all kinds of other things. And we had a stage, like, and on

the stage we had telephones, and we demonstrated Call Waiting and Three-Way Calling and so forth. And today I look at those commercials on television, and I see these same demonstrations for the first time. It's taken all this time since 1960, when we first invented this stuff and showed how it could be done, until now when you can universally offer it to people and to demonstrate it and try to sell it, actually, and promote it on television. So that's like 30 years--32 years. And it's sort of interesting because it's the same dialogue. It's the same [Chuckling] example. Of course, they have really good actors and actresses. We did our own. We even took our secretaries there to help us demonstrate them. [Chuckling] So at any rate, I'm sorry that I haven't been able to--For example, I put out this document--I think I mentioned to you; maybe I gave you a copy of it--about the history of the panel system from birth to death.

ASPRAY: No, I haven't seen that.

JOEL: You haven't seen that. Anyway, I have it. I'll give it to you. That story is interesting because it's one of the few really important switching systems that served, you know, millions of lines--millions of telephones--that was born and died as completely taken out of service up to now. There are not any other large serving switching systems that are in that state. I mean, step-by-step is still in service in many places around the world. And so are many of the contemporaries of the panel system, like the Swedish system and the rotary system, that grew up with the panel system. They're still in service in many places in the world. So there are very few systems that are completely dead, and that's one of them. Of course, all the manual switchboard systems are dead. But automatic systems,

that's one of the few--at this time. Of course, hopefully, in time we'll see a lot more of them die.

ASPRAY: In a way to begin to wrap up, first of all, can you tell me what you thought were the greatest engineering challenges you confronted in your career? And whether you succeeded or not in achieving what you wanted?

JOEL: Well, the greatest engineering challenge is not the specific inventions which, as you know, I have many. But the greatest challenge to me has been--is to try to fit together the state of the art of switching, as it's evolved, and to make something of this. A pattern of this--either in terms of what we certainly accomplished by teaching it and what not. We were able to show there are certain principles that can be taught and that we can explain to generations--succeeding generations--what switching's all about. And as new switching techniques evolve, we can continue to do that. So I think we've put the framework down for doing that. Of course, as I've said before, my big disappointment is we haven't been able to formalize it any more than that. We haven't been able to formalize it to the degree of putting some mathematics with it or something of that kind so that we can evaluate the various architectures and things. But at least I think people now understand the principles pretty well--which they didn't. When we first we started out--when I first started out--there was no such things as principles. I couldn't go to the vice president or even the engineer that had been working the longest on switching systems at Bell Labs and say, you know, What kinds of switching systems are there? He'd tell me there was step-by-step and panel and manuals, but he wouldn't be able to tell me the principles upon which they were based. And I think we've done an awful lot over the period of my career to make that

understood by people. That you can indeed classify the technologies that are used in switching.

ASPRAY: If I wanted to tell a young engineer in just a few sentences about your career and your accomplishments, what sorts of things should I tell him? If you wrapped up the major accomplishments?

JOEL: I don't think it's something new, but I think that what you should do is to find something very early in your life that you think is something you'd like to do, that is of interest, and learn as much as you can throughout your life about it. And stick with it. I think, you know, that you have a better chance of succeeding that way than to know a lot about--a little about--a lot of things instead of a lot about one thing. And certainly for me I believe it's worked, that knowing a lot about one thing--namely, switching--has paid off and has been a very-- I think I've accomplished something with it. And that I would recommend that to anybody. Particularly today when there's so many distractions and so many things--paths--that people can go down. It's good to have a firm root in one particular thing.

ASPRAY: But setting modesty aside, tell me what three or five or ten technical or organizational or political or social accomplishments that you'd like to be remembered for.

JOEL: I don't think there's anything. Just that here is someone who spent a lifetime being interested in this subject and that there had not prior to him been anyone who took this kind of interest and looked at it as broadly in this way. There have been--like him--many people who invented things in this field, but I don't think that there's been anybody that has looked at it in the broad sense that I have. And, you know, I'd sort of like to be remembered for having started that. I hope there will be

others to continue this way of doing things in this particular-- It's a very important part. I don't see any way we're not going to have switching with us for many generations. It's essential if you're going to have person-to-person telecommunications. So therefore, hopefully, there's a lot more progress to be made. Not just in the invention of systems of switching, but in understanding the philosophies and the way in which switching systems can go together. And I hope that, you know, I've done a lot to start this kind of thinking. Probably haven't done enough to advertise it.

ASPRAY: Could you tell me something about your personal life? Your family, your children, your hobbies and so forth.

JOEL: Yeah. I'd be happy to. My family life has been, I think, a very important contributor to my ability to do the things that I've done. I think that's important. Because it's been a very tranquil family life. We've had no tragedies. We've had no very great upheavals of any kind. Things have gone along, for the most part, the way they should. My wife and I are celebrating our 50th anniversary this year. And we've had, you know, a very good life together. The children-- Our son will be 45 years old this year. None of our children are married, or ever have been married, which is sort of interesting. Much to the dismay of my wife in particular. And my father was very unhappy that none of them had any offspring or anything like that. But our son is 45. He studied mathematics. He didn't get his Ph.D. at MIT. But he got his mathematics degree at Princeton. Then almost got a Ph.D. at MIT, but then gave up on the thesis. He's now into other things. He spent almost 18 years with Mathematical Reviews, and so he's now out doing other things in the publishing area. Our daughters are twin daughters. They'll be 42 this year.

They've been a joy. Well, they've all been a joy--all our children have been a joy. Plus there's been no problems. They've never given us anything to be unhappy about or given us any pain or any sorrow or anything. Except for not having offspring--at least that bothers my wife. And they have their own careers that they're doing. My daughter in New York-- They're on both coasts: One's in New York and one's in California, but they keep the telephone company in business communicating, especially twins. They have a great affinity for one another. One of them works for Wiley, the book publisher. She's the manager of advertising. And the other one is a set decorator for "The Young and Restless," so she has a very exciting job. The soap opera--CBS. So that's exciting. They're a great joy to us. We have good times together when we can. We can't get together very often. As far as my hobbies are concerned, I've always been interested in music. I can remember, you know, practically going through college listening to nothing but classical music. And so I had a great collection of records that were all classical--all the symphonies and so forth. I knew them all, and I could recite them all, and so forth. I've often felt that I would like to turn my creative talents to music, but I've never had a chance--never had the time. And so then I did have a period when I was rather ill with--ulcers, you know, bleeding ulcers--and the doctor found out that I was a workaholic, you know. Because I worked-- My own personal life is I work as much as I can. I do have to devote some time to my family, and my wife would like me to devote a lot more. But really, you know, when I worked, I'd come home and I'd read and maybe watch television. I can do several things at once. I love to do several things at once, so I can watch television and be writing a paper and doing a couple of other things. Really, my attention span is not long.

If I concentrate on something for an hour, it's a lot for me. So I move around a lot. And so as I result of this period when I was ill, the doctor said, You can't be a workaholic all your life. You've got to have other things and have hobbies. And do you have any hobbies? Well, I was always interested, as I said, because I got interested in switching through toys and things like erector sets, trains and so forth. But I was always interested in music so I decided I would like to play the organ. I would like to play music. By the way, when I was a child I also--when I was growing up in New York--I took lessons on the clarinet and the saxophone. So I knew something about music. At least I could read music. I always said I wanted to have an organ in the house. And so my wife went out and rented an organ after I was sick. And once we had an organ in the house, we never let it go. Kept buying newer and bigger and better. Right now I just got a new gadget for my birthday that's coming up. I just enjoy playing the organ. And it got to a point where for the last 15 years or so, I guess, every night after supper I sit down and play the organ for at least a half hour. And I get a lot of relaxation out of that and a lot of pleasure out of that. I wouldn't say I play well, but it's just a good hobby, and I enjoy it. And, of course, unfortunately--my wife doesn't like this--but I get involved in the technology of it, and so I've got all kinds of gadgets to go with it. So I don't just play straight. I play these other things as well. She doesn't like that particularly. But the point is that I have fun with that. Now since I retired-- Of course all through the last 20 years and more at Bell Labs--well, it's 20 years, I guess--I've always had computers, access to computers, and have used them, too, a great deal in forming databases and doing research and whatnot. Writing papers. And of course I became a buff, being at Bell Labs, of the UNIX and used UNIX

all the time until I retired. And then I had to buy a computer for myself at home and had to go to DOS. But the point is that I've, you know, kept up, spent a lot of time keeping up to date with computers and enjoy that sort of as a hobby, too, now. So that's a second thing. I like to exercise reasonably well, especially since 1980 I had a heart attack. I had one a year or two before that. I had two heart attacks. And then late in 1980 I had a quadruple bypass operation. So I try to do a reasonable amount of exercise and watch my diet, things of that kind. But I will say this, that my family has really helped me in my endeavors professionally because they've caused no problems, if you will. I have not been diverted from my constant thinking about inventions in switching and so forth very much. In fact, it was hard to get me to take a vacation for many years. Right now, since I've been retired, I have enjoyed taking vacations--particularly cruising. I like to take a boat. My wife says that's because--I like it because--there's no telephones to answer, and I don't take my work with me, and so I enjoy it much more that way. So that's sort of a hobby, too, you might call it. But my family has really been a very important part of my life, [strange banging sounds on the tape] made it much easier for my career to progress the way it has.

ASPRAY: Do you want to make some comments about the future?

JOEL: Yeah. I'd like to in this respect: Certainly, as I said, I'm a child of the monopoly period of the telephone in this country, when we could sort of plot our own destiny at places like Bell Labs and AT&T, and plan the network the way it is today. In fact, the things that have been done with it since divestiture couldn't have been done if we hadn't done the things the way we did during the monopoly period. Such as introducing common channel signaling switches, introducing

electronic switching and so forth. It's certainly been a disappointment to see what's happened since divestiture as a result. There's no question in my mind that business interests have taken advantage of the divestiture, have been able to get much lower long-distance rates and more variety perhaps--and will in time even get more than there is today. But that's been at the expense of the average customer. I think that's just going to continue that way. The next big push in my opinion is already on the horizon. And that is that even the local monopoly is going to go. You know, like the New Jersey Bell will not be the only supplier of telephone services. Going back--and I don't know whether I mentioned this before--but going back to my childhood, I can remember when there was this competition in the city of Philadelphia where I was born. It was very undesirable. Now whether the new competition will be like that, I don't know. Certainly the things that are tying the network together today is by a very slim thing called the numbering plan. That's what's holding the network together today. The only reason you can dial a number on MCI or AT&T or Sprint is because they all use the same numbering plan. If it turned out that because of various interests of a group of people and the types of services you want in the future you had to disband and give up this numbering plan, then you'd find some serious defects in the way service is going to be given. Now they claim that the numbering plan is going to last with the next revision, which is coming in 1995. That'll last to the year 2025. So we'll see--by then see--if the numbering plan is still held up all that length of time.

The other thing is that unfortunately today-- Well, when we made plans back for many of the things like distance dialing so that the customers could eventually

dial long distance--initially the operators could--as we introduced those kinds of things, we made a long-range plan. We were making plans for the future. There's not that kind of planning going on today. Nobody's planning for the long-term future. I mentioned the numbering thing which is probably the most important thing, and that is going on. But even now the people all over the country are throwing brickbats at this plan that's supposed to start in 1995 because they have their own little private interests that they'd like to pursue, which this numbering plan won't let them do. For example, there are numbers today in the numbering plan that allow you to dial a 7-digit national number and get the local store to answer your call--like Domino's Pizza. And 1 for 30. You dial 950130--1430. And you can do that today because there's a hole in the numbering plan that allows that to happen. But that won't happen in the future because there's only 10,000 of those numbers. And you know darned well in a country this size there'll be a lot more than 10,000 entrepreneurs that'll want to take advantage of this. So you've got this kind of problem. That there's nobody planning, you know, worrying about the long-range implications of these kinds of things--except the numbering plan. And I think that's a clue to the whole thing. They're putting out fires. They're worrying about the immediate competition. There's many indications that places like Bell Labs won't be able to stay in existence. I mean, how can-- Bell Labs costs over two billion--over 2.4 billion, I think, now--to run. Nobody else is paying that kind of money of their receipts to running a company like that. To further research and development of telecommunications. These other companies are leeches on, that in a sense. They're not paying it. You don't see Sprint running a big laboratory or MCI or any of them. It's not only the

laboratory. It's not only the development of new products and new services. It's also just simple things like the money that AT&T contributes to cultural events over the years. You don't see these other people doing very much along that kind of line. So you really worry, you know. We had a very good system, one that did worry about the long-range implications and planned in a very methodical way how you'd get there. And there are certainly-- There's a lot of people say, you know, We know where we'd like to go, but there's so many political things holding it back. I mean, we know that there are lots of things we'd like to do with cable service--cable TV--but we may not be able to do it in future.

There's certainly a lot of promising things that people want to do in the technology as applied to bringing fiber to the home, you know, things of that kind. And bringing selectable programs to the home. Even though there's 150 channels on cable, they may not satisfy everybody. So, you know, you'd like to be able to introduce some switching. [Chuckling] Have the ability to select programs. Things of that kind. So there are a lot of things we can do with the technology, but somebody's got to sit down and plan it, solve the political problems, solve the competitive problems, and that's not going on today. It's every man for himself in the business, and it's all short range. Nobody can predict because of the politics of it where it's liable to--what you're liable to be able to do, let's say, ten years from now. And what you're not liable to be able to do. So it's very discouraging to somebody like myself who grew up in an era where you could do your own planning. We could say how we wanted to render the telecommunications services. Now some people may not feel that we did a good job, but I think we did. I think that we bring good technology and good service to

the people. The reliability of the service--And quality of the service is another thing that certainly has gone down.