IRWIN MARK JACOBS
ORAL HISTORY

COMPUTERWORLD HONORS PROGRAM
INTERNATIONAL ARCHIVES

Transcript of a Video History Interview with
Irwin Mark Jacobs
Chairman & CEO, Qualcomm Inc.

Recipient of the 1999 Cap Gemini Ernst & Young
Leadership Award for Global Integration

Interviewer:	Daniel S. Morrow (DSM) Executive Director, Computerworld Honors Program
Location:	San Diego, California
Date:	March 24, 1999

DSM: The date is March 24, 1999. We are at the home of Dr. Irwin Jacobs in San Diego, California. This interview will become part of permanent record, a public document, as part of a permanent research collection at the Smithsonian Institution's National Museum of American History. This is part of an on-going series of interviews and oral histories with the leaders of the global information technology revolution.

This particular interview is made possible by a generous grant from Ernst and Young, LLP. Dr. Jacobs in June of 1999 will join Scott McNealy, Hasso Plattner, Robert Kahn, Recipient of the National Medal of Technology, Mark Andreesen, Larry Ellison and Ted Turner, as a recipient of the Cap Gemini Ernst & Young Leadership Award for Global Integration.

Before we begin, I'd like to formally outline on the tape the ground rules for this interview. Without objection, the interview in its entirety will become part of the public record, held in trust, and made available to the public by the Smithsonian Institution's National Museum of American History, and subject to their rules and by-laws. You may, however, stop the interview at any time, and request that portions of it be embargoed, withheld from distribution for up to 25 years. And, in any case, you will be sent transcripts of this interview for review and correction before any portions of it are made available to the general public.

In that regard, I should say that all present here are honor-bound in that regard, and they include myself, Dan Morrow, the Interviewer, Tom Lippert, Simone Ross, George Lang, Peter Schofield and Mel Baracliff of Upstate, New York. You should also feel free, Dr. Jacobs, to stop the interview at any time. I suggest questions or topics be referred to discussion. Is that acceptable?

IMJ: There are no lawyers here? (laughter)

DSM: No lawyers. (laughter)

IMJ: I'll relax a little more then. That's okay.

DSM: In that case, if it's cool with everybody, we can begin. Let's start very formally. I would just ask you to state, for the record, your full name and where you were born.

IMJ: It's Irwin Mark Jacobs. And I was born in New Bedford, Massachusetts, so if you have any trouble with my occasional Boston accent you'll know why.

DSM: And your parents?

IMJ: David and Shirley Jacobs. My father died almost a year ago, and my mother is living here in San Diego with us.

DSM: I'm sorry. I missed your birthday.

IMJ: You did? October 18, 1933.

DSM: Tell me about your parents. What was it like growing up in New Bedford in the late 30's?

IMJ: Of course it was during the Depression, and the period I remember the most was World War II. It was always a struggle. My father had a number of different jobs before he was married. He was a taxi cab driver in New York City. He was an electrician's aid. He married my mother, moved down to New Bedford, and worked in the insurance industry for many, many years, as an insurance agent. Later he became part owner with my grandfather of a butcher shop in New Bedford. So we ate a little bit of meat during World War II. And later he bought and owned a restaurant for several years; and married in Massachusetts. And then he went into the auto parts business and eventually we got him to retire and move out here to San Diego.

DSM: What about your mother?

IMJ: My mother mostly worked at home, but when the folks bought the restaurant, she became a hostess and did a very, very good job of that. Still, she was available to raise both my sister and myself. Then of course, as we had children, she helped quite often with the grandchildren.

DSM: So there were two children in the family, yourself and one sister?

IMJ: Right. My sister lives about four houses from here.

DSM: For those looking at this from a perspective of 100 or 200 years, tell me something about New Bedford when you were a child and the homes you lived in. What was it like?

IMJ: Well first of all, New Bedford was not a very wealthy city. It was a very poor city. It had gone through a number periods of fame. Of course it went back to the whaling days - the Moby Dick-like stories. In fact one of my fond memories is of a library in downtown New Bedford, with a statue of a whaler with a harpoon raised up, getting ready to go after a whale. It was a very, very good library, with a very good children's section.

We lived in a rented home in the north end of the city. Luckily, the basement had an old coal bin, but we switched over to oil. So I converted the coal bin to a dark room. So I think that was my very first hobby, and then in some sense, business. I developed and printed films and took pictures for my grammar school classmates when we made a trip one place or another. Then I sold books of pictures. So very early on I got into an entrepreneurial position.

DSM: That's always one of my first questions - about first experiences with technology. So it was photography?

IMJ: It was photography and this was during World War II, so it was very hard to come by cameras. The film was war surplus. The chemicals were war surplus. And so it was always a little bit chancy as to whether something would actually come out very well or not.

But it also made an opportunity, because there was a photo dealer nearby and I managed to get a job with him developing and printing films for him and his customers. So it provides an income.

DSM: So you were born in the year Hitler became Chancellor. You were, I guess about five or six when the war broke out in Europe. So you already started school in World War II. What was it like in school then?

IMJ: Well actually I don't have too many memories from those early days, but one of them was hearing the announcement of the bombing of Pearl Harbor.

DSM: Where were you at that time?

IMJ: I was with a cousin's family, an aunt and uncle, in Fall River, Massachusetts. We were listening to the radio and I could tell by looking at the adults that something serious had occurred.

DSM: When did you learn to read?

IMJ: That, I don't remember. I enjoyed reading as far back as I can recall.

DSM: Let's go back to starting school. Were there lots of other children around in that sort of a neighborhood, or were you pretty much a loner as a child?

IMJ: There were a reasonable number of children there. I'm Jewish, but there were very few Jewish children in that part of town. So as a result, there were occasional unpleasantries. But overall, it was a very good place to grow up.

DSM: When did your family come to the United States?

IMJ: My grandparents on both sides, maternal and paternal, came from Eastern Europe. So my parents were both born here in the U.S.

DSM: Tell me about your earliest formal school memories; teachers that may have made a difference in your life.

IMJ: Luckily, the grammar school that I went to, Mt. Pleasant Street School, was just a short distance from the home. I remember a few teachers. A third grade teacher introduced me to art. Actually one I still remember explaining "The Angelus". And whenever I get to Paris these days, I try to stop in and actually see it.

I skipped the fourth grade. When I went into the fifth grade I had a very difficult teacher. A woman whom, I think, thought teaching meant being very, very difficult with the students. But after a period of time of adjusting to the material I had missed, everything worked out well.

I remember my eight grade class when the science teacher came in and explained that he was teaching science because he was the newest teacher in the school, had the lease seniority, and had no choice but to teach science. So it could have been a better education.

One of the things I do remember in going through grade school, we of course had sports and other activities, that we'd self-organize. We were in organized sports at the time. But I'd keep trying to find ways to really keep busy. And one of my concerns at the time was I might end up being bored, or just not have enough things to do. I'm afraid I've over-compensated for that. (laughter).

DSM: Who were your mentors while you were growing up; either fictional or real?

IMJ: I was rather lucky in high school. I had two teachers that made very long, lasting impressions on me. One Mel Felton, a black man who had capabilities going much further than teaching mathematics in high school. But lucky for me he was there and gave me a very, very good grounding and actually provided counseling as I went on to college. Then another teacher, Abe Bronzbegal, a chemistry and math teacher, who kept me excited about science and different projects and working continually in math and science as I went through high school. Unfortunately, when I was about to graduate high school, the Guidance Counselor at the school was convinced that there was no future in science, nor in engineering.

DSM: This is in the 1940's?

IMJ: This was Class of 1950. I have to keep my decades straight. (laughter) So I went into meet with him, knowing my family really hadn't much experience with college, and he explained that there was no future in science and engineering and that there was a very good School of Agriculture in the County. I explained to him I didn't think that would really fit me very well. Then he asked what my parents were doing at that time. They were in the restaurant business. So he said, "Well let's see, Cornell University has a very good School of Hotel Administration." So I applied to Cornell and was accepted to Cornell. I spent the first year-and-a-half in the School of Hotel Administration.

I was somewhat dissatisfied with that, and I was beginning to learn more about the world. I had a roommate who was an engineer and kept explaining to me that I couldn't possibly get the grades I was getting if I was in engineering. And at the end of the first term, Christmas break, I went back to New Bedford and met with Abe Bronzbegal and Mel Felton, and discussed the whole situation. I decided to go back early and transfer from Hotel into Engineering, which was a rather unusual change. Actually I decided that was best for me.

DSM: So this was your Sophomore year?

IMJ: It was the middle of my Sophomore year.

DSM: When you were talking about photography, was it your interest in photography that kept you interested in chemistry? Or did you just earlier realize that you had really good math skills on the academic side?

IMJ: Right. It's the math, the chemistry, the physics that have always appealed to me. It was a little bit of a disappointment when I really didn't have those subjects when I started college.

DSM: So you've got your degree in Electrical Engineering on the eve the launch of Sputnik, which put an entirely different perspective on the value of an engineering education.

IMJ: Right, but even earlier than that it was beginning to become clear that there was a lot of excitement in engineering and science. The transistor was invented. Computers were becoming very active. One of my last engineering courses, as an undergraduate at Cornell, was a course in a Vacuum Tube Laboratory. It was studying the theory and then actually constructing vacuum tubes. As a Senior Project, I organized a group of students, and we built what is called a 'digital differential analyzer'. It was an analog computer, except it was implemented with digital technology, using parts from an old IBM 650 computer. So a logic element was a large module with two vacuum tubes, two 6J6 vacuum tubes in it performing a couple of logical functions. The memory was a large rotating magnetic drum. So it was rather interesting technology and rather exciting to get involved with that type of area.

DSM: How big was the memory in this?

IMJ: Not very large. (laughter)

DSM: So this is '56, and in 1957 you make a decision to go to M.I.T.

IMJ: I graduated with my Bachelor of Electrical Engineering from Cornell in '56, and by then we were married. I had entered Cornell in 1950, and my wife-to-be, also entered in '50. We met as sophomores, and when she graduated in 1954, we decided to then get married the next fall. Of course, because I had switched Engineering, which was a five-year program, I still had two years left as an undergraduate.

DSM: This is a good time to talk about your wife and family. Family was an awfully important thing to consider, evidently. Congratulations on your ninth grandchild. Tell me about meeting your wife, who she is, and what she was doing, what she's doing now, and your children.

IMJ: We met at Cornell. We were both Sophomores at the time. A mutual friend introduced us. It was somewhat of a blind date. We continued to date through undergrad years; then married. She was in what was then called Home Economics. Now it' called Human Ecology, at Cornell. And we actually shared one course in Food Chemistry while I was still in the Hotel School. So I had the first term of that course, and she always jokes a bit that the course was marked on a curve, and when I left after the first term, everybody else in the class was very, very happy. (laughter)

DSM: How many children do you have?

IMJ: We have four sons. All were born in Boston. The first was born just as I was completing my Master's Degree, in spring of 1957. Then we've had subsequent sons about every three years. So we have four sons all living here, and all are married. And as you mentioned earlier, we just had our ninth grandchild, a boy.

DSM: Tell me about the change from Cornell to M.I.T. Was it an exciting time in the sciences? Who was there? Who did you work with? What did you work on?

IMJ: I've mentioned the Vacuum Tube Course I took at Cornell, and I also had some very good theory courses, in particular, Electromagnetic Theory, with Professor Henry Booker, and another in Antennas. So I was thinking that perhaps that would be an area that I would go into. I debated whether to go into Graduate School and we decided that I'd apply only to M.I.T., and then I'd apply for one General Electric Fellowship, which was a very nice fellowship. If both happened to come through, then I would go on to Graduate School. So I was still feeling my way along. And luckily both did come along.

DSM: Well even an undergraduate degree, just after the war, it was relatively rare to have an undergraduate degree.

IMJ: Right. And there were a lot of exciting opportunities, even with an undergraduate degree. IBM was in its heyday and things were happening, and lots of research opportunities, and some in communications. But I decided that indeed if I could go to M.I.T. I could go on to Graduate work. So I entered M.I.T.

One of the professors I had in that first year was Norbert Weiner, the famous mathematician. There are many, many stories about Norbert. I was taking one of his classes with about seven or eight other graduate students, and the lectures were incomprehensible. So we would take down notes and then, after each lecture, we'd go off and meet for a few hours and try to make sense of just what it was that he was trying to tell us. Gradually we made a little progress here, a little progress there. But halfway through the term, Professor Weiner found out we were doing this and came in and asked to see what we were doing. He said that perhaps we should write a book from these notes. So we said, 'That would be exciting and we would like to do that." So we continued to work on that. And every single day he would stick his head into the door of the room where we were working, and ask one question, "What page are you up to?" (laughter) So the book was finished and published. I always get the title a little bit mixed up. It's either "Non-Linear Problems and Random Theory" or "Random Problems and Non-Linear Theory". (laughter) Actually, it's the former. (laughter)

So that was very interesting and inspiring. And I had another professor very early there, Stanislaw Ulam, who is also known as one of the fathers of the Hydrogen Bomb. He was a very, very good mathematician, and was teaching Probability Theory. Of course we had a text book, but he would always come in and talk about individual problems, and give one a very intuitive way of understanding and working and thinking about that problem; elegant ways. And so I've always built on that kind of approach, ever since.

Claude Shannon, the father of Information Theory, was also there. And Bob Fannow, Peter Allious - a lot of key early people on the subject called Information Theory. Claude Shannon really founded the subject. I got very excited about that subject, so rather than going into the Antennas or Electro-Magnetic Theory, decided to go into Information Theory. And that, of course, has pretty much determined the direction of the rest of my life.

DSM: What was the topic of your Master's Thesis?

IMJ: I worked on a Master's Thesis under Professor Lee, and that had to do with some problems in detection. I worked with another professor who was trying to analyze artistic work expressed in electronic form, that is, make various measurements on, artistic works, art, music, and from that, try to decide what it was that was essential to that particular artist, composer, and then be able to perhaps reproduce it. At the time, I never could make much progress on it, because it was a very difficult subject, but an interesting one. I worked more on filtering type of problems. And I wrote my Master's Thesis in '57.

Then for my Doctorate, I worked on Probabilistic Graphs, networks that have unreliable links, things that very much later approximated the Internet, approximated the several telephone networks, etc. So that was very interesting, and an area that I've built on ever since.

DSM: Given the progress of technology, the tools that we're going to have to aid us in mathematical thinking. When you're thinking in mathematical terms, how do you think about that? Do you doodle? Do you think graphically, visualize mathematical problems?

IMJ: Often we'll try to draw something. For example, in applied mathematics and trying to design signals for transmission, one will often draw pictures - geometric representations, very abstract models of those signals - and allow one to think about them a little bit better. Other times, I think an unusual situation, you have a problem, you're thinking about it, worrying about it, and then suddenly when you least expect it a breakthrough occurs. You suddenly see a nice way of approaching that problem.

I still remember an undergraduate course; it was just after I had transferred from Hotel into Electrical Engineering. I had been debating about also going into Engineering Physics so I has taking a math sequence in Engineering Physics with Professor Mark Cotts, another very famous mathematician, KAC. It was a very amusing course.

When you first went in there, he liked to introduce differential equations with what he called the 'snauw plow' or 'snow ploe' problem - you could never really rely on the spelling to get the pronunciation. So I struggled with that course, because I really did have a good deal of background, right up to the final examination. And luckily, he put on a fairly difficult problem, but if you worried about it, thought enough about it, there was a very clean elegant solution. Luckily I did think of that one, and came up with it. Just one other person and myself in the class managed to get a 100 on that exam, and that kind of gave me further assurance about proceeding ahead with mathematics.

DSM: What was hard for you? Well of course, you were raising a family of course, in those days, but on the academic side, what really gave you difficulty?

IMJ: I guess the hardest course I ever took was back in Hotel School - Cooking. (laughter) I could never remember which vegetables were strong, and therefore you should leave the cover off the pot, and which ones to put the cover on. (laughter) Although I did end up spending one summer, between my Freshman and Sophomore year as a professional cook.

DSM: Where were you?

IMJ: This was at a country club in Massachusetts. Actually an exciting thing happened there also. I was working under a German Chef, a short man with a very short temper. He used to chase me around with a knife. (laughter) He also taught me quite a bit. One day he would be off, so I would be in charge of the kitchen. A group came in to play golf and stopped in the kitchen and said they wanted to have Lobster Thermador for their dinner that night, could I prepare that? I said, "Oh, certainly." They went out, and I got on the phone to find out how in the world you made Lobster Thermador.

I called the chef over in my father's restaurant, which was several miles away. And over the phone he explained to me how to take the lobster out, how to cook it, how to make the white sauce, and put it all back in the shell, and paprika, and broil, etc. So as I was making the white sauce, I tasted it. It didn't seem to taste right to me, but I didn't really know how it should taste. Of course the usual thing happened, we sent out all the dinners, the Lobster Thermadors, and about an hour later the whole party came into the kitchen, saying it was the best Thermador they had ever had, and "What else had I done that day?" I said, "Well I baked these pies and I have some cakes." They bought everything! That probably convinced me that maybe I should leave the business while I'm still ahead. (laughter)

DSM: You finished your Dissertation at M.I.T. '59?

IMJ: In 1959, that's right.

DSM: You were admitted as Doctor of Science and you decide to become a teacher. Tell me about that.

IMJ: Well again, I wasn't quite sure if I wanted to teach or go out and enter industry. I explored both about the time I was finishing what's called SEDPhD, a Science Doctorate. But I had an invitation to stay on and teach at M.I.T. as an Assistant Professor.

Given the people who were there, the tremendous quality of the school, and the fact I did like the idea of teaching, I decided to stay on as a professor on the faculty. So I joined the faculty in 1959. One of my early courses was a laboratory, and that was always a challenge; to find things to be both educational as well as interesting and exciting enough to students so that they would really proceed ahead and work on these. It was a large, early laboratory, and that was a very interesting challenge.

But I also taught graduate programs. Fairly early on, another professor, Jack Rosencraft and I, began to teach a course on Communication Theory and The Application of Information Theory. At the time, a lot of people didn't think there really were any practical applications for applied mathematics. But we worked at how one might be able to use this in the future in communications.

DSM: The time frame here is about when?

IMJ: This would have been about 1960-61. So we taught the course and then began to write a textbook. The book eventually was published in 1965 - "The Principles of Communication Engineering". That was also a very, very exciting experience.

Teaching always fascinated me. First of all, I like to teach courses three times or so. The first time you do it just to learn the material. You are presenting it to students and staying a day or two ahead of them to really try and understand it. The second time, you feel much better about it and so you could get a good orderly crust on. And then the third time through it could be very professional.

Of course with teaching you take in a lot of material. I mean, so much is happening in technology and in engineering. You would try to bring it together to set the size, find some way of presenting it in a very clean, clear fashion. Then you present it. The thing that always worried me a bit is that in getting there yourself, you're walking along a very narrow precipices. If you make the wrong turn, in just doing something a little bit differently, you could very easily fall off this precipice. It's very important that the students do occasionally fall off the precipices, so they understand what it is, and why you are taking the particular path and route that you're taking. So I always found teaching quite interesting.

There was another thing that always struck me teaching at M.I.T. - which by the way is a super school with a tremendous emphasis on teaching, even though it's well known for its research - but you go in, and perhaps give a course to a class that had completed its PhD qualifier. So it's a group of students that have been very, very carefully selected, and then had managed to pass the qualifying exam, which was quite a filtering examination. So you would be teaching these students, and after about the first week, you were to separate them into the bright ones, the medium ones and the not-so-bright ones. Then you had to continually catch yourself, and realize that these not-so-bright ones were really very, very bright.

DSM: Who were your colleagues in your age peer group at that time? What names stood out?

IMJ: Well, Jack Rosencraft was a little older; we worked very closely together for a long period of time. Bob Gallagher, a professor at M.I.T., who had just retired, was a very, very excellent teacher and theoretician and has written several very, very good books. We've remained close. I still go to M.I.T. on Visiting Committees and interact with Bob.

DSM: How about the students? Are there any particular students that you remember, from this time?

IMJ: One of them, Jerry Heller was a graduate student when I decided to move to California and start to teach at the University of California, San Diego. He came out with me to San Diego, and finished his M.I.T. Thesis, here. Then later, when I started LINKABIT, which we'll come to, I sure; he was the first full-time employee. I also remember another student, Dave Forney. As I mentioned, in these classes there were various levels of students. Dave Forney was off the chart, at the top end, and we've remained very close ever since. He's currently part-time faculty back at M.I.T. Tom Kayloff is a professor at Stanford. There are a whole set of very, very good graduate students that I went through M.I.T. with. They then continued on there or elsewhere, and then I had students that have gone on to become either academics or taken on positions in industry.

DSM: I want to bring you back to, if I may, to Mel Felton and your early career. You're a Jewish kid living in Bedford, Massachusetts with a good friend and counselor who is black. This is a time when Hitler is still alive, and American society for the most part, is very strictly segregated, in terms of race. Can you talk about how those things effected you?

IMJ: Well as I mentioned, I don't think Mel Felton would have been teaching in a high school in New Bedford, Mass. if he had broader opportunities, because he was very, very capable. And similarly Avon Spiegel teaching chemistry, had wanted to go through medical school, but had run into problems. They were excellent teachers, and that was very fortunate for me.

Of Course at the time one was not quite aware of what was happening in Europe with the Holocaust. We heard occasional stories, but I don't think until after the war it really made too much of an impression. Then we began to get a lot more information about what had happened.

Growing up in New Bedford, it was clear that there were tensions and problems, but nothing too strong. And our high school was a very well integrated school. I played football for a couple of years, not very well, but with a number of other black students, as well as students with a variety of backgrounds, and I don't really remember very many tensions because of race or religion once you were beyond the grade school level.

DSM: When you were at M.I.T. from '59 to '66, this was another extraordinary period of American history - the beginnings of the Civil Rights Movement; John Kennedy was killed in '63... Where were you when John Kennedy was assassinated?

IMJ: Everybody always remembers, of course. I was actually in my office at M.I.T., talking with a student, and another student came in to tell us the news. Of course, nobody believed it, and ran off to find a radio to listen to the news. When I heard that was verified, I left M.I.T. and walked from M.I.T. up to Harvard Square and then took the bus to our home in Arlington. One of our sons was going to have a birthday party late that day, and so the debate was whether to carry on with the party or not. We decided to have a subdued party. But it was obviously a very, very shocking event. We were very strong supporters of President Kennedy, and it was a difficult time for the nation.

DSM: In 1967, you make a big decision to move west. Can you tell us a little bit about that?

IMJ: Well actually it started a little earlier. Going through college we always had friends who talked about California, and so on. So we decided, in the academic year of '64-'65, to take a leave of absence from M.I.T. I had been offered a resident Research Fellowship at Jet Propulsion Laboratory in Pasadena. So we accepted that and went on our one visit to California. We found we enjoyed California very much. Of course, that was also the period when I finished the homework problems for the textbook, so I had a little time to do that. We had a little time to tour up and down the coast and we found San Diego. We were impressed. We saw Berkeley, Santa Barbara, and so, California made a very positive impression.

We did a lot of camping. We had three children at the time. To come here, we bought an old van. Vans were not very much in use at the time but a real estate firm had an old Ford van. We bought it used. I built a shelf across the back, put a mattress so the kids could sleep there. Then we had a canvas tent and all our belongings underneath it. It was actually fun driving cross-country, stopping and camping in lots of wonderful places. But also knowing you had, not only the whole family, but all your belongings all in this one constrained space.

DSM: How long did it take you to get there?

IMJ: We took about three weeks to drive cross-country and we spent nine months out here. On the way back we drove up the coast to Vancouver, and then across Trans-Canada-1, which had just opened. We camped our way across Canada to Montreal, and then drove back down to Boston.

Just after arriving back in Boston, I had a call from Henry Booker, this professor that taught Electro-Magnetic Theory back at Cornell. He told me that he had just decided to leave Cornell and come out to a brand new university here in San Diego. He had been trying to attract us to teach up at Cornell, but we decided although it was a great place to be an undergraduate, it was probably but really not a place we wanted to live full-time.

I told Ron I remembered San Diego and it sounded exciting. I would come out and look. Joan couldn't come with me at the time, so I came out. It was quite impressive.

There is one interesting thing I always tell people about; in La Jolla we were staying in a motel which was a converted horse stable. And one night we walked downtown near what is now, the Museum of Contemporary Art, and next to it was a bookstore that was open all night. I figured that any community where's there's a bookstore open all night can't be all bad. So that was what really impressed me.

We went back and talked it over, and as much as we liked California, and the idea of moving at a new university, and an opportunity to really start something from scratch, we had all our family back on the east coast, friends, and career. So we called up and turned the job down.

DSM: That's M.I.T. for goodness sake!

IMJ: Absolutely. For two days, we were miserable with the decision. The second day turned out to be a really rainy day, and I left M.I.T. and took the subway up to Harvard Square. I got out and there were these huge crowds waiting for the buses to Arlington, and people were pushing their way through. I finally managed to get on the fourth bus, and I was standing in the rear of the bus, I had wet clothing, everybody's clothing was wet, and about halfway to Arlington, the clothing began to dry and this terrible odor filled the bus. I got home and I said, "You know, we really do want to go to California." (laughter) So we called up and said, "Well, we're ready to come." And the position was still open, so out we came.

DSM: I should say, since we are doing this in front of the screen, the rest of us in the room are looking out at an absolutely spectacular spring day, looking out at the Pacific.

Moving from M.I.T. to the University of California at San Diego, you moved at an interesting time in the history of the United States - 1967 we were still in Vietnam - 1972 with the whole Watergate era. Describe the atmosphere at the University of California when you got here.

IMJ: Actually let's talk about before I left M.I.T. At M.I.T. there was quite a bit of concern about the Vietnam War. There was, I think, one of the very first ads that appeared in the *New York Times* by academics protesting the war. I did sign that ad. I was active at the time.

When we came out to San Diego, there was still a lot of this concern. I remember one event. There was a Marine Corps recruiter, who would each year, come to recruit students on campus. And a group called 'Students for Democratic Society', SDS, met this recruiter and argued with him and then one of them shoved him. They didn't hurt him but that obviously was against the rules.

I then found out that I'd been appointed to the Student Conduct Committee. The way the University of California appointed you to committees was that they send you a letter. If you ignore them and don't refuse, then you are automatically on the committee and I didn't even realize this at the time. The group of students involved in this incident decided that they didn't want to simply have a reprimand from the Dean of Students. They wanted to have a full-blown trial. They looked up the rules. They were entitled to a trial by the Student Conduct Committee and so I had to show up one day at the trial. It was an older part of the campus. UCSD has originally been a military camp so there were Quonset huts, and the trial was to be held in one of the Quonset huts. There was just this huge group of students outside the hut, and I kind of worked my way through. They were checking who was going in. They would allow each one of the defending students, defendants, to have two others to join them. So they all went in, but of course that almost left everybody outside. And the faculty person that was chairman of the committee decided that he didn't want to allow all the spaces to be filled. That wasn't quite the right decision because the kids climbed up on the top of the Quonset hut and started pounding. I don't know if you've ever been inside a drum or not, but that was the effect. So quickly, the rest of us voted that we should move to a much larger auditorium and hold the trial over there.

It was an interesting trial. The first thing the Dean of Students brought was a videotape, and claimed there was some evidence on it. The students again, they had read the rules very carefully, claimed that they had not had a chance to see and review this tape, so they wanted to have some time off.

Further, there were a couple of students, charged where it was clear that the charges against them were really circumstantial and second-hand information, so we tried to dismiss those charges. But they refused to have the charges dismissed. (laughter).

DSM: This is '69, did you say?

IMJ: Yes it was probably '69 or '70.

DSM: So what happened at the trial?

IMJ: The trial was adjourned, which gave the students a chance to review the tape. Then we came back to conduct the trial. We finally convinced the chairman of the committee that the best way to deal with this was to let everybody have their say. So it started early afternoon and I think about two in the morning, finally, the last student said everything they wanted. Then we had asked all the questions. We indicated to them that whatever our various sympathies might be, we certainly recognized that the University was a place for free speech, but not for physical pressure; and adjourned. We then found the students guilty.

But whereas everybody thought there would be a major explosion from this, because of the fact that they had been able to say everything, they actually came up and thanked us. They made their points. We listened. The students were put on probation and nothing ever really came out of it, but it was somewhat of a tense time.

There was another time that students decided to take over the building I was in. It was about two in the morning. I was working in the building, and a bunch of students suddenly showed up with paper bags over their heads. They didn't bother me, and I didn't bother them. So when it finally came to the end of night, I left, and eventually they got tired and left the building also. So there were those types of tensions.

A little later there were some stronger tensions. You mentioned Civil Rights areas. UCSD has multiple colleges and after I came in the first college, I moved on to John Muir College. I was then was part of the committee to work on the beginning of a third College. That College was supposed to have significant community orientation; it was focused on being well integrated.

One of the faculty asked a group of what we now call African-American students, and a group of Chicano students, which was called the Chicano Club at the time, to review the plans and help and make suggestions. One day I was bringing around a new faculty member, and I had an urgent call. I was also on the Committee of Educational Policy, and I was told to come to the meeting in the Chancellor's Conference Room. I arrived late, and there was a room just full of the students from the two clubs, and a small group of faculty, and the Chancellor. A student at one end was reading the Lumumba Septa Manifesto. And another well-known student, Angela Davis, was there. They were essentially saying that this school had to get rid of all the irrelevant subject material that's usually taught, and teach subjects more pertinent to black and Mexican background. Then they basically said, "You have one day to review this and agree to it, and if not we really can't guarantee what might happen. " On the way out, one of the faculty members, who was black and an advisor to one of the groups, said, "This really wasn't what was intended." And they really almost physically shoved him and said; "Now this isn't our approach. It's what we want to do." So it was a tense period.

In any case, we finally worked it out so there was a period of negotiation that lasted several months. I spent several months negotiating with Angela Davis and others, faculty and students. She's a much better politician. She's a very bright woman, but we were not making too much progress. Again, it was a very tense time, so there was another faculty meeting of the whole academic senate. They had made a demand that recruiting, selecting faculties, deciding on promotions; should be done by the students and not by the faculty. We said that was not acceptable. So it went to the academic senate, and it was a very tense meeting with students ringing the building, ringing the room itself. Most people didn't feel comfortable speaking out. I and a few others did, but the faculty felt very insecure about it. So in any case, they voted in favor of the students. I think there were just five votes on our side.

When I went home that evening, I had 20-25 calls where people said they didn't feel comfortable speaking up, but they did vote with us. But there were only five of us. (laughter) It was that type of period. That, by the way, eventually did work itself through, and now, is a very, very good college. But it took a while. The Chancellor at the time, Bill McGill, was very, very, capable. I knew him out here as a faculty member and then as a Chancellor. Very shortly thereafter he left to become President of Columbia University, and has written about those times as well. Some were tense times.

But all during that period the University, despite the tenseness, we really never had the major problems that occurred at Berkeley, and managed to continue to improve, rapidly, academically and as a research institution.

DSM: All the time this is going on, this is a young professor, with new family. You were also writing and publishing, given the length of your list of publications. You obviously enjoy it. Was the textbook your first publication?

IMJ: I don't think it was the first publication – I probably published some papers as well - but it was a very substantial publication where one could give a whole story about one's approach to digital communications, communications in general and the practical applications.

DSM: This is an impossible question, but which of your writings and papers pleases you the most now, looking back, or had the most effect on your career?

IMJ: A lot of what we do is based on what we call 'coding'. And at the time, one of the subjects was something called "Sequential De-Coding of Convolution Codes". Obviously I won't get into great detail on this. (laughter) This is something that, you send a coded signal over a noisy channel, and therefore you get a noisy version at the other end, and you try to reconstruct the original signal. There are bounds set by information theory about how much noise one can have and still be able to get back an accurate record. But then there's a question of - how do you do that? There was a technology developed actually, by several back at M.I.T., called 'sequential de-coding', which was one of the first practical ways of pulling back out the original signal from the noisy signal. The question was, how much computation is required to do that? So there was one paper that did up KPL, with Elwyn Berlekamp, where we managed to get a measure of the amount of computation required. So, both the thinking that went in, the kind of approach and the practical implications has been very, very interesting and many of the things that I've done since.

DSM: What were you working on at JPL?

IMJ: Applications and information, at the time. JPL was very interested in deep-space communication - sending out initially rockets to the moon and then out to the planets, and wanted to get back communication from them. So it was really an ideal type of medium for using these concepts of information - the re-coding, de-coding. So I worked very much on the underpinnings of both the modulation coding that one would use for deep-space communications.

DSM: If there were one of your papers that you wrote, that one could know and prove out, would it be your textbook of principles?

IMJ: I think the textbook has a lot of the thinking. I'm very pleased with the way that came out, and the way it has been used.

DSM: Everyone knows that academics, and especially engineers, are just terrible business people. (laughter) During this period you were also in the midst of starting, I gather with a group of part-time people, something that eventually became LINKABIT. Would you tell us the story?

IMJ: Sure. When I first moved out to Southern California from M.I.T., there were a lot of defense companies around Southern California. They heard that I had this communications background and knew me from M.I.T. So I had many, many requests for Consultant. Usually, when you are teaching, you might consult one day a week or so, and obviously I couldn't handle all of the consulting requests.

One day I went up to a meeting at NASA Ames, and flying back down I was with two of my friends who were professors at UCLA, Andy Viterbi and Len Kleinrock. And I mentioned that there was all this consulting potential that I couldn't actually handle myself. So one of them suggested that perhaps we should set up a company and we can share consultant. I said, "Well that would be fine, as long as I don't have to be involved with management."

So we set up LINKABIT at the end of 1968, as a 'day-a-week' type of consulting company. After about nine months it was clear that one couldn't continue that way. It was either too much work, or too many problems having a company to try to do this on a day-a-week basis. So we hired our first full-time employee, Jerry Heller, who had been a graduate student of mine. Then shortly thereafter, we had hired a second person, Andy Cohen, who I've known from working with on the east coast, and he had just moved to California. Suddenly it began to grow. I remember the third person we hired, Klein Gilhousen, a person I had known as a technician on one of the consulting jobs that I had, and then had left and gone elsewhere. I don't think he had an undergraduate degree, but he was very, very sharp. And so I approached him to see if he would join us. And at the time, we had a small office above a store in Los Angeles. It was actually an old dentist's office. So he came in and we talked about all the things we were doing at the time, for consulting - really applications of coding theory to different types of government programs. So I explained to him these various things, and on the way back out he said, "Boy, you know it's exciting. I can see myself being well occupied for the next three or four months. But what are we going to after that?" Now he was with me through LINKABIT, now through Qualcomm, and every so often I remind him that he asked what we were going to do after that! (laughter). Of course, there was no lack of things to do. So that turned out to be a prescient question. (laughter)

DSM: Tell me about some of the things that people in the projects were working on at the time when he was beginning to ask these questions.

IMJ: LINKABIT, for the first ten years, was largely working on defense-related programs or NASA-related programs. At the time, if you were a very small company, nobody ever heard of you as a university professor with no business expertise, so it was harder to get commercial business. But with the government, if you had a good idea you could send it in, you could win a contract and proceed ahead. So we were involved with several interesting programs. Some had to do with coding and de-coding. One had to do with working with NASA, of digitizing a television signal - compressing it and sending it over satellite to another location.

This was back in the early 1970's when we became involved with that, and came up with a scheme for doing that. We actually set up a link to demonstrate it between Stamford University and Carleton University in Ottawa. They could conduct lectures back and forth over this link. Of course then everything was much bulkier than it is today. So working with NASA we set up a digital, compressed signal and satellite communication system. At the time, the components that one had available to do this were rather bulky, so it really wasn't quite a commercial possibility. Although, later we did go and touch on that into the transmission of television from satellite to cable headed to home. So that was a very interesting project.

There was another project we worked on. We got into that in an interesting fashion. We had been working coding and de-coding equipment, and that led to systems that you might use this equipment in. The government and the military were interested in satellite communications and allowing many users to be able to communicate among themselves and back to headquarters, etc., through the satellite. So they were interested in the use of time-division multiple access, the multiple access of a satellite by many users, by sharing time.

IBM wanted to bid on the program. We had been working with them, a bit, on a few other programs - character recognition and compression. So they came and asked if we would work them on this particular program and bid it. That was a great opportunity, but it thinking about it, they had a system where there was a single, large computer controlling all the various functions of the system, and much of the other signal-processing, etc., was done is specific hardware – so in thinking about it, we came up with the idea of using, rather than one big computer, many small computers.

Now remember, this was before microprocessors, etc. It was somewhat of a foreign concept. So we had a large argument with them. We digit-designed with these multiple small computers – which of course one would have to design because they were weren't off the shelf - showing the great advantage to building the system that way. And sure enough, we came up with the design that was much less expensive, much less bulky, but we couldn't quite convince them that, that was the right way to go.

They thought surely there had to be something wrong with this approach. So they did their approach as the prime approach, and ours, in an appendix - as a possible alternative should they wish to explore further - when unfortunately it was a seven or eight million-dollar program. They lost, I think, by ten or twenty thousand dollars, to another company that I won't name. So the idea didn't go any further at that instant. By the way, that other company was never able to build a good system. I was always sorry that this system didn't get itself built. However, we had this idea, and we continued to develop it.

A different company came to ask if we could work on an Air Force program. By the way, this is the way a lot of things happen. We're a company that would react to whatever opportunities might come along - where we thought we could make a difference, and provide something that could be useful and clever. They came to us and said that they had to bid a particular piece of satellite modem. I guess everybody knows the word, modem. And they didn't have that expertise, and could we design that modem for them. And we said, "Sure, we'd be glad to take that on."

We had this idea of using computers to do a lot of the processing that we just developed on another program. So we decided to use that in this satellite terminal. Well nobody had ever approached doing a lot of the processing for a satellite modem in a computer at the time. So we had to go out and give lectures at Lincoln Laboratory, Aerospace and other government labs.

DSM: I thought we were still talking here about before l980.

IMJ: Early 70's. It was probably 1973 or something. There were no single-chip microprocessors at the time. They eventually decided to award a contract to us, and to another competing company. We were a sub-contractor to; I think it was Sylvania at the time. We went ahead and went through design reviews. They came in, and the specifications said you had to do this, this, this, and the other. And we're spending three days saying, "No, we could do it that way, but why don't we do it this way." And at the end of the three days they came back and said, "Okay, you are free to go ahead and design this the way you like." So that moved ahead in a very promising fashion. And suddenly the government realized that with the two contractors they didn't have enough money to support both, and the company we were teamed with wasn't doing quite as good a job on the rest of the program, and so that program suddenly got canceled.

So again, we scrambled a bit. But there was another program working with Lincoln Lab - a new experimental satellite system called 'Les 8 and Les 9'. The Air Force had heard that we had this novel approach to satellite terminals. Here was a very complicated satellite system, and could we design a modem for them? There was already work at Lincoln Lab, but could we go ahead and try using our approach? We did that, and went through a design for that.

We were very late getting into the game and suddenly had a call that the satellites were being prepared for shipping down to Cape Canaveral to launch. So the only opportunity we would have, prior to launch, to test them out, was to take our equipment back to Lincoln Laboratory, outside of Boston, and do the testing. So, again, we said, "Sure, we'll go ahead and do that." So we packed up the equipment in boxes. We shipped it on the airplane as 'baggage' and almost everything got through. One radio got a terrible dent in it, but we arrived in Boston, and went to the motel that night. The next morning it turned out to be one of the coldest mornings they'd had in Boston. Nobody's car would start. We finally got someone to come by and get us and we arrived at Lincoln Laboratory about 11 in the morning, and set up the equipment. The people at the Lincoln Lab kept saying, "Well, let's go to lunch. There's no reason to test it. It's not going to work for several days." And I said, "No, no, no we have to go ahead and try this." It had a very complicated signal-link structure. They said, "Well, we'll turn it into one of the simple modes." And I said, "No, let's go for the whole thing." So, sure enough, they turned on the satellite and we turned on the equipment. So it goes through an acquisition phase - the satellite searching for our signal - and we were trying to respond to it properly. So you are waiting and waiting, and suddenly, the message began to go through. So we said, "Now we can go for lunch." So this was going from the terminal to the satellite. We also then had to have a different link to go from the return-link through the satellite, back to the command post. And that was a different type of signal-link.

When we came back and said, "Okay, let's try that. " Well, we tried it and it wouldn't work. We were kind of puzzling about that and began to look at the details. Lincoln Laboratory was a little less formal kind of place, so all the notes that we built the modem and the designs, for the modem and a lot of these signal-processing intricacies, were from hand-written notes. It turned out that we read the notes correctly but they had read their own handwriting incorrectly. We found the error, fixed it, and sure enough we were able to send signals both ways through the satellite. So this was about three in the afternoon. They immediately put a call into the person in charge of that group at Lincoln, and he came up to see this whole thing. We put on the demonstration for him, and he turned to me and said - I'll never quite forget it- "We've been trying to convince the military for years that we, at Lincoln Laboratory, could do work; and you didn't need a PhD in order to understand and implement it." And I said, "Paul, I'm afraid this doesn't prove your point." (laughter)

In other words, the processor in the machine, which we had put together from lots of little parts - it really is what is now called a 'risk reducing instruction set processor'. We had 32 instructions. We had a number of stacks that could easily jump from one [subrateme] to another. We actually had that implemented. Regarding those terminals, we eventually won a production contract. So they went out in the late '77-'78. They're still in use and are still being upgraded by changing the code in them.

And it has been a just tremendously successful project. I might add one more point on that one. We actually added the capability to talk. The Lincoln satellites were experimental. There were other satellites that were going operational, so we had to add mode-stopper to the operational satellites. We had done that, and finished the development, but we were competing with another major aerospace company. And we had this nice small thing, because it was all computerized. They had huge racks of equipment. I went up to see the Commanding General to talk with him to see the program, to see whether we could move on into production. He said, "Look, as a Program Manager for this very large and complicated program, it would be crazy to introduce a new piece of hardware from a small company at this late date - a company that's never manufactured any quantity military equipment. So, as Program Manager, it would be a terrible mistake to make." He said, "On the other hand, as a taxpayer, it's be a wonderful thing to do. So he said, "We're going to do it." (laughter).

DSM: So about 1980 was the big merger.

IMJ: Right. We had been growing. For the first ten years or so, we had done mostly military business. Then we were getting into a number of commercial products. And we were approached by Maycom, located back in Boston, about the possibility of joining them. They were acquiring us really, by a stock-merger. We had been thinking about whether to go public in time. They had a lot of components. It sounded like a very good idea, in the sense that we would be a very vertically integrated company. They were already on the New York Stock Exchange, so that would take care of the issue of providing liquidity to the stock that various people owned. It sounded very positive. Further, the CEO and Chairman of the company, Larry Gould, a person who had graduated at age 21 or 22, with the PhD from M.I.T. So we could get along very well together. So we decided to merge. We went ahead, and I stayed on from 1980 through '85.

We came up with several additional products. One product is called DSAT. It's a very small aperture earth terminal. It's the system used for business communications. We first developed it on a contract with Flumberge', for them to take with the oil exploration vehicles to sites, and bring data back, send it immediately back to the customer, and let the customer decide whether they want to instruct the drillers to continue, to stop, or whatever. It had a tremendous economic pay-off. Then we made it smaller, less expensive and sold the first ones to WalMart and 7-11 stores. And that kicked off a huge business.

We came up with another product based on this NASA television experience, which was a scrambling system to deliver television from satellite. Originally it was going to cable-heads. But just as we were ready to start production of the cable equipment, the professional equipment, we were told that there were problems in Congress, that people with backyard dishes who had been receiving these signals (HBO, for example) for free, they could understand that it could get scrambled and they would have to pay for it. But they at least wanted to pay for something and have access, and they could never afford a professional quality de-scrambler. So we suddenly had to stop and develop a de-scrambler that would be a commercial consumer product - inexpensive, reliable consumer product. Luckily, a year or two earlier we had a few of my people go to schools like Cal-Tech, M.I.T., to work on some technology for designing integrated circuits on a computer, which, again, was just beginning. We were beginning to do what I called our 'homework problem'. You know, do little simple chips and learn about it. And suddenly we had this issue of designing a commercial de-scrambler. The new way to do it was to take all the very complicated technology and put it on silica, on chips. So we started working on that, designed the three chips that would implement a lot of this technology. All three chips essentially worked the first time. And this was with basically experimental software.

We had never been anywhere with this type of complication and it allowed us to, in effect, take over that business. The product was called 'Video-Cipher'. After I left, it was sold to General Instrument, turned into a huge business. We set up a very nice factory down in Puerto Rico. Puerto Rico had tax advantages, in that any value added, when you manufactured in Puerto Rico and sold in the United States, you didn't have to pay tax on that. And so here was a product that was essentially a monopoly product being manufactured in Puerto Rico and sold and was very, very popular. General Instrument did very, very well with that product. So we're very, excited about that. There was one other I missed that I should have mentioned. You mentioned Bob Kahn.

DSM: Yes.

IMJ: He's now, by the way, on a Board, and a friend from way back to M.I.T. days. Back in the early 70's, we won a program to lead a group extending the ARPANET over to Europe. And Bob was in charge of that group. So he and I went on a trip over to Europe to meet with the various telephone companies and some of the government labs and universities, to try to get some support in Europe for the APRANET, which, of course, is now called the Internet. There was zero interest from any commercial company. Zero. I mean, they would at least listen for a few minutes, and then throw us out.

We did get a couple of universities and a couple of military labs, and we did extend the ARPANET over to Europe, but there's been quite a change every since then. (laughter)

DSM: So by virtue of climbing up from a group of four up to 1,400-1,500 people working for you in 1985 - you retire.

IMJ: Right. Larry Gould, whom I mentioned earlier, we got along very well, but he went through a mid-life crisis. He felt that perhaps the company should merge, that he wanted to change some of the other officers in the company, etc. He had some concerns. And the Board decided, that rather than doing that, they were going to replace Larry with some other executives, which they did. I was on the Board, but I was over in Europe at the time and I didn't get a chance to influence that as much as I would have liked to. We had all kinds of great things happening, but the management, I didn't think, was capable of dealing with those issues. So I tried to split the company, and the Board did consider it. We had investment bankers look at it. It looked positive, but at the last minute they decided that they didn't want to do that. So after that, I finished the de-scrambler product, and we had also worked on a TV-made digital telephone, and I had a Press Conference for that. Then I retired on April lst of 1985. April Fool's Day. I had to send around an e-mail, and I had to start out trying to assure people that it wasn't an April Fool's joke.

DSM: So this retirement lasted how long?

IMJ: Three months. (laughter) I assured my wife that we'd have lots of time to do things - that every Wednesday, at the very least, we would go out and have lunch together, etc. But there were so many things to catch up on, and so many people that wanted to talk, that I ended up probably being as busy during retirement than I was before.

A number of people that had grown up at LINKABIT with me - LINKABIT had grown at least 60% a year. There was a very, very rapid growth there, so one of the people that had worked with me said, "Hey, why don't we try doing this over again?" I said I would think about it. I took the entire family - my parents, all the children - to Europe. We rented some cars and we took a nice slow tour through Europe. I guess part-way through that tour I decided that maybe I would start Qualcomm as a way to just keep the hand in, to be able to work with interesting people and maybe grow to around 80 people, if we were lucky. So we came back.

On July 1st, after my three months retirement, started Qualcomm. We didn't have any specific products in mind. We did know that we wanted to work in digital wireless communications, but we weren't quite sure what we would work on. Again, our strategy is to have several very good people, but then be very optimistic - listen for things that might lead to - if we could come up with the good idea - to a very marketable product.

DSM: Did everybody know in 1985 that digital wireless communication would work or was practical?

IMJ: Well at the time, there wasn't too much digital yet. The idea of using digital technology for just about everything hadn't quite made the headlines. But we began to open shop, and began to look around. I thought probably we'd do just what happened at LINKABIT with government programs, and for the first several years it would be mostly government business. And indeed, very early on we did win two interesting government programs.

One of those programs had to do with orbiting satellites for military communication systems; how we'd survive with a military communication system. And we began to work with that. In fact, we took that project up through preparing to build prototype satellites. We were teaming with Hughes on that. When the government decided they didn't have the funding to continue, then the program came suddenly to a stop. At that time, we were still relatively small. And I said, "Gee, this is a good idea for commercial applications." But we checked to find out what it would take to get frequencies around the world, to get permission in all countries of the world to operate - because with lo-with orbit satellites, they're not what is called 'geo-stationary.' They don't want to appear to hover in one point above the earth. You need a fleet of them, and they cover all points. And to make it economic, you want to provide worldwide communications. I said we were too small to do that. And, again, one of these fortunate events occurred. Some people came by from Ford Aerospace to talk about a different product, our OmniTRACS product. They asked whether, rather than using trucks, could you could put on automobiles? And I explained that, "No, that the antenna was probably too large to allow it to really be very popular in an automobile. But, if we had lo-with orbit satellites, we'd be able to indeed to that quite well." They went away, and a year went by, and I never heard another word from them. After about a year, Ford sold Ford Aerospace to a company called Loral. Loral heard about the idea and immediately called and said, "Can't we go ahead and work on this together?" So that led to what we called the Global Star System, which we hope to have fully operational by the end of this year. So again, there were some lucky circumstances and some good ideas.

OmniTRACS is a communication system for using satellites to allow trucks to communicate with the headquarters, to communicate with the truck. And the headquarters to always know where the truck is located. A small company up in Los Angeles came to me, again, right at the very early part of the company, and said, "You know, I know there's a market. It there a way to do this?"

What he had told me is that he had already spent six million with others trying to find a solution, and hadn't been able to make a break-through. We thought about it and decided that indeed, we could build a scheme that would allow us to receive a signal from the satellite, but that transmitting back to the satellite would require a very complicated antenna, and I didn't quite see a way to do that. So there was another company who had launched a special package on a satellite, piggyback on another satellite, that would allow it to receive a signal from the trucks and relay it on. So, if the two would gun together, we could have a good system. Well the other company decided, no, they wanted to do it all themselves.

They had already raised already about 150 million dollars and were proceeding, so they didn't want to listen to us.

I still remember in being in an office talking to a couple of our people - Harvey White, Tom Bernard, neither of whom are technical - explaining the difficulties in this antenna. And you might remember that in my education I was, at one point, interested in the possibility of pursuing antennas. I said, "The trouble is you need to have a high-gain antenna, which means it has to always point at the satellite. And you have to have it so that as the truck drives around, it continues to point at the satellite, and it has to do that but be very inexpensive, and be very reliable because trucks have a terrible environment." And I said, "I just haven't been able to think of a way to do that.

You think about beacons on top of police cars. There they stand, spinning around, and they go on reliably. Maybe we can do something like that." Sure enough, we came up with the idea for designing an antenna with a simple probe. Everything that could be used for this application was very simple. Then we went out to a small antenna company here in San Diego to work with them, to get it actually reduced to practice. And we ended up building an antenna that cost about 50 or 60 dollars and was highly reliable. The competitor was going on, and kept publishing these stories about us - that we have a moving antenna and it's going to break and could not be trusted - that the economics of what they were doing were much better than what we were doing. They eventually went bankrupt. And what we called the OmniTRACS business became a very successful business.

DSM: Who was your first big customer?

IMJ: The company was called Schneider. They are one of the largest trucking companies. They're privately held. They had about 5,000 trucks at the time. We were working with them. There were other ideas that people would come up with - media-berths communications, sending communications off the tail of the media, not through a satellite. This other company was working with them. Luckily we convinced them that ours was, by far, the best approach. And they did go with us.

They now have 13-14,000 other trucks equipped with this product now. They're worldwide - about 270,000 trucks that are equipped with these terminals. It's been a very, very successful product.

Another government program that we bid on, and won, had to do with HDTV. It was a contract request put out by DARPA, a defensive advance research projects' agency. And about 120 or so teams of companies responded, trying to win the contract. We bid by ourselves, we meaning Qualcomm, and proposed an all-digital transmission and compression system for HDTV. We actually were one of three companies, but the other two were teams of companies, that won. So we began working on all-digital HDTV.

About two months after we won the contract, the White House decided that the U.S. should not have an industrial policy. By that they meant one thing, that if you had defense support for a program, you could not commercialize it. It had to be one of the craziest things that ever occurred. In any case, we suddenly had to stop the possibility of the work we were doing, in applying it to commercial uses, and focus on only the government uses, which we did. But shortly thereafter there was the competition for HDTV programs moving ahead with digital compression analog transmission system, which was really not the right way to go.

There was a lot of panic in the U.S., and feelings that we can't let the Japanese industry stay ahead of us. We had to find a way to compete. So they had a competition. Unfortunately we couldn't enter with our all-digital system, but, although we didn't talk about it with them, the group that had done video cipher at LINKABIT had split off and been sold to General Instrument, did propose an all-digital system, and of course the world did swing over then, to go all digital. We kept our military program going at a low level. And now it may be coming back as a commercial program.

There's a lot of interest in replacing film as a medium for distributing movies. And the digital projectors are now getting good enough that you can find a very clear contrast, excellent color picture from a digital projector. So we have been working on a system to support that by providing the distribution of a compressed signal to the movie theatres, store it locally, and then you can show one, two, three, four, whatever number of screens at any given time that you wish to. So it's very flexible, and it has enough protection that the distributors can keep track of how many times its used, and charge appropriately. Moreover, because it's all-digital, you don't see the noise that you see very quickly on a normal film. So it turns out to be actually a better experience and the pricing is coming down to a point where it's becoming quite practical. George Lucas just announced that he's going to use this system for showing the next Star Wars film in several theatres. By the time many other people watch this, perhaps it will be old hat, but we kept it going long enough, and now it looks like it has potentially interesting application. So we're pursuing that.

Now the one that has gotten the most notoriety, or interest, and certainly produced a max amount of growth for Qualcomm, and has had now major impacts world-wide, is our work on CDMA - Code Division Multiple Access for mobile communications. Originally, when we started the company, we looked around for possible contracts, and I went up and spoke with some friends at Hughes. They had just bid on a mobile to the FCC, actually put in a filing, on a mobile satellite system which would support mobile voice communications over the continent. They asked us to review the proposal they had made to see if it was technically correct, or whether there were some things we might be able to suggest improvements on.

Driving down from Los Angeles in the car, it suddenly came to me that the use of co-division multiple access would allow a more efficient use of the satellite - more users for a given satellite - and therefore make it more practical. So when we got back to San Diego, we were still eight people, we started a couple of people looking at the various possibilities of using co-division multiple access. I think for the first two days nobody wanted to even bother thinking about it, but I finally convinced them.

Klein Gilhousen, whom I mentioned earlier, began to work on it, in particular and we came up with some ideas that appeared quite promising. So we went back up to Hughes to explain these ideas and they almost through us out, but they couldn't see any holes. Eventually they supported us to do computer simulations and then to actually build a satellite simulator and a terminal to put in a car that we could demonstrate that everything was behaving exactly according to theory.

Well, it was clear that the hearings at the FCC were going to go on many years, therefore, there was no sense in really pursuing this at the time, given that we're still a very small company. So we set that aside, and went ahead and worked on our OmniTRACS, and we had the first major contract with Schneider Trucking Company in the fall of 1988. Once we did that, we were kind of over the hurdle with OmniTRACS. It was now going to be commercial.

Then we began to focus on the CDMA. But rather than looking at it in the satellite context, let's look at it for terrestrial, for cellular communications, what is now called 'Personal Communications'. In November, December and January, a number of us worked on it. Klein did a number of simulations, and everything was looking very promising. We went up to the closest company in the cellular business to us, was Pac Bell Cellular. They were just up the coast a little way. And we explained these ideas. Luckily, they had someone who was technical, Bill Lee, who was technically very good, listening. And they also knew our reputation. But of course it was such a foreign idea that they were skeptical. Moreover, the cellular industry had been seeing significant growth in the late 80's. So about a year before we came to see them, the industry had said, "Hey, in looking ahead, we have to change over to a digital system." And they had a competition for how to do that.

There were two approaches being proposed. Something called 'frequency division multiple access', which are very similar to radios where you change a radio dial and it changes you to different frequencies; and 'time-division multiple access'. By the way, back at Lincoln we had built the very first time division multiple access telephones, so we were quite familiar with that technology. But the industry argued over this, and companies such as AT&T, Motorola, supported frequency division multiple access. Other supported time division multiple access, including the company that we had done the work for. Well, they had a vote in January of 1989, and time division multiple access won the vote. So the industry decided to go with time division.

Code division had not been considered at all. Although some labs had looked at it, nobody thought it could be done practically. And that debate was rather bitter, so people were just glad to get it over with. So later we showed up saying, "Hey, you should think about code division." (laughter) We said, "You know it has this great potential for much more capacity and quality." They said, "Okay, work on it a bit further and come back and talk with us."

So, we did that over a period of a few months and it got to the point where we decided that perhaps we ought to present it to a larger group. So I wrote to what is called Cellular Telephone Industry Association, and told them that we had this idea, that we know that decisions have been made, but this looked sufficiently promising, and at least people should be aware of it. And they agreed to set up a public hearing in Chicago, on June 6, 1989, and Klein and I went back to that. I made the presentation on CDMA, and I figured on a 50-50 chance that somebody might find a hole in what we were doing, because we were not experts on cellular communications and the various intricacies of cellular and radio propagation of those frequencies. But nobody found a problem.

So, working with Pac Bell, we decided to go ahead and build a demonstration system. We had people working day and night, with just tremendous amounts of effort and good thought going into it. By November of 1989, not even six months later, we sent out letters to the world, inviting people to come in over a week's period of time, in reasonable sized groups, to see this demonstration, and to go out and drive around and try the system. Of course the portable telephone was a huge box, and fit in the back of a van, because we hadn't made it small. But it had all the key features of code division that people didn't think would work, areas that we had solved the problems, and had come up with new inventions and implemented them.

So the very first day, on Monday morning, people came in. Pac Bell made a presentation. I made a presentation, and Klein described how the drive was going to occur. Butch Weaver was in the back of the room and suddenly he began to wave to me, to keep talking. So I got up and started to tell them more about CDMA, and telling them more and more. Well, I talked for another 45 minutes or so. Luckily, nobody really quite picked up on it. And I suddenly got another wave from Butch that things were okay.

What had happened was that we had two bay stations, and we used GPS, Global Position System, timing signals, to synchronize the two bay stations. Well GPS was still early and wasn't a full constellation. One of the satellites had a problem, a hiccup, and sent us out of sync. And until he discovered that was the problem, we didn't have good operation. Well anyway, people went out, the system worked fine, and we did gain additional support. We moved ahead to try to build a practical system, which meant reducing the very complicated technology to small pieces of silica. So we developed silica chips, and exactly two years later, in November of '91, we invited everybody back to see a nice sized portable telephone - a number of them - we had been working with companies to do all types of measurements, and we put on a presentation.

The industry - which was still terribly divided, mostly still favoring TDMA, Time Division Multiple Access, which also had gone into commercial operation by that time - said, "Okay, we will have a large meeting next month, December, in Washington, and each group can bring in their test results and their performance results, and present them." Well, we made a video and a recording demonstrating the capabilities of our system. We set up a nice system back in the auditorium. The time division people were on first. They played the recordings from their use of the system, and it sounded terrible.

DSM: When was this?

IMJ: This was December of 1991. We then played our system, and we had the video so that you could see exactly how the system was coping with various propagation difficulties. You could listen. It sounded beautiful. And people became believers - many people - not everybody.

A month later, the Cellular Telephone Industry Association met, and decided they would sponsor a second standard and we went through a series of hearings. Finally it took until July of 1993 to finally finish the standard, to proceed ahead and go into full commercial development. The first CDMA system went into commercial operation in Hong Kong, in roughly, October-November of 1995.

So if you think back, we started thinking about this seriously, in November of 1988. It was seven years from kind of a concept using it for terrestrial, to the first commercial system operation. The fastest time going from thought to commercial operation of any such complicated system. Since then of course, it has gained strength. For the next several years, people first said, "It wouldn't work." and then, "Well you can work with few subscribers," and then as you got more and more...at each point it was going to break at the next addition of subscribers. Well the systems at work - we have over 12 million using it in Korea. We have a large number now using it in the United States, and over 60% of the cellular PCS companies are using CDMA. And now the industry, in general, has said that even those that are not using it, most are now saying that their next generation will be CDMA. So it's pretty well now the accepted technology.

DSM: You were talking with Alberto and he asked what is the future for Qualcomm. Are you going to be Intel inside, or are you going to Bell selling the boxes, outside, or a combination?

IMJ: It's an interesting situation, and the industry keeps developing. We - because of these demonstrations we had put on - had developed a design manufacturer to do the software for what's called the infrastructure - the radio towers and the switching equipment that you communicate with, on your little telephone. So we had expertise on infrastructure.

The Koreans were the first country that decided they wanted to go digital and would consider CDMA. They said to us, "Gee whiz, we're behind Japan on cellular things, and TDMA, let's take a chance and go with co-division." So we transferred information about building the infrastructure to them, using our infrastructure background. We kept developing infrastructure.

Then, in the United States, when decisions had to be made on the choice of technology for what's called 'personal communications', and a new frequency band was made available by the FCC, there was a debate between TDMA, another TDMA in Europe called GSM, and CDMA. And one of the issues was having enough manufacturers. So again, because we developed our infrastructure, we did relationship with [Neuratel] where they would build it with their designs and we would have a certain percentage. We also have been developing the chips, and selling the chips to the various manufacturers that provide these capabilities.

On the handset side, it was a similar situation, in that every other technology was delayed. GSM was delayed at least a year by the lack of telephones. The said GSM stood for 'God Send Mobile'. (laughter) As a result, we wanted to make sure that telephones were available. We set up a joint venture with Sony, called Qualcomm Personal Electronics. We own 51% and they own 49%.

They have, of course, the expertise and manufacturing consumer products in large quantity, and are a very well known brand name. We had the expertise on CDMA, so we thought it would be a good combination. And it has worked out very well. So together we developed the first telephones. And it was luckily that we did, because for the Hong Kong systems and the first Korean systems, we were manufacturing the phones in San Diego and sending it to Hong Kong, and selling them in Korea. That was very unusual. Then when they started up in the U.S., we were, for a long period of time the only supplier of telephones. The more traditional manufacturers were late in getting their phones made. So it's very, very important, and we have continued to build on that.

One surprise that's occurred is - despite the fact that Qualcomm is not a household name - by providing a very good product, and providing very good support for it, our phones are actually out-selling Sony, even though the phones are manufactured at the same factory and are very similar phones. So that has turned into an interesting business. But we also supply the Intel, the silica parts that allow other manufacturers to make them. So right now we're still proceeding ahead to develop new models of phones. We're still selling all we can manufacture.

Looking ahead, it may become a box business, a Dell type of business, where inexpensive companies with no R&D involved, but good marketing strategies, probably using the Internet, will take orders and have the phones built to demand. And they will buy the components, such as the chips, from others with that expertise. So it will be interesting to watch to see how this industry goes.

The interesting aspect is that every year you can put more and more capability on a chip. And of course, many years from now they'll look back on the chip we're using today and kind of laugh at them. We have a single chip now, that has on it all the digital circuitry for doing code division multiple access. It has a circuitry for doing the analog mode. That's also used in this country. It has a digital signal processor on it, for converting voice to digits and digits back to voice, in a very efficient fashion. It can do echo suppression and noise suppression, if you're talking on a hands-free kit in a car. We have a powerful computer, all on the same chip, a risk processor, that does the user interface - but now has all the Internet protocols on it - and a browser all on the same chip. Now you cannot only talk on your phone, you can access the Internet. That's what we're now shipping.

When you look ahead a year or two, you'll have more and more processing, speed, lower power - all types of capabilities, and of course continuous communications with the Net, no matter where you are.

So what we think is going to happen is, what you thought of as your pocket telephone will become your laptop computer. Your computing will be done via voice commands and communication, on a small screen, and a portable device. You can work in your office, set it down on the desk, and if the red link will connect you to a larger display and you can use the larger display at that time. The whole industry is continuing to move ahead. I've always said that each stage of starting LINKABIT and Qualcomm, that I could see another decade of interesting things to do. And each year, that decade moves another year out. So looking from today, there's another interesting decade ahead of things that we'll do with mobile digital communications and computing.

DSM: I've got to ask you that question about Global Integration. In a hundred or two hundred years, when people look back on this, and they say, "Ah, Dr. Irwin Jacobs, what impact did he have on the world?" What do you hope they'll say about it?

IMJ: Well I would hope that they would remember me for a few different things. One, as a teacher and writer of textbooks that trained a number of people on the use of digital communications; digital technology for a variety of applications. And secondly, for reading this use of code division multiple access, to provide communications wherever you might be, worldwide in a very convenient fashion. I hope that will have major impacts on how we live, how we're educated and how we get along with one another. And finally, there's always the issue, if you have been successful, on how one might use one's rewards from that, and hopefully a number things that we've been able to support through philanthropy, would also be viewed in a positive fashion, and will be a very good model for other successful entrepreneurs.

DSM: If you could put together a group of eight people at a dinner table, who would you like to have to sit down with you to talk about the impact the technology has had on making the world a smaller place, and where it's going to go in the future?

IMJ: Of course it would be very nice if Claude Shannon were there, because it was his theories that promulgated a lot of what we're doing. But, unfortunately he's suffering from Alzheimer's now, so he would not be available. We used to say that he had more unpublished papers in his filing cabinets that would have made several people famous, if they had published those papers.

You mentioned Bob Kahn earlier. I've mentioned him in being very instrumental in the Internet, and his very fascinating, and very early, ideas on the use of Internet for communicating. I think he's played a very interesting role in these areas.

You sort of want a political figure, and of course, these days one might think of Bill Clinton. I guess Al Gore is very interested in some of these areas, and always quite knowledgeable. I think I would want both of them actually, for current political figures.

The other areas from communication, of course some of the biologic sciences, from the work that done on the D&A, would of course be a fascinating. It's always hard to think through and remember. But it's interesting to get a variety of people together to talk about both the technical aspects and the implications.

DSM: I want to ask you a question about innovation from whence it comes. Of course there must be about ten thousand theories where innovation comes from. From what I've heard you say, this frustration about being unable to solve the problem. Where does innovation come from? Is it a general theory, or is it a combination of things?

IMJ: One tries to leave oneself open for opportunities so people will come in and talk about a problem in the area where they think there's possibly a good application. So if one could solve some technical aspect of it that would get you thinking about that. You can never tell when these might occur; reading in journals; reading about work others have done. I don't read very many novels, but I often will read histories, about physics, about astrophysics. Sometimes in strange places you come up with an idea that might lead to something that could be practical.

Those ideas or issues may go away, and then suddenly be sparked by a discussion you're having with someone. They can happen at very odd times. You can be flying in an airplane and luckily be away from telephones for a little period of time (I shouldn't say that, being the business), but away having a quiet period of time and something would come to you - or you wake up at 4 in the morning and have an idea. Or you may be in a car talking back and forth, and suddenly come up with an idea. It's very strange with innovation.

One of the things I've thought that's always very important, is to have a variety of possibilities open. Don't dismiss things out of hand. Just kind of leave them, and come back and re-visit them every so often, and occasionally you'll make a break-through. At Qualcomm, we try to keep a very intellectually stimulating area, partly because a number of us came out of universities. So I always try to bring in faculty who are on sabbatical, bring in speakers at various times - trying to keep an intellectual firmament.

We are always terribly busy. We can never get jobs done on time, but still, let's go in and listen and talk and have some other ideas. E-mail. We send around possibilities. Let's try this. Let's try that. It's very, very important. It's very useful to swap ideas with other very thoughtful people, and you never can tell what is going to come out of that. And that's been the exciting part of having a company and being able to gather in some very good people and work with them. I've often described a company as being something like a university. Running a company is like being a professor at a university.

When I used to supervise graduate students, a student would come in initially looking for a good idea. And you would talk with them and point them in a direction and away they would go. They would then come back and say what they've accomplished. And you talk about it and re-point them a little bit, and away they would go. So you kind of work back and forth. The end result in that case was a thesis or a research topic as a post-doc product, so the end result was a little bit different, but the mechanism was not dissimilar. Of course at a university you spend half your time working on committees - never coming to decisions of course - but spending a lot of time of committees. I figure in business about half your time may be on business activities or marketing, and so on. So there's that kind of swap-out. But the intellectual side - providing direction to people, bringing in and discussing problems - I view that as very similar as operating in a university environment.

DSM: I think everyone in this room, perhaps by virtue of what we are doing, are very optimistic about the future of Information Technology and its positive impact on society. Can you tell us what you are optimistic about, what you worry about in terms of IT?

IMJ: I am always optimistic about technology and the things that it can do to improve our lives. I think the thing that is still so bothersome in the world is that there are still so many divisions, tribal issues, that we haven't learned yet to get along with one another, to work together to improve peoples' lives – that there is still so much fighting in the world. I think we all expected that when the Cold War ended, that economies would improve, that all these tensions and battles would go away, but that doesn't yet seemed to have happened.

I'm grateful that education is solving many, many problems. Becoming educated not only allows them to make a better living, but also allows them to understand others better and therefore hopefully not battle, but again, we all know of nations that are well educated that have done some terrible things.

So that's the major concern – the major hope is that we don't ignore all these other countries and problems, to provide them with communications and also work to improve their education, and help provide some stability so people can improve their lives.

DSM: One question I forgot to ask you about was about something your father gave you when you were young. Can you tell us about that?

IMJ: Well when I was fairly young, my father bought me some boxing gloves and he was teaching me how to box all the time. That continued on and off for perhaps a year's time until one day I, well perhaps I learned too well and hit him a little too hard. And as a result we never boxed again. (Laughter) I think those same boxing gloves survived and I brought my sons up with those boxing gloves.

DSM: Are your sons in the business?

IMJ: Three of the sons are in the business. The fourth son had been with me at LINKABIT, and after I left, part of the business was sold to General Instrument and he went with that side and worked with General Instrument.

Joan, my wife, and I had a bit of an argument after our son Paul had graduated with his Ph.D. from Berkeley and went for his post-doc in France. He came back and was debating whether to go into academic work, or come to work at Qualcomm. I kept arguing that we needed him, one always needs good people desperately, and my wife wanted him to teach. Ultimately, of course he made the decision, and decided to come to Qualcomm.

Our other sons Gary and Jeff have worked in different ways at Qualcomm. Gary is very active in the educational programs with Qualcomm. Qualcomm is very supportive of the educational programs, K-12, University and so part of Gary's responsibilities are to interact with the educational groups around the city, as well as some assistance with some human relations type activities.

And Jeff is kind of in the business mode. He was responsible for setting up our joint venture with Microsoft called 'Wireless Knowledge.' The one negative I think from my wife and the boys' wives' point of view is that when we get together for family gatherings, we do manage to avoid business for two or three minutes, but not very much longer. (Laughter)

DSM: Tell us about some of your interests.

IMJ: We have a fairly wide range of interests, some of which are educational, so we supported activities at Cornell, MIT, here at UCSD, also at the Technion over in Israel. And that gives us great pleasure and also the opportunity to go back and spend time at the various universities so that's always very, very satisfying. Also I have always been a very strong supporter of education. Having been an academic drop out, I believe that one should support other faculty that are currently doing the teaching.

We are also very active in the arts. Theatre, I'm on the board of the LaJolla Playhouse, that's just very close to us so we're going over there and the Globe theatre, the San Diego Reparatory Theater. So we're very much interested in music, supporters of the San Diego Symphony. It's been an up and down battle over the years with issues of bankruptcy and its always a struggle to keep a live symphony operating in the black these days.

DSM: Did you every play an instrument?

IMJ: I never played well. I played a clarinet and a trombone at one time, but have mostly strictly listened. I have thoroughly enjoyed that. We have the LaJolla Chamber Music Society here that we support quite a bit. They have a variety of programs, with that, other musical groups, the opera in the city, some other chamber groups. We are active with a number of museums, in particular the Museum of Contemporary Art. When you go out of the house you will see that we have a collection that keeps us happy. So whenever I do business travel, Joan will go with me and we will always to to find some time to be able to stop and visit museums wherever we are in different parts of the world.

There's an interesting story going back with the family, I mentioned that with the boys we used to do camping here in this country. We also used to camp around various parts of Europe. I would give talks at a conference and we would rent a camper and camp in various sections of Europe and we always stop. We would do days. One day we would do what we liked, going to museums, and another day what they (the boys) liked. Museums, they didn't really weren't really too interested in them, they would run through them as quickly as they could, but at least they were there.

My younger son, before he was married, was over in Paris with some friends, and called us up and said, "We've been going to all these museums in Paris and enjoying them now, but we found a museum you never took us to, the Musee d'Orsay." And we had to explain to him that it didn't exist back then. (Laughter)

DSM: What advice do you have to offer to future generations, future entrepreneurs?

IMJ: I think there's one aspect of my life, of, for example, starting in the hotel school and then changing over to engineering, of starting in academics and then working into business – that one should be prepared for changes and open to changes. That one can never really know all the opportunities that life can provide, and so it's important to be flexible. And if you happen to make a bad choice, you can always recover, make another choice and move ahead.

So I've been quite fortunate in having these opportunities, and even going into Hotel School. Well I learned business law, I learned accounting, which was helpful to me later. And I married my wife!

DSM: Well, on behalf of all of us here, researchers, scholars worldwide, and future generations, I thank you for sharing your time and experiences with us today. It has been an honor.

IMJ: A pleasure! Thank you very much.