Oral History of Martin Cooper

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Sean Maloney: [This is an interview with Martin Cooper conducted at the Computer History Museum on May 2, 2008.] So what were your earliest memories of Chicago? Earliest memories?

Martin Cooper: I was actually born in Chicago, but my family moved back to Canada, which was where they had come from, when I was only a year old. So my earliest memories really are in Winnipeg. And amazingly enough my earliest memories are technological memories. Watching some older kids with a magnifying glass burning paper and desperately wanting to do that myself and I couldn't understand why when I took a broken bottle and used the base of the bottle, I couldn't get this thing to focus and burn the sun. So, it's those kinds of things; I was always curious about those things; trying to build stuff. Mostly unsuccessfully.

Maloney: Did you have brothers and sisters?

Cooper: Yeah, I have a younger brother. My younger brother is, or was a banker, and a musician. Both of them, very, very successfully.

Maloney: Do you think your parents in any way encouraged you to get in what I guess later you'd call technology?

Cooper: No. not at all. But what my parents did was encourage me to read and I've always been just an avid reader, and actually my interest in technology really came out of just being imaginative. I've been a dreamer my whole life and it made me not as effective an engineer or executive as I should be, but if you think about it, at least one aspect of technology is imagination, thinking about what they call "out of the box." And that kind of environment, encouraging that kind of thing is something that is part of our culture. We always had books, been surrounded by books.

Maloney: When did you move back to Chicago?

Cooper: When I was about seven years old. And you know my family actually was in Canada and started some businesses, so they were entrepreneurs but didn't do extremely well in Canada and moved to Chicago and started a business, which in fact kept them going for essentially the rest of their lives.

Maloney: What kind of business was it?

Cooper: They were selling door-to-door, sales people. They had a clientele who depended upon them to bring things to them. It could be anything from furniture to clothing to things around the house. So. But this is what immi-- my folks were immigrants from Russia, and that's the kind of things that immigrants did to make a living. And they were both people oriented, my mother especially, who has always been my model. My mother would talk to anybody, any place, any time, and she was a real dynamo and she kept us going for years and years in that vein.

Maloney: What's your memory of high school? What did you get interested in in high school and what do you recall?

Cooper: Well, by the time I got to high school I already knew I was going to be an engineer of some kind. So even though there was a high school very close to where I lived in Chicago, I actually went to a technical high school, Crane Tech, which was a very tough school at that time. Got even tougher with the years. And, I mean, as an example, one of the reasons you go to a technical school is you have all kinds of shops, so everybody starts out with wood shop and then you have all kinds of alternatives, like forging and print shop and every scientific kind of course. But in the forge shop, as an example, people made brass knuckles. So, very, very tough school. And the fun thing was, you worked at a forge, you had to shovel coal in from time to time and the fun thing was to, when somebody wasn't looking, you'd heat up the handle of their shovel in the forge so that when they picked it up-- very-- I mean, you built a veneer of toughness in a school like that. But it also taught me a lot about science and about getting, using things, doing things with your hands.

Maloney: At what age did you decide to go to the Illinois Institute of Technology?

Cooper: Pretty natural. You know, I lived in Chicago, we were not wealthy people and so I knew I wasn't going to go to some fancy school and here I had an engineering school that was-- at least my view was it was a quality engineering school, right in my home town, so I pretty much-- I always knew I was going to go to college, never any question about that. And it just seemed very natural to go to Illinois Institute of Technology. And then it turns out that, after I started there, they came up with the Naval ROTC program, which I joined, which was a great blessing because they ended up paying my way through college, and it was a great help to my folks. I'm not sure-- of course at that time my recollection is that the cost per semester was $256 when I started school in 1946, so things have changed a lot since then.

Maloney: So what was it like going into the Navy?

Cooper: The Navy made a man out of me. I really should have gone in the Navy first and then gone to college because I never really took things extremely seriously. But the big deal with the Navy was not so much the fact that they paid for my education-- and the Navy courses weren't all that great-- but you did, each summer, go on a cruise, and get to deal with situations where you were on your own. It helped you grow up a lot. And then when I got out of school, I actually went into the Navy and served on destroyers for a couple of years, and submarines for a couple of years after that. And talk about understanding leadership, dealing with people. I think the Navy was really an essential part of what I am today.

Maloney: Round about the time of the Korean War?

Cooper: Yes, I was in Korea in fact during the Korean War. Actually I have explained that or have that explained to all my Korean customers and they all say "thank you," and then get on to business.

Maloney: So you served under McArthur? Indirectly?

Cooper: Yeah, I suppose. I never met him though, but yes, I was actually in the Yellow Sea blowing up North Korean bridges for six months, which didn't do a lot of good because we blew them up during the day and then during the night they'd rebuild them and we'd come back the next day and they were back again.

Maloney: You also did a spell on a submarine?

Cooper: Well, this was on a destroyer.

Maloney: But you also worked on a submarine?

Cooper: Yes, I actually-- I considered staying in the Navy for a number of years. I enjoyed it, I did well at it. I went to submarine school and was on the last class of submarines before the nuclear subs.

Maloney: What were the communications systems like on those? What was the technology like on those boats then?

Cooper: Very elementary. They were talk and listen. In fact, especially on the destroyer, I mean, they still used flags, and pulling flags up on the poles and yes, there was radio, but nothing as sophisticated, not even close to what cellular telephony is today. They were effectively like mobile radio.

Maloney: At that point were you interested in communications technology or hadn't it really got into your mind at that point?

Cooper: Only incidentally. They made me a communications officer, but that was only because I happened to come from an engineering school, but I didn't have really much understanding or interest in communications. I have always been interested in anything technical, but my interest in communications didn't start until I joined Motorola in 1954.

Maloney: You passed over it, but being on active duty on a boat during the war has an element of risk, right? How did you feel about that?

Cooper: Never occurred to me. You know, when you're in a situation, it's exciting, and I don't think people-- there's as much risk crossing the street in San Diego as there is getting shot up on a ship. And even in the Army today, there's a lot of fuss being made about that sort of thing and I certainly admire people who take those risks but when you're doing it you don't think about that very much. You exclude yourself from the possibility of you being one of the injured.

Maloney: What about the discipline involved in the Navy? Has that shaped you or did that in any way form an impression on you?

Cooper: I've never been much subject to discipline and wasn't to the Navy and that might have held me up, but the organization in the Navy, the systemization of everything has been very, very useful. The decision making, the aspects of leadership, because they really have to teach leadership there, they can't assume that you're a natural leader. In our business culture, the people with natural abilities, if there is such a thing, they kind of rise to positions of leadership, and in the Navy they really have to make you a leader, and it turns out that can be very effective. Because even if you have natural leadership abilities, the fact that they teach you specific elements of leadership is very important.

Maloney: The next step was Motorola. When did you decide you were going to apply to what was then a very small company and what led to that process?

Cooper: Well, actually what led to that is when I got out of the Navy, of course the first thing I wanted to do was-- I was a submarine officer, the world should have really wanted to use all that ability. I discovered the world didn't care much about whether you were ever on a submarine or not, and I joined a-- at that time, this was 1953, there really wasn't that much demand for engineers, believe it or not, and so I just got a job, and the job was at a company called Teletype Corporation, and you're too young, Sean, to know about what a teletype machine is, but this was a mechanical typewriter that was a communications device. And here's this huge company who was devoted to this one product, which ought to be an example to somebody because today not only does the product not exist, but the company doesn't exist. But it was part of Western Electric, which is part of AT&T, which was the largest company in the world, and that is the system that we used at this Teletype Corporation. And I sat in this huge room, with about 500 engineers, and the thing that I remember very clearly, we had all these desks, no air conditioning by the way, and at five o'clock every evening a bell rang and everybody stood up and walked out the door. Which is astounding to me. And I was approached, I was a research engineer and I was approached by Motorola while I was there, when I had been there less than a year and was really starting to chafe at the bureaucracy of this organization. I remember that our boss sat in an office right next to this floor with 500 engineers, and he had a title that might have been superintendent or something of that nature, and he rated a carpet in the office, and he got promoted and they put a new man in the job but his title was assistant superintendent, he didn't rate a carpet, so they pulled the carpet out of the office. You talk about bureaucracy. So they approached me at Motorola and I got a job as a senior development engineer. I started December of 1954 and my clear recollection of every day just about five o'clock, interestingly enough, maybe a quarter to, somehow or other there would be a conversation starting about some business issue and we wouldn't go home until we finished talking about it. Sometimes that was six, sometimes it was eight, but people were engaged in their work. They really cared about what they were doing and they weren’t jobs they were doing; a huge, huge difference in attitude and outlook on life.

Maloney: What do you put that cultural difference down to at Motorola at the time? That was Bob Galvin?

Cooper: Yeah, well, at that time Paul Galvin was the founder, was still the chief executive. Bob Galvin was actually a vice president of the company. And the real issue was that the company was run by engineers, and so that culture of really understanding what it is that you were doing, and there was also a culture of not only understanding your customer, but understanding your customer's problems better than the customer did. And boy, if there's anything I ever learned at Motorola is that specific problem. I spent a few years in the research activity at Motorola which really wasn't research, it was advanced development. But then I was moved into the land mobile area where we were doing products and my recollection is that

every morning as I drove to work and when I drove home at night, I had a two-way radio that was our product in my car and I was communicating, all morning, all evening, so we really immersed ourselves into the business. And not only that, I installed every radio that was in my car for the first 10 or 15 years of my career at Motorola because installation was part of the customer's task. So you really got to understand the business in a way that you could never do in a theoretical kind of way.

Maloney: And that radio in your car, then, would have been operating on what frequency?

Cooper: Started out, at the beginning, it was 25 megahertz and 150 megahertz; we moved up to 450 megahertz. I actually built the first gigahertz, it was actually 900 megahertz, a mobile radio equipment which really wasn't mobile, we used it for traffic control in Washington, and that was around 1963 or so.

Maloney: Those first radios though, the 25 megahertz and so on, I guess you got good coverage across Chicago with that?

Cooper: Oh sure. They were-- spectral efficiency was not necessarily an issue and the way we handled spectral efficiency was by just making the channels narrower and narrower and narrower. So when I started at Motorola, channel bandwidth was perhaps 100 kilohertz and we would go down to 50 kilohertz, 25 kilohertz and would have gone down lower until we found more effective ways of improving spectral efficiency. And by the way to answer your question, a transmitter covered the city and some of the transmitters covered a better part of a state. You could really cover a lot of area at 25 megahertz or even 150.

Maloney: And this was a shared radio?

Cooper: No.

Maloney: You had a dedicated channel?

Cooper: Well, some of them were, they had a thing called community repeaters, which were just what you say, shared, but people liked to own their own systems, so certainly all the public safety people-- and Motorola even today is still the leader in public safety communications-- and the public safety people, the firemen, they all liked to have their own personal channels and that is still true today.

Maloney: At some point you ran the IC lab. You were working at Motorola for a year or so, and then how did your career develop there?

Cooper: Well, as I say, started out in research and we actually got involved in the very first semiconductors and what was the semiconductor? Well, I can tell you that. One of the projects I worked on was cryptographic equipment for the government using punch cards, would you believe? I'm sure our audience has no idea what a punch card is, and vacuum tube equipment, and I was on a program that a huge rack of stuff with a thing called a delay line which was literally coils, we don't use those any more.

And we had the vacuum tubes on top of these coils and somehow they were loading down the coils. We had built the equipment, ready to ship it and somehow the thing wasn't working right and I needed some way to fix this problem and to isolate the delay lines from the rest of the equipment and the way we used to do that was with a thing called a cathode follower, except I couldn't put any more tubes in this thing, so I thought, you know, there's this new thing called a transistor, maybe we can do that. And I go in to the expert and I say, "Can you make a cathode follower transistor?" "Well, let me think. Well, we've got a thing called the emitter follower, maybe it has the same characteristic." Well, it does. It's an impedance transformer and so I had to go find some transistors. Well, our transistors were made by our semiconductor division and they were shipped to us in wooden barrels with long leads and all just thrown into this barrel. I'm not exaggerating. And you had to pull these things out and sort them because they had-- they didn't know yet what to sort for never mind how to sort them. And of course the issue with the emitter follower is the beta, the impedance transformation is the beta of the transistor, and so I would sort through these things and pick out all the transistors that had a beta more than 6 and sure enough I got a 6 to 1 impedance transformation and wired these things into the data lines and shipped the equipment off to the government. So that was my first engagement with semiconductors.

But after a couple of years I was moved into the two-way radio area, and not because of any special technical ability I had, but I was a very good recruiter. And here we were by this time, now we're talking about 1955 or 1956, shortage of engineers suddenly, and so we had to recruit. We got all kinds of students coming in about to graduate, we had to sell them on the company and they desperately needed people in our product areas and the research department was hiring all the people. So the only way they could solve their problem was moving me into the two-way radio area where I could hire more people and that's where I got started to get involved in real products. Like traffic control. We made the first 450 megahertz two-way radios in those days, and products of that nature.

Maloney: When you were making those early public radios, what were the big technical challenges involved?

Cooper: Things that seem so mundane at this point but the frequencies were, the channel was established by a quartz crystal and it turns out that the quartz crystals at that time were not extremely precise, and Motorola made their own quartz crystals and it turns out almost went out of business because the quartz crystals started to drift and their customers were finding that they would with time go out of business, so I ended up running the quartz crystal business for a number of years and solved, along with the help of a lot of people, solved that kind of problem. But the other kinds of problems were radio frequency kinds of problems. Remember you didn't have digital filters, so all the filtering was done by coils and capacitors, and the narrower we made the channels the more difficult that problem was, so then, even as today, the biggest problem was interference rejection. So now that you mention it, Sean, I haven't gone anywhere. I started out in 1954 working on interference rejection and here I am in 2008, we're still doing that in a little different kind of way.

Maloney: Your work at that time, you ended up developing the first portable handheld police radio. So that would have been early sixties?

Cooper: Yes, around 1965 or 1966. We were approached by Orlando Wilson, who was the police commissioner of the city of Chicago, and his problem was that his police have to stay in communication,

communication was crucial for the police departments, and yet he wanted his police to be on the beat with people instead of trapped in their cars. Once they got in their cars they became isolated from their constituencies, so he asked. "So, is there some way you can build a radio that a policeman could carry with him?" and what a great challenge. And so we actually created a radio with a microphone that the police would clip on to their uniform with the antennae in the microphone so that they could get out of the car, mingle with the people, be visible to their constituency and then get in the car and still have the car transfer it to the RAF from the microphone. And we built a system that literally had cells so that we could cover the city of Chicago because the coverage for portable units like that, the power output of a mobile radio, and you asked me about what the big problems were, well, the more power you had with a mobile radio, the better you could cover a big city. Putting a 100 watt or even 1,000 watt transmitter and covering the whole city was relatively easy. How do you talk back? And the way you do it is you put a big power amplifier in the car and so going up from 40 to 80 to 100 watts was the kind of thing you have to do. Now we were putting a one-watt portable on a policeman. The first examples of kind of cellular technology; it wasn't really cellular because it didn't have hand-off from cell to cell, was with these police radios. Hand-off is not an issue because the police communications are 15-seconds communications, typically, so you didn't really need to do a long conversation.

But that's when I really made the discovery that is my mantra today. That people are fundamentally, inherently mobile, that these policemen were much, much more effective when they could carry their radios with them than when they were trapped in cars. And then we got to see other examples of that when we really got good at making portables; we could make a portable two-way radio for as little as $800, which would be about $3,000 today, and we had people buying portable radios and putting them on a messenger boy on a bicycle. So here's this guy, he's riding a bicycle that costs $15 and he probably made fifty cents an hour, but he had a multi-thousand dollar radio. But it made him effective; it let him do things that could not be done any other way. Boy, if there isn't a message there about mobility of communications, I don't imagine what.

And then we started observing that the people, once we start becoming more sophisticated, now we're dealing with people in airports, as an example. And we wonder about how people are using these things in the airport and little details, should we have pouches for people to carry their radios on, like you do your cell phones today. Turns out you didn't need a pouch for the airport employees. They walked around the airport and they had their two-way radios in hand because it was a tool that they used continuously. Another example of how vital these kinds of communications are in commercial kinds of applications.

And then the ultimate was when we came out with the first pagers. Once again, young guys don't know about what radio pagers were, but at one time there were almost fifty million pagers in the United States alone, but the very first paging system of any consequence was used in hospitals, and it was implemented by putting a loop of wire around the roof of the hospital, and perhaps on one of the floors, and these pagers received their information by induction and they actually had little vibrating reads that operated at different frequencies. And when you got one that made your thing vibrate at your frequency, it would close the contact and beep you, you know, if you remember what a beeper is. And these are the very first ones, and used little miniature vacuum tubes and we didn't do very well. The housings on these things were literally made by a company that made the cores of toilet paper rolls and we produced the first system for a hospital in New York called Mount Sinai Hospital. And I don't know if you know about doctors, but doctors can really be prima donnas, and here these doctors were complaining that their pagers were failing. And we had this one story about a doctor that got so angry that he threw his pager against the wall. Well, you know, we really had a strong sense of taking care of our customers. We

apologized to Mount Sinai Hospital and told them, let us take the system back and work on it for a while and we'll make the technology work and we'll get it back to you. They wouldn't have it. And the doctors would not give up this system. Maybe it was not as reliable as they would have liked, but once they started building their lives around these systems they could not get along without it. The freedom that they got by not having to be next to a patient, by being able to be reached when they had to be reached, it was so vital, that this excruciatingly poor reliability was just not a handicap. So all those things put together, you can understand how you develop a religion about mobility, personal mobility, about the freedom that you get from mobility.

Maloney: You were, I suppose, by then, an engineering lead?

Cooper: Yeah.

Maloney: But you sound like a product marketing guy. Was there a distinction at that point between product marketing or custom marketing and engineering management? Tell us how that was structured.

Cooper: Well, there certainly was. Not until 1965 did I get a role where I was called a product manager, and where I had marketing people and engineers working for me. But I cannot overemphasize the culture at Motorola at that time where you had to put yourself in the mind of your customer and you have to understand your customer's problems better than the customer. I see a lot of people now that talk about being responsive to customers, "the customer is king," everybody knows that. But to understand the customer's problem better than the customer does is really the objective. Remember you're the specialist. The customer understands his business, but you understand the tool better. Now, if you can understand not only his business but understand the tool better, you can go and teach him how to use these tools better. And that kind of made every engineer into a marketing person. And the net result of that is there are many businesses that we introduced two-way radios into, after which they could no longer function in their business without them.

Maloney: When did you first think of a portable phone? A mobile phone?

Cooper: You're talking about an interconnected phone?

Maloney: Yes.

Cooper: I actually invented one in 1950. 1950? No, that can't be right. Around 1956. And the issue there was rural telephony where we had customers in rural areas that needed public switch phones, needed home phones and radio was the only way to get it there and teaching people how to-- remember these two-way radios were "press to talk." All the ones we've been talking about that police departments use, that the airport employees use, you push the button and talk and then you let go and you listen for somebody else. It's a very uncomfortable way for people to talk in their homes. So we developed a system for rural telephony that actually used push buttons for dialing-- this was 1956, it was really kind of ground shaking, no one had done this in a commercial way before-- and had what's called a duplexer, so they could talk and listen at the same time. And if you want to know about technology, the way we

switched channels on these things, they'd use a couple of channels, and the way we dialed, was we had a little motor that would rotate and actually break contacts and just by today's standards, just incredibly primitive, but that was the first public switch telephones.

Maloney: So you had been working in pioneering a number of products that circled around the idea of replacing a conventional telephone. And when did you start thinking about the early ideas of a cell phone? When did that come into your mind as a project?

Cooper: Well, it was brought into our minds very forcibly by the fact that in the mid-sixties, around 1966, AT&T started making noises. This is the old AT&T, not the present AT&T. This was the AT&T, the largest company in the world by every measure, number of employees, revenues, profits, everything else. And they had dredged up out of Bell Laboratories' files a concept called cellular telephony and what was cellular telephony? It was splitting up the city into a lot of individual areas they called cells, each one was kind of its own little radio station, but then making them interconnected by introducing a concept called hand-off. So if you were in one cell and you moved to the next cell, your call was transferred into that cell without your knowing about it. And they dug up this concept, which had been created in 1947, and in 1966 it was time to commercialize this and so they went to the Federal Communications Commission and said we want 30 megahertz of spectrum; "We will in this 30 megahertz accomplish several things. We will do a new thing called cellular public telephony, we'll let everybody have telephones with their own telephone number and make telephone calls; we'll do land mobile for police and fire and we'll do air to ground. And we're the only ones capable of doing this financially or technically." And here we were at Motorola, and we were in a very competitive industry. Our competitors were RCA, General Electric and we were very successful against those, but here AT&T was proposing literally to take over the business and then on top of that their version of this public telephony was car telephones. If you can believe that. And here we were, I've already talked about the religion that we had about people being mobile, so this combination of things, that was really made urgent by the monopoly issue, and that's when we started inventing alternative ways to do what AT&T was proposing, but focused on portable telephony, on hand-held portables.

Maloney: Was there a specific project where you said, okay, this will be the first portable cell phone or did it evolve through a series of projects?

Cooper: No, it was a specific project. The technology we had been working-- all these individuals technologies, the power amplifiers, the synthesizers, all the pieces that were necessary to make a handheld portable telephone, people were working on in our research departments, that I had a lot of influence on, but around November of 1972 we got word that the FCC was about to make a decision about this spectrum and one of the real cultural issues in the communications group at Motorola is we always were-- we were never complacent, always worried about the competition, always thinking about the worst possible thing that could happen and the worst possible thing that could happen to us was for AT&T to take over our business. So we decided in November that we were going to go to Washington and demonstrate to the FCC that AT&T is not the only one that could operate. First of all we had to prove that we could use 900 megahertz. For years, up until then, we had been explaining to the FCC that the highest possible useful radio frequency for mobility was 450 megahertz; 900 megahertz was just not practical, and beyond that, well, that was just a pipe dream. And now AT&T says well, 900 megahertz is just perfect for us. Give us 30 megahertz. So now we had to go to Washington and say, well, we changed our mind. Technology has advanced, 900 megahertz is good, and then we had our second issue, which

was portable telephony. So at that point I said you know what, if we really want to do a splash, let's demonstrate a real handheld personal portable telephone at 900 megahertz. And the project started in a very simple way. We certainly didn't have to go talk to management, we were the management. And so the first guy I called up was the guy who ran the industrial design department who didn't report to me, Rudy Krolopp, and I said, "Rudy, I need a handheld telephone." He says, "What's that?" I said, "Well, you know, it's a telephone you can carry with you all the time and it's got to be really jazzy because we're going to use this for a demonstration," and he stopped all work in the industrial design department, which did not report to me, and asked his whole team to do a competition. Who could make the best portable telephone. And we gave him two weeks and after two weeks I took them all out to dinner and each guy stood up at this thing and presented his version of the telephone and some of them were just beautiful. Some of them were actually suitable for a telephone today. Sliders, folders, just amazing what these guys-- and we're talking about 1972. So we ended up picking one that was not all that spectacular, because it was a single piece and it was simple and even then-- the more complicated you make something the greater the chance it was going to break. We already knew that and we knew that grown-ups were much harder on devices than children are; having things be rugged so you could drop them was part of our mantra. So we selected this unit, which was about this big, little tiny-- suitable for even today's cell phones, and we took it to the research department where the RF experts and the synthesizer experts were and we said, could you make this into a real phone? Well, yeah, they could, except they had to put well over a thousand parts in there, and extract all of the best technology in our whole company, and so this thing grew. It grew from a couple of inches high to a half inch wide to a inch deep into 10 inches high by an inch and a half wide by four inches deep, and it ended up weighing two and a half pounds, but it worked. And that was the project. And we completed that phone, the actual work started around the middle of December of '72 and we had a working phone three months later in March, and on April 3rd, we actually had a working system, and in order to do all of that we literally shut down all engineering at Motorola. There were literally hundreds of people working on this system. Because not only did we have to build the phones, we had to build bay stations to drive these phones, and we al--

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Maloney: So you have to demonstrate it, so you have to develop the phone from nothing, the bay station from nothing.

Cooper: And we created these vans that we literally set up with all kinds of equipment; not only the cellular equipment, but we also had to prove that we could do land mobile at 900 megahertz as well. And we worked out scripts. We went to a hotel called the Watergate Hotel, which was famous for other reasons, and set up a demonstration where we brought in congressmen, senators, FCC commissioners, this is in Washington, and told our story in the most effective way I could, and then took them out into these vans and drove them around Washington along very carefully selected routes, I should point out, showing that all this equipment work in the centerpiece of all this was the DynaTAC hand-held portable telephone. And people were dazzled.

Maloney: I want to take you back a little bit. You've got hundreds of people overall working on it. But on the DynaTAC itself, how many people were working on that?

Cooper: Aside from the industrial designer, and there was one, Ken Larson, actually developed that. But Don Linder had a group of about nine people. And he actually created the phone itself, the design of the handset. I don't recall who did the bay station, but it took another group, and I would guess it was four or five people that did that. And the bay station power amplifier was a Klystron, which people don't even know-- in fact I'm not sure I remember what a Klystron is myself, other than Klystron is still-- of the first one that we did is still up on top of a building in New York as we speak, because in order to get the bay station and equipment up to the top of this building we had to hire the union. And they wanted so much money to take it down, it was cheaper just to leave it there. And as I mentioned, it's still there today.

Maloney: So this was December, '72 to April '73. Let me say then from a semi-conductor point of view, what were you grappling with then? What did you have available? What was the difficult stuff?

Cooper: Well, we had already, in our laboratories, developed power amplifiers out of gigahertz. It was a real stretch. Getting more than a few tenths of a lock was a really serious problem, but we could do it. Battery's not a problem, because this thing was so huge that we could put a pretty big battery in it, and battery life was not a serious problem. We ended up with about 20 minute of battery life, but that was not a problem because you couldn't hold up two-and-a-half pounds for longer than 20 minutes anyway. But things like the synthesizer, we had never built a two-way radio with more than 11 or 12 channels, and now we had to have 666 channels. And so you have to build a pretty complex synthesizer, and that we had never done commercially. Somebody had to do that. There's some very specialized filtering that had to be done. We needed obviously a 900 megahertz antenna. And hopefully we'd like to get a little gain because we couldn't get very much power. So there are a lot of little details like that. But the biggest problem was, there were no large-scale integrated circuits at all. And a Silicon Gate CMOS wasn't even a pipedream at that time. So we have to use a large number of discreet parts, a large number of small-scale integrated circuits, all bipolar, all with heavy current rate. So the really big problem was jamming all of that even into a box this big and having it still work. So every time we do a demonstration there always had to be an engineer standing by just in case things failed. Real challenge to put 1,000 parts together and do things that had never been done before.

Maloney: If I could spirit you back to Christmas in 1972 when you're four months off demonstrating it, what would the room have been like? How many engineers would have been in there? How did you physically record what the design should be like?

Cooper: Oh, well, don't even think computers. What you have are log books. And, in fact, I just witnessed the-- or saw the first drawings recently, and they were just sketches on pieces of paper. And that's what people actually work from. Now you had log books, and sheets of paper, and they'd draw stuff out and if necessary make copies for other people. There were engineers working in the laboratories. Everybody had a multimeter and an oscilloscope. But if you had one spectrum analyzer in a laboratory, that was a lot. Today's engineers are really very spoiled. They have all this test equipment surrounding them, everything computerized. We had no computers or anything. So what you had are people literally building circuits one at a time, and combining them, and everything on paper.

Maloney: How did you coordinate all the various moving pieces of this, the bay station development, the handset development, who's going to call up the politicians? How did you coordinate the effort?

Cooper: Well, you've got to start at the top. And it's really kind of a crucial question, because the real effort was Motorola versus AT&T. This was not just me versus Joel Engel who was the AT&T cellular guy. And so the chairman of the company, Bob Galvin, was personally involved. And the president of the company, Bill Weiss, was involved. John Mitchell was my real spiritual and technical leader, and he was personally involved. He's the guy that kind of taught me, mentored me on this issue of personal communications. So we actually held top-level management meetings with a group of Washington lawyers just to work out the strategy of how do we deal with the FCC, with Capital Hill, and manage the overall situation. The technical problem was managed by a guy named Jack Germain who kind of coordinated all these different efforts, the bay station, the handset and so forth. And my contribution was more the creative, and kicking people in the rear, and getting them excited about our specific objective.

Maloney: So again, back then in that Christmas in 1972, what would you have been most worried about? Three months, four months from demonstration what was the thing that you were most concerned about?

Cooper: Well, there weren't many people that believed this thing was ever going to work in the first place. So some of us knew it. Don Linder knew it and I did. And the small group of engineers working in that research laboratories have, but there's no way anybody else was counting on us having this thing done. So it really was a breakthrough at that time, even within our division. But I should also mention, though, everybody was behind us. There was never any question about whatever priorities we needed, anything, whatever people we needed. And as I mentioned before, we just shut down-- the engineer, there were hundreds of engineers working on various aspects of this thing at one time or another. But the portable itself was a group of some nine people working in the research lab.

Maloney: So the big guy arrives when you believe it works, and you place the first call to your rival. Tell us what went through your mind then. What was the day?

Cooper: Well, this is April 3rd, 1973. We're in New York. We're getting ready to go to Washington, kind of shaking the system down. Our objective is lots of publicity. So I'm with a radio reporter, as a matter of fact, and showing them this thing. And you should know there had been lots of calls made before that, but all engineering calls. This is the first public call with somebody else actually looking over our shoulder. And I thought about who I should call, and it occurred to me that the ideal guy was Joel Engel. Because Joel is a neat guy, a very smart guy, but a typical AT&T guy. You know, "We are Bell Laboratories. We are AT&T. How dare you suggest that what we are proposing is not the ultimate, the best and the only." And, in fact, his number one guy, Dick Frenkiel, even this day, states that as far as anybody's concerned Motorola's an obstacle to their progress. And so it's just very natural for me to call Joel, which I did, and picked up this phone and said, "Joel, this is Marty Cooper." "Hi, Marty." "I'd like you to know that I'm calling you from a cellular phone." "Yeah?" "Only this is a real cellular phone, portable, handheld." And there's silence on the line. I'm suspecting he's grinding his teeth. And he responded politely and we've been friends ever since. But, by the way, he doesn't remember this call. And if you were he, you probably have forgotten it yourself.

Maloney: That was what day?

Cooper: April 3rd of '73.

Maloney: And then you had to go into production, which is a whole new set of challenges.

Cooper: Well, keep in mind that the decision had been made, just to go very quickly, we took the thing to Washington, demonstrated to most importantly the FCC but also to every congressman and senator we'd get our hands on, and politician, and literally-- and did our sessions at the Watergate, trying to educate all these people on what the future was. The FCC made their decision a few months later and they made all the right decisions. The decision, it was that there would be competition, there would be multiple systems, not just one, and that they would give some of the radio spectrum to-- or assign it to the wire line companies, some to non-wire line companies. And they set up a process where portable telephony became a very practical alternative in contrast with what would have happened with AT&T. So now to answer your question, we have to commercialize this thing. There are two major issues. The first one is you're not going to have a commercial product with 1,000 parts in it and an engineer to along with each one to keep it running. Clearly we have to build something that was reproducible. And it had to be smaller and lighter. Our mantra, aside from mobility, was you can't be too small, you can't be too light. But the more important issue was who was going to be the operator. And the FCC had to make that decision. And one thing the government does not do is operate very quickly. And this had never been done before. They had to set up somehow a competitive process. Picking the wire line carrier was not a hard problem, because at that time it was just AT&T. And so after a few years a process was started where AT&T conducted the trial. And they did do a trial starting in 1979. And of course there had to be a non-wire line trial. And Motorola selected, and I was involved in a process of selecting a carrier in Washington D.C. to do a trial in Washington. And that started around 1981. So what did we do during this period? Four different generations of this portable, each one a little more-- a semi-conductor technology, fewer parts, smaller and lighter. So that by the time we got to Washington D.C. in '81-- 1979 AT&T started a trial in Chicago, all mobile phones. And what is a mobile phone? The phone itself was a box about this big. It had two antennas sticking out of the rear fender. We had multiple antennas even then. Didn't do very much. The box weighed 20 pounds and it was as light as they could make it, because we-- a typical mobile radio at that time could be as much as 40 pounds. And two years later we introduced in Washington D.C. a handheld portable, and we are now down to less than a pound-and-a-half. And the power out for this thing was something less than a watt, and it worked. Not extremely well. It didn't have much in the way of indoor coverage, but it functioned. And in 1983 finally the FCC made their final determination of who actually got the license. Not a trial, but a real license. And the two licensees were the same outfit in Washington D.C. that we had selected. And by the way, in order to convince this little carrier in Washington D.C. to do this we have to literally finance him and twist his arm, because he didn't think that this cellular thing was ever going to be very much, and he certainly wasn't going to risk much of his future. He actually became very wealthy just based upon that one system. And the wire line license now went to Illinois Bell, not AT&T now had been split into a number of operating companies as well as AT&T, a long-distance carrier. So Illinois Bell was actually the first wire line cellular operator. And almost all of the phones sold in those early days were car telephones, after all that work. Yes, there were portable phones, but the portable phones cost in 1983 dollars, $4,000, which would probably more like $10,000 today. And their performance was not fantastic. Because as an example the city of Chicago initially started out with perhaps a dozen cells. So getting coverage from a portable radio inside a building at the cell edge was virtually impossible. You would learn how to walk to the window closest to your cell site in order to make this thing work. But we still sold them by the hundreds. And each year the phone-- the first commercial phones weighed a pound. By 1987 we came out with the Startec which was the phone that weighed some nine ounces, first flip phone. And now there were many more cell sites, now portables were practical. So there was an evolution.

Maloney: A lot of the coverage of what you did focuses on that early activity in '72, '73. But it seems to me that the endurance and determination needed to get it through the next ten years and not give up along the way must have been quite something.

Cooper: That's a very insightful comment, because you're right. In '72 and '73 everybody supported us. There was just no question about it. The enthusiasm of the whole company was there. But by the mid-'70s we were spending money still by the millions. And we had gone through a couple of generations, there was still not a single dollar of revenue. And even by 1979 and 1981, when the other trials went on, still there was outgo, but no income. About the only income we had was building some 500 mobile phones for the laboratories, which they reluctantly gave an order to Motorola, although Motorola didn't get the biggest order. A company called E. F. Johnson did, and another company, Nokia got the bulk of the business. So you can bet that there were a number a people, primarily the financially-oriented people. But there were other conservative people said, "Why are we doing this? This company is not big enough to support that kind of investment." And this is where the importance of having visionaries running your company. Because start with Bob Galvin, he just knew that we have to be in this business. And Bill Weiss and John Mitchell were extraordinarily supportive. But beyond that it was a battle. A battle getting financial resources. I just never, ever worried about my bonus and, by the way, never got too much in the way of bonuses. Because if you worried about husbanding the bucks, you're never going to get the job done.

Maloney: You're talking of the vision. You said to me once that you knew very early on that there would be a billion units, and you're just surprised at how long it took to get there. When did you first conceive of this as a mass consumer item?

Cooper: Well, you know, it's easier to conceive of the portable telephony as a consumer item when you're not actually in the market. And believe it or not, when we were talking about these things in the early '70s, we just know that at this-- ultimately everybody would have a cell phone. In fact…

Maloney: Everybody?

Cooper: Everybody. Our story was when you were-- maybe it was a joke but it was only half-joking, that when you were born you'd get a telephone number. If you didn't answer the phone, you had died. So you knew that sooner or later that'd have to happen. But to think about that happening and people giving away telephones for nothing would've have been a stretch. But you imagine even selling $10,000 phones, not a huge market.

Maloney: If I put the two things together, if I went back into the Motorola finance department in the middle of the 1970s, Marty Cooper would have been this nut who believed that everyone on the planet would have one of these things, and here was this loss-making business, so maybe late 1970s. There must have been quite a bit of organizational pressure around on that. There was gap between your vision and what it looked like at that point.

Cooper: There's no question about it. I have marveled many times since then why they ever tolerated me in all those years. And all I could think about is that somehow the vision was not mine, the vision was

the guys who tolerated me and let me keep going. Because you're exactly right. There was enormous pressure to not spend this money. We actually did a calculation. By the time we actually started to get revenue we had spent, it's like $90 million, and this is 1980, 1970 dollars. And for a company who's total revenues were the order of several hundred million, that's a huge amount of expenditure. So I have nothing but admiration for those people. In fact, I'm still very friendly with Bob Gavin, and he continues to be a visionary.

Maloney: But the root of it, you had seen how addictive communications was. And you'd seen that earlier on. And your experience was whenever people had a means of communicating with each other they were incredibly reluctant to give it up.

Cooper: If you think about that, that's true for any product. You want to find out if your product decisions are successful, try to take your product away from somebody that start to use it. and they refuse to give it up, then you know that you were successful. And I think that it has been established by a number of surveys that the cell phone is now in that category, that people will give up almost anything before they give their cell phone up. I think the only alternative is food.

Maloney: What's your definition of technology?

Cooper: Technology is the application of science to create products and services that serve humanity, that make people's lives better. And I put a lot of thought into that because every one of those elements is important. Science alone is not adequate. Technology for the sake of technology is a disaster for any engineer. To create something that's a thing of beauty, but doesn't do anything for anybody is an engineering nightmare. You haven't done any good unless people end up benefiting. But of course there are some other elements to this issue of what is technology. Good technology is transparent. You shouldn't ever see the technology at all. And the best technology is totally invisible. And there are some good examples of that. But one example is not cellular telephony. In my view the computer geeks have gotten control of our beautiful cellular industry and try to turn us all into computer experts just like they have done in the computer area. You think of what's the best technology that you use on a daily basis, and my view is that that's the automatic transmission on your car. And especially on your car. But if you look at your automatic transmission, it really is a marvel of technology. I mean, it's got electronics, electrical, hydraulic, and mechanical. And every one of those elements is hugely complex. These are not very simple things. And your car, that's another science, that's chemistry. And yet I can get any car in the world, I get in and I drive. When I shift that shift lever I never even think about what's going on. That's good technology. And then you had somebody, their new cellular phone-- and not to pick on Motorola, but the manual for my Motorola phone is bigger and heavier than the phone. Now that's not really-- technology, good technology, ought to be intuitive. So in that context I think our industry is still-- by the way, I include the computer industry as well, is still immature. And I know this is not very practical for people that are building products for the market today, but ultimately I think we are going to see lots of specialized devices, each of which is very simple, very intuitive, very inexpensive, with inexpensive transport. And people are going to stop wasting their time learning how to be computer engineers and focus on living and doing things that humans do best.

Maloney: Along the way back then you ran an IC lab. Tell us a little about that.

Cooper: One of the things that Motorola did that I think affected our whole industry is they understood first of all that portable telephony or portable any kind of communication is going to be important, and that that was going to require-- successful execution of personal communications was going to require specialized devices. And Motorola had a semiconductor group at that time. And they forced the communications group into the semiconductor room to communicate with each other with the hope that out of this would come some specialized devices that would give both groups competitive advantage. Somehow the management didn't believe that was quite enough. So they established a integrated circuit laboratory separate from the semiconductor group, which was managed at first by the communications group. And then ultimately when I became corporate director of research and development, by-- the corporation is called the Motorola Integrated Circuits Applied Research Laboratory, MICARL. And what we did is try to reach out and do so to technology that wasn't necessarily commercial, but that would, in fact, push the state of the art in ways that the semiconductor group might not. Interestingly enough the first effective products of the MICARL were not communication devices. We built the first engine control management integrated circuit for Ford Motor Company. But then as we start evolving, silicon gate CMOS technology, which is very low current drain technology. We started building devices specifically for the communications group, and it turned out to be a very effective way of giving us some leadership, with the objective always of having the processes be very similar to the semiconductor group processes so that we could transfer products to the semiconductor. But I have a recollection, just to give you an idea of how things have changed since then. This chip that we built for Ford Motor Company, the engine management chip, was among the most complicated chips that anybody was producing at that time, many thousands, many tens of thousands of components. And the design of the chip was plotted out on a printed circuit plotter, and literally put on a single sheet of paper, I mean real paper, and posted up on a wall. And the trekking of this integrated circuit was done by people with colored pencils following lines along this sheet of paper. So the extent to which we could create complicated integrated circuits was determined by how big the wall was in our laboratory. Ultimately we did grow into computer-rated design, and, in fact, participated with Carver Mead in his silicon foundry-- what do you call the other end of a silicon foundry, the compiler, silicon compiler. So you had to be at the state of the art then, but when we started out there were no such things.

Maloney: When did your time at Motorola came to an end?

Cooper: Well, the end started in 1982 when I was approached by a guy named Russ Shields with whom I still work. Russ had been calling on me for some years just to discuss various things, mostly of a technical nature. And Russ perceived that there was a severe gap in the evolution of cellular telephony, and approached me in 1982 and said, "Why don't we start a new business?" "What's that?" "Well, it's billing and information systems for cellular operator. Well, I'm not sure what a billing and information system was, but we made an observation that the primary focus of operators and operators-to-be since the early 1970s was getting a license. And then once you got a license the next issue was getting financed. And then once it got financed, the next issue was the technology issue and deployment, a very difficult job to deploy things because nobody had ever built a cellular system before. And then, of course, once you had the system deployed it wasn't much without customers. So, you know, by the time you got through these things they had pretty much exhausted their attention span. And nobody thought about how you were going to keep track of all your customers and collect the money from them when they used your resources. And Russ had the vision to think that we could do that where nobody else did. I tried to persuade Motorola to get into the business, but since I really didn't understand it myself it wasn't likely I was going to talk them into it. And after a year where I was doing my job as vice president and director of R&D for the Motorola Corporation, and at the same time starting this new business, I had a talk with our CEO and he said, "You know, I'm going to do you a favor and let you go and start this new business."

And he did, and we in fact, created a company called Cellular Business System, Inc., and called upon operators in this new business throughout the world. But AT&T already had their own approach, so the only other operator at the beginning was an operator in Washington called American Telephone Company, or something of that nature. And finally since, I had selected them as the carrier when I was in my role as running a division at Motorola, and they finally-- some weeks after they had started commercial service they selected Cellular Business Systems as their supplier. They already had people out on the street making phone calls, and they only then hired us to do their billing and information systems. And so we immediately had people working day and night, back again to 1973 there were people working day and night building a cell phone, now they're working day and night, you know, designing the software to collect billing information. And the first month I recollect that we had a lady in her office was an extraordinarily fast typist. I've never seen that. She could do 120 words a minute, and she literally typed each of the 113 bills for those first customers on a typewriter from a computer readout.

Maloney: You spent a lot of the last 10 or 15 years working on advanced antenna. You said something that's paradoxical, which is that there won't be a shortage of spectrum. Could you explain what you mean by that?

Cooper: Yeah, it would take about 16 hours, but we'll do the quick version. If you think about it, what we were doing at Motorola in the old days was trying to figure out how to get more and more telephone conversations in a very limited amount of spectrum. We were literally starved for spectrum. We were out there evangelizing the importance of keeping people in touch while they moved around. But when people wanted to buy new systems they were competing with other people. So we were constantly trying to improve what we call spectral efficiency. How many conversations can you squeeze through a limited amount of spectrum? And even with cellular, preceding cellular I introduced a system called trunk systems where instead of having a bunch of individual systems in the city, we would build a system that would reach out and find a channel. And somebody wanted to talk, let them talk on that channel. And then when they were finished with their conversation you give up that channel and let somebody else talk on that channel. And if you could select among a group of channels, you could improve your efficiency. You could share a hunk of spectrum between a number of people. We call that a trunk system. At the time I thought that was a much bigger contribution than cellular telephony, and also Motorola made a lot more money at that than they did at cellular telephony for many, many years. But that revolutionized that concept, revolutionized the land mobile radio business. And by the way, you mentioned this issue about people-- obstacles within the company. When I conceived of this first trunk system which I did working with the FCC because they were interested in spectral efficiency, our sales people, who were among the most effective sales force in the world, Motorola did all their own selling. And their management came back, said, "Nobody will ever buy a trunk system because it's going to cost 15 percent more, which is what we told them, and just forget about it. And nobody's going to want to share their channels. And I came back to the division ten years later, and 90 percent of the company's business, multi-billion dollar business was trunk system. So sometimes it takes somebody with a little vision to make these things happen. So after Cellular Business Systems was sold and my wife and I started another couple of businesses, I decided it was time to retire, which I did for all of six months. And I was approached by a guy named Richard Roy [ph?], who was a, I guess you'd call him a computer genius at Stamford. And he had a concept at which he informed me of as we were running down the boardwalk in New Orleans when I found out what a real jock is like, because I was gasping for air as we ran along and he was talking in a perfectly normal speed running at the same speed. And taught me about a new way of improving spectral efficiency that incorporated all the ideas that we had thought about in the past, but it did them in an elegant, new kind of way that used all the latest computer technology. And the next thing you know he had me in his laboratory in Stamford, and that has consumed my life for actually the last 17 years. And

that is what we now call multi-antenna signal processing, but it's really smart antennas. And I can tell you what smart antennas do. If you think about what-- it was a contribution of cellular telephony. It really was improving spectral efficiency. That's why the FCC even considered giving a hunk of 30 megahertz. They've been allocating frequencies literally by the channel, by 25 kilohertz channels or several 25 kilohertz channels at a time. Here they were giving 30 megahertz of spectrum away. And the reason they did that is because of the promise of spectral efficiency. You will never need to do anymore spectrum assignments for this mobile telephony area because we can split the cells. And what the cells did, I think I explained before, small cells, each one a system by itself, handoff between them. If you run out of capacity what you do is make the cell smaller, and then reuse these frequencies throughout the city. So it was really revolutionary. But there is a problem with that if you think about it. Because within each cell you transmit from a transmitter at the center of the cell. You transmit in all directions. Almost everything that you transmitting is wasted. All that's useful is what reaches that little tiny antenna on your handset. And then when this bay station listens, it's listening in all directions. Well, it's hearing everybody. All it wants to hear is this person that's on this specific channel that it's handling. What smart antenna technology does is it allows us to use an array of antennas, unimportant what this array does, but a lot of signal processing. But the result is that a person starts transmitting this array, this multi-antenna system, listens to where that person is and listens only to that person. Somebody else tries to talk, we reject them. We listen only to that person. And then when we talk back, we'll talk back only to that person and avoid talking to other people. It turns out that's revolutionary. It does more for spectral efficiency, for getting more people on a channel than cellular did in the first place. It really is the next evolutionary step. And what's interesting, and it became obvious to me the longer I worked in this area, that as time went on this business of being more spectral efficient is going to go on forever. Certainly in my lifetime and in your lifetime, Sean, and in your children's lifetime. Because…

END OF TAPE 2

Maloney: So, people have talked about “Cooper’s Law.” Can you give us your own words on that?

Cooper: Sure. Well, first of all, let me tell you this. It’s kind of embarrassing because it’s really not a law; it’s an observation. But what the observation is that if you look at 110 years ago, Marconi made the first commercial wireless transmission. He did this using all of the available radio spectrums. He used a thing called the spark gap transmitter that used literally all the spectrum that technology would avail itself of at that time. And furthermore, when he transmitted, it was not possible to hold another transmission anywhere near. Well, he transmitted from Newfoundland to England, which is big hunk of the surface of the earth. So, it’s not likely you could hold more than two or three conversations like that, if I could call it a conversation, on the whole earth at that time. So, I used that as a reference point. And furthermore, this transmission was very, very slow. He would send a bit per six seconds, if you could imagine. So, I picked a number of points in time and made the same measurements. How many conversations, defining conversations the way I did before, could you _____ the whole surface of the earth using all of the radio spectrum that was technically possible to be used in the most effective technical way at any given time? Amazing discovery because I discovered in the first 50 years, we got a million times improvement in what I call spectral efficiency. You would think that you’d get saturated by then, but it turns out the next 50 years got another million times improvement. So, we have, by now, improved our spectral efficiency by the order of a trillion times. What does all of that mean? Well, spectral efficiency is kind of an abstract thing. We even know how to measure that in technical terms. It’s bits per second per hertz in a fully loaded system. By the way, all of this for personal communications. But, the real issue is that the more spectrally efficient you are, the lower your cost is. So, I discovered for the first issue,

spectral efficiency, that we have doubled our spectral efficiency every 30 months, every two and a half years for 110 years. So, I went and looked at what it cost to deliver a bit of information wireless starting with Marconi and amazingly enough, we have halved the cost of sending a bit of information every three and a half years for 110 years. There are some other observations you can make about that. Number one, that it was not uniform. There were bumps and you could guess what one of the bumps. It was cellular telephony. There's going to be another bump in smart antenna technology. Most of these bumps happened either for two reasons. One is people were starved for spectrum. That's why we worked so hard at Motorola in the old days of making filters that let us make the channels narrower and narrower, or the government does something. They demand that you use new technology before you get new spectrum. I hope that our future is more in the being starved area, which is, I think, where we're going right now with WiMAX and similar kinds of technology. So, I was about to make another-- Oh, the other observation is that it's clear now that this process is going to keep happening forever and that's one reason why I think that auctions, spectrum auctions are a travesty. I think a radio spectrum that belongs to us, the public; it's well and good to sell something for what it's worth, but if you could know that something is going to double in value in two and a half years and ten years from now is going to be ten times in value, we're giving away for nothing today. The government ought to have a much better way of delivering a spectrum. But, the availability of spectrum is going to continue forever. We've never had a problem finding spectrum when we have a new idea. Somebody comes up with something like WiMAX; oh, we suddenly found some spectrum. Guess what? The next generation is going to come along and it's going to be much more spectrum efficient and somebody is going to find some spectrum. Technology is always going to stay ahead of our ability to consume the spectrum. Having said that, our ability to consume the spectrum is also going up at a very rapid rate. All of that points to a very different world than we have today; a world where people are really connected in all kinds of different ways at very, very low cost.

Maloney: Well, your work, the average layperson, what you've done, would say that you've changed the way that people live, which is a huge achievement, in a relatively small piece of time. And so, I'd ask you a final question. What would your advice be to a young person now who was looking to get into technology, to make a difference to society for the good, which is how you described it earlier on? What would your advice be to young people now?

Cooper: The first thing is to put your mind into the mind of who your customer is. Everybody's got a customer. If you're going to be a technologist, you want to understand that your technology is going to ultimately do some good for society. But if you're talking about a career kind of issue, it is try to run through a project from conception to finish. That is just so important. If you're ever going to be a leader, if you're ever going to do something really important, you really have to understand the whole process. And so, I advice youngsters who are all anxious to spend one year doing engineering and then come CEO to be a little patient, get into every aspect of the thing, understand the marketing, understand every aspect of the engineering, including quality control and going into production. When you see that product going out and you see customers using it successfully, now you understand the process. It's so important, in my view, for people to understand that and I suspect that's true even outside of the engineering field.

Maloney: Great. Thank you very much.

Cooper: My great pleasure.

END OF INTERVIEW

