ANDREW VITERBI

An Interview Conducted by

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Interview: Andrew Viterbi
Interviewer: David Morton
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Morton: Tell me a little about your childhood. Were there any influences that led you toward a career in engineering? I'd also like to hear about your education.

Viterbi: I was born in 1935 and immigrated with my parents in 1939 to the United States as a refugee from fascist Italy. My family left Italy because of the so-called racial laws that were anti-Semitic and against all races except the so-called Aryan race. We lived in New York City for a couple of years and then settled in Boston when I was six years old. I essentially went through all the Boston public schools, second grade through high school. I went to a particularly good secondary school called the Boston Latin School. It's the oldest school in the country and goes back to 1635.

Morton: Did you know English at that time?

Viterbi: I learned English at age four, with a little hardship in kindergarten. By the time I was in first grade in New York City I was perfectly fluent. I never had any difficulty in Boston. I don't believe in English as a second language, but I don't think we want to go into that. From the time I was ten years old and looked across the Charles River it had been my dream to go to MIT. I did a five-year program at MIT that led to a Master's degree. It is now the standard program at MIT for the electrical engineering and computer science majors, but at that time it was reserved for the co-op students. MIT had a program to get Bachelor's and Master's degrees in five years combined with a year to year and a half of co-op experience. To fill in, courses could be taken at night. Being refugees, we were economically limited at the time, and for my purposes it was ideal. My father was a doctor, but had a very limited practice.

Morton: Where did you do your co-op work?

Viterbi: At Raytheon.

Morton: Did you work on specific projects?

Viterbi: It was an excellent program. I first worked in the semiconductor area. In those days it was brand new and was called the transistor department. That was 1954. I went on to what they called communications equipment, which were radio links and some early television and closed circuit TV. I actually designed some circuits. Then I went on to a division that was a joint venture with Minneapolis Honeywell called Datamatics. They were competing with RCA in making some of the very early computers. It was still tubes then, believe it or not. I didn't enjoy the hardware, but really latched onto the software. I wrote some diagnostic programs and so forth. That was quite a broad set of assignments. I can't say it had a tremendous impact on my later industrial experience, but it opened my eyes to what engineering was all about.

Morton: You went to the Jet Propulsion Laboratory (JPL) in 1957.

Viterbi: After I graduated with my Master's in 1957, I immediately went to JPL that June. That was three months before Sputnik was launched. I was privileged to work on the first successful U.S. satellite program, Explorer I. More important for my later experience and career was the fact that from day one in my full time engineering work I was exposed to spread spectrum technology. In 1957 neither NASA nor a space program existed. The Jet Propulsion Lab was owned by Cal Tech but operated under contract to, and was entirely funded by, the U.S. Army

Ballistic Missile Command. It was the same command that funded Redstone Arsenal under Werner Von Braun. We did the communications and the command and control for the missiles that were being built by Redstone. We worked under Bill Pickering, a professor at Cal Tech. That was a radio inertial guidance system using spread spectrum technology. That was the first time I learned about things like shift register sequences and other things that have served me throughout my career. When the Russians launched Sputnik in October of 1957, JPL began to convert to the space program almost immediately. The U.S. space program was transferred over to NASA sometime in '58, but Explorer I was launched in March of 1958 with an integrated package. The communications was mostly implemented at JPL. We called it telemetry, because it was really measurement at a distance. Although I worked a little bit on spread spectrum at JPL, mostly I worked on the tracking and receiving equipment, particularly a device called the phase lock loop. It was brand new then. It had been used commercially in color television, but much more so it had been used in coherent communication tracking, which was being done at JPL. That work was more advanced than that of many other places, including Lincoln Labs at MIT.

Morton: The phase lock loop technology is essentially for analog communications, is it not?

Viterbi: It is also needed for digital communications. The receiver has to be synchronized first to the carrier and that carrier has to be tracked. Secondly it has to be synchronized to the bit timing. That is called a delay lock loop, but it's all the same technology.

Morton: Were they using digital communications from the start?

Viterbi: That's a good question. A lot of it was analog, there's no question about that. There probably wasn't any digital technology in the communications of Explorer I. Communications was not done as much as tracking and commands. Commands were digital of course. Digital transmission of communication in space vehicles may not have happened until later. By 1960 we were heavily into digital communications on the theoretical side and doing the first experimental work. What I did at JPL initially, and what JPL was very heavily involved with, was tracking and synchronization. My first book, which appeared in 1966, was *Principals of Coherent Communications*. About half of that book is on the phase lock loop and the other half is on its application in analog and digital communication. By 1960 I was very much interested in digital communication, transmission, modulation and error-correcting coding, analysis of error probabilities, and so forth. I wrote my first papers on digital communications in 1960-62, and by and large they were well accepted. I didn't yet have my Doctorate, so I was taking some courses, but mostly I was trying to write a thesis at the University of Southern California (USC). They had some very good and very dedicated teachers, particularly on the E&M and control sides. Communications was a bit weak. I also had excellent mentors at JPL who are currently professors at USC.

Morton: You finished up at USC in 1962. Did you begin working at JPL before entering graduate school?

Viterbi: No, I began working at JPL and entered graduate school at the same time. My first choice for graduate school was Cal Tech, but Cal Tech didn't want me unless I would go there full time and do nothing else. I was working for Cal Tech, but

Cal Tech had a very snobbish attitude towards JPL at the time. The people at JPL were considered to be the workers. They wouldn't allow one to do both.

Morton: Why did you move to the West Coast after you graduated from MIT?

Viterbi: I loved Boston and I still do, but I was tired of it. I still go there often, and I'm very involved with MIT, and even my old high school. My last teleconference was a fund raising effort for the Boston Latin School. My family were refugees and we were peculiar refugees in that we were Italian Jews. There were lots of Italians and lots of Jews, but the intersection barely existed. We made friends, but no one very close. There was a push and a pull. The push was the weather. The weather in Boston is miserable. My parents were getting older, and I felt the weather on the West Coast would be better for them. We also had relatives in Los Angeles, my mother's sister and some cousins, so that was another attraction. Possibly as much of an attraction was the openness of the West Coast industry as compared to the East Coast. A lot of that has been mitigated over the past forty years. Raytheon was a very good company, as was GTE Sylvania, and many other communications companies, but the opportunity of working for what then was Hughes Aircraft or TRW or something a little more academic like JPL appeared much more exciting and the working conditions were better. East Coast engineering kept a lot of engineers in bullpens. The aerospace industry is also faulted for that, the General Dynamics and the Lockheeds.

Simon Ramo and his colleague Dean Wooldridge, [Ramo wrote the book *The Business of Science*] were the founders of TRW. They had previously been vice presidents at Hughes Aircraft. They really ran Hughes, because Howard Hughes was off doing his thing in the movies. They improved the quality of life and professional standing of engineers on the West Coast dramatically by giving everyone an office, or at least putting a limited number of people in each office. At JPL we had four people in one office. The people I shared that office with were exceedingly good, and it was a pleasure to share an office with them. Also, it was not a big bullpen. It seemed to me that the East Coast was behind the West Coast because of these attractions, and didn't really catch up until the mid-'70s. Companies like Hewlett-Packard ultimately spawned a whole Bay Area entrepreneurial thing, but that didn't yet exist. Anyhow it started on the West Coast and was emulated only much later in places like Boston, North Carolina and New York.

Morton: I managed to lead you off track. Let's get back to JPL.

Viterbi: I finished my Doctorate at USC on Digital Communications. My thesis was not my finest piece of work, but it was solid and started me thinking. Once I got my thesis out of the way I started doing good work. About a year after I got my Ph.D. I had the opportunity to join the faculty at the University of California Los Angeles (UCLA). That was a great opportunity for growth. For quite a number of years after that I continued consulting for JPL one day per week. I learned a lot at UCLA because I had to teach. Early on I had a considerable interest in information theory. Even though I had been doing digital communications work and theory, I really didn't know enough about information theory. The Shannon Theory had originally been developed at Bell Labs, and then MIT became the mother church. Bell Labs was still strong, but I think MIT became the center of mass. Unfortunately, I hadn't taken any of the information theory courses at MIT because I left too early.

I started following what had been done and started teaching it. That was a great learning experience, and that's when I developed the so-called Viterbi algorithm for convolutional codes. It came out of my teaching. I was teaching some stuff that was pretty difficult, and particularly difficult to teach. When doing research one gets into a mindset where it becomes second nature, but when it comes to teaching someone else that's when it becomes clear whether one understands it fully. I found information theory difficult to teach, so I started developing some tools. This algorithm came out of that.

I wrote the first paper on that in March of '66, but it wasn't published until April of '67. It proved certain characteristics of convolutional codes. At one point I was discouraged from actually publishing the algorithm details. Fortunately one of the reviewers, Jim Massey, encouraged me to include the algorithm. (Jim Massey, who is a great friend, was one of the major contributors in information theory, coding and cryptography. He was then at Notre Dame.) It was an unwieldy description, but at least it established itself. Nobody thought it had any potential for practical value because my estimate at the time was that making it work would require several thousand registers. About a year later my colleague at JPL, Jerry Heller, did some simulations and found that it could be done quite well with as little as 32 or 64 registers. That made it more practical. However it still was a big monster filling a rack of about 18" enclosures. Now it's a little fraction of a chip.

Morton: Where did you originally publish this article?

Viterbi: In the IEEE Information Theory *Transactions.* A second paper I wrote, which was somewhat more practically oriented, published also in April of 1967, was in the Communication Society *Transactions*. I think it was called the *IEEE Transactions on Communication Technology* at that time.

Morton: Were you tied in with any of the emerging digital signal processing community at that time?

Viterbi: There really wasn't a digital signal processing community in 1967. There were no microprocessors. Certainly some people were thinking in terms of RISC machines in the late '60s, but everything was built out of components. There was some level of Small Scale Integration (SSI). That's a term that doesn't exist anymore. In those days we talked about SSI, MSI (Medium Scale Integration) and LSI (Large Scale Integration). Very few did LSI at that time. What we call SSI today was probably called MSI at that time. I'm getting a little bit ahead of myself, but the first chip that our first company, Linkabit, designed and built was a hundred transistor integrated circuits. That was in 1973 or 1974. It was really a signal processor for the Viterbi algorithm. Linkabit almost went under because several fabs flaked out on us. In 1967 there were no signal processing chips as such. There were devices implementing arithmetic units, which is what our chip became a little later. If I remember correctly, Intel did its first microprocessor in the early '70s, the Intel 404 or 4004.

Morton: I think that was around 1975.

Viterbi: That was not a signal processor but an arithmetic processor. If you look at it from the viewpoint of IEEE history, what is now the Signal Processing Society was then called the Audio and Acoustics Society.

Morton: It has changed names several times.

Viterbi: I maintained an interest in things like control theory and signal processing, or what it was back then, because it was really quite closely allied to communications.

Morton: Based on the fact that you liked JPL and then went into teaching, from the first part of your career you seem to have been attracted to the theoretical side of engineering, but then you started Linkabit in ’68 or ’70.

Viterbi: I wasn’t completely removed from industrial applications. While at UCLA I continued consulting one day a week at JPL and kept very close to the space program. Even the algorithm, when I was thinking of where it applied, it was clearly in my mind for a wide band Gaussian channel, i.e. the space channel. That is where much of the early work was done. JPL picked up on it very quickly, much faster than any other research lab or company. I was also consulting for quite a few companies. I can barely remember back to the ‘60s, but ITT Defense Communications and Ford Aerospace were some of the companies for which I consulted. I also consulted for some small companies in the Los Angeles area. In any case, I had continual opportunities to see real systems.

I wrote my second book, *Principles of Digital Communication and Coding,* during that period. Actually I wrote most of it while at UCLA, but finished it around 1973. A colleague who was still on the UCLA faculty, Jim Omura, worked with me on that book and wrote about a quarter of it. This applicability issue was always there, and opportunities to apply it in real defense and space communications systems at NASA and for the government abounded.

In the late ‘60s Irwin Jacobs, a faculty member at UCSD, Len Kleinrock, who was with me at UCLA, and I got together and decided to pool our consulting.

There were plenty of opportunities, including opportunities to get small government contracts. Our first contract was with the Naval Electronics Lab in San Diego. We looked at error correcting coding and its application in naval communications. Later we did similar work for NASA. None of us could run the company alone, and we saw that we probably needed a full time person, so we incorporated Linkabit in 1968. In 1969 we hired Jerry Heller as our first full time employee. It wasn't like jumping in, but more like getting our feet wet. Very little happened in '68 or '69 other than writing some reports. We probably built a little hardware in 1969 and developed software to put into Navy computers. By 1970 we were building prototypes for NASA.

Morton: Was the Navy still using this for space communication?

Viterbi: No, that first Navy job was actually for HF. It was terrestrial or nautical high frequency digital communication with messages at 1200 bits per second.

Morton: I take it that digital communications was spreading.

Viterbi: Yes, it was spreading by the '70s. Two things were happening. First there was the wireline development, and modems were still at their beginning. If you have a PC at home and with a built-in modem that ties into the phone line, we call that an analog modem but it's really a digital signal generated on an analog line. That was already happening in the late '60s. There were debates and a famous workshop of the Communication Society in 1970 where it was concluded that coding would never have any application to commercial systems and that even data modems were never going to go very far.

Morton: I'd like to find that somewhere.

Viterbi: Bob Lucky, mostly in jest after he'd heard several speakers say coding was dead, got up and said, "Well, data is dead too. Or is it data are dead?" That was one theme. On the wireless side, probably only NASA and the military were really doing digital communication. The military needed to have a signal that was immune or resistant to hostile interference, so they went to spread spectrum, and using spread spectrum requires going digital. It doesn't make much sense to have an analog signal on a spread spectrum. People have looked at that, but it's never really been practical. Digital is a natural, however, because the spreading waveform is digital. The simplest form of spreading involves hopping the center frequency around very fast in over a wide spectrum. The military were doing that even in the '50s, and certainly more so in the '60s.

What really gave everything a boost, both for the military and clearly for the space program, was satellite communication. Now we were looking for efficiency in systems that could transmit from very far away. These were geosynchronous ranges, which meant 40,000 kilometers. All the technology for the military spread spectrum became even more important because the geosynchronous satellite is a sitting duck and anybody could jam it, whereas on the ground the antenna can often be positioned to avoid being jammed. Commercial satellites, which in the very beginning were analog, were already using digital technology by the '70s. Digital communication got a big boost from satellite communication. Some of the heritage from the digital satellite systems of the '60s and '70s into even some cellular systems in the '90s can be traced to that. I'm not talking about spread spectrum. I'm talking about things like TDMA, which had first been done in satellites for a very good reason. Then they were imported to cellular with much less justification.

Morton: Was it tough competing with a company like AT&T that had its own in-house research and development and a lot of experience?

Viterbi: Linkabit wasn't competing with AT&T. Essentially beginning in 1970 Linkabit was a very small military contractor. We had a little office in LA in '69, and in 1970 moved to Sorrento Valley and we got our first 4,000 square feet. We had ten people and went after little government contracts. AT&T, with Bell Labs, paid no attention to us. We'd meet with a lot of folks from Bell Labs from our academic days and due to our professional reputation. I visited Bell Labs a few times and gave a few lectures there, but that was more academic than competitive technology.

There was no such thing as IPR in those days. It was marvelous. You didn't worry. It's kind of interesting what happened with the algorithm. We got a lawyer to incorporate the company, and shortly thereafter we had some work from NASA and the Navy which was on the algorithm. We went to that same lawyer, who was also a patent lawyer, and asked, "Do you think we ought to patent this?" His response was, "That's ridiculous. This stuff is only good for government applications, and you really have no protection. The government can do whatever they want." That was an overstatement and isn't totally true. He convinced us that it wasn't worth spending three thousand dollars or whatever it was to prepare and apply for a patent.

Morton: Do you regret that now?

Viterbi: No. If we had patented, it probably would have slowed down its acceptance, because no one patented in those days. AT&T and IBM patented for commercial reasons, but we were a small government contractor. Through the '70s we started thinking about commercial applications but didn't really go into them until 1980 when Linkabit had been acquired by M/A-COM, a mini-conglomerate whose headquarters were in Burlington, Massachusetts. We then did a number of things that became major commercial successes. One of those early successes was VSATs. We took technology that was essentially military and applied it to commercial satellites. Satellites were a natural. That's where the transition was the easiest.

We had a contract from American Bell Iranian International (ABII), which was actually a subsidiary of AT&T. In the mid-'70s AT&T had been contracted by the Shah of Iran to redesign and refurbish the entire telecommunication infrastructure of Iran, a large part of it via satellites. There was something that was to be called IranSAT, and we built a transmitting and receiving modem that was high speed for the time for satellite communication on the IranSAT. I went to Bell Labs in Holmdel, NJ in early '79 and asked whether there might be a problem. I was told by the Program Manager, "I think this program is going to survive. We don't worry about politics." The revolution was in March, and they woke up around May or June and said, "Maybe we should cancel this program. If we cancel, what are the total costs that you'd have to be reimbursed?" Our financial folks did an honest assessment and it came out to about 90 percent of the total cost. They said, "In that case you may as well go ahead and finish it. We'll use it somehow." I don't remember how, but we delivered it. That turned out to be a kind of prototype for VSATs, which we started on seriously in the early '80s. By this time we had funding and could invest in commercial developments. M/A-COM was a much larger company and had something just shy of a billion dollars in revenue, whereas Linkabit had maybe $25 million revenue when it was acquired. Even more interesting, we developed the first video scrambling system that was digital video called Videocipher. That lives on to this day. It was initially designed for Home Box Office (HBO), who was the customer. By the early '80s they were beaming their analog transmission to all the cable head ends. They called it prime video services. When the service started out, the only organizations that had three- or four-meter dishes were cable companies, and it was assumed that they would be the only ones. However by the early '80s, affluent ranchers in Texas and some other places starting getting these dishes. Then when the price came down from something like $100,000 to $10,000, people in rural communities began to purchase them, until there were about a half a million three- and four-meter backyard dishes. They were getting HBO's signal for free, so HBO got upset and decided to encrypt their signal.

We developed what we considered to be a very secure system at M/A-COM Linkabit, but it required fully digitizing the video and audio. We would have shipped maybe two or three thousand of these costing somewhere around $3,000 to $5,000, but the backyard dish owners had a powerful lobby called SPACE, the Society of Private something-or-other, which lobbied Congress. Their argument was that, "This is unfair. We're willing to pay for the service, but they can't take it away from us. They've got to give us a descrambler. We'll pay for the descrambler and we'll pay something to the service provider." I'm not sure they really said that, but that's the way it worked out.

The problem was that descramblers couldn't be sold for $3,000 apiece to people who paid maybe only $5,000 apiece for their dishes. The price for this equipment needed to be in the $200 to $400 range. Therefore we had to make a compromise and completely redesign from a more expensive and professional piece of equipment to less expensive consumer equipment. We could still digitize and hard scramble using the Digital Encryption Standard (DES) on the audio, but on the video we had to do something else. Digitizing the video meant using a very fast A to D converter, and those costs were too high. Therefore, instead we simply rotated each line so that the lines wouldn't line up. That way the cost came way down so that descramblers could be sold for under $400. By the way, the key step in that was building an Application Specific Integrated Circuit (ASIC), which is a signal processor. That was our first major ASIC development. We had done some medium scale integration for our decoder work, but as I recall we hadn't done anything on the scale of that device. That was in the early '80s.

Morton: You raise the point about how important consumers are at some level in designing a product that was at first intended as something that would have been irrelevant in the consumer market. The consumer market in this case had a big influence.

Viterbi: That was the case with the VSATs also. They weren't professional equipment, but they were for industrial use initially and were not developed with the consumer in mind. We did other things such as networking together a number of terminals sharing a mainframe. We did that in the early '70s just for our internal use. By then the company was about a thousand people and we had close to a thousand

VT-100 terminals. They weren't PCs, but dumb terminals all tying into a VAX, manufactured by Digital Equipment Corporation (DEC). As a corporation we were heavily oriented to Digital Equipment Corporation and ultimately sold the networking product to DEC.

About this same time, things at M/A-COM started to kind of fall apart. M/A-COM actually no longer exists except as a division of AMP. The original chairman and CEO of M/A-COM, who acquired Linkabit, was forced out of his position and the new leadership wasn't visionary. Therefore a number of us left in the spring of 1985. Interestingly, M/A-COM then sold all the businesses. They started out by selling the VSAT business to Hughes for I think $100 million. That became a half billion dollar per year business within a year or two. They also sold some very early wireless mobile telephony work we'd done. It was not necessarily mobile, but it was wireless. They sold all of that to Hughes. All of Linkabit's commercial satellite business and also another division of M/A-COM in Maryland called Digital Communication Corporation was acquired by Hughes. Hughes began the Hughes Network Systems out of these two divisions and it has been very successful.

Another piece that M/A-COM sold was the video scrambling business, which was acquired by General Instruments (GI) along with a cable plant for about $250 million. That turned into a multibillion dollar per year revenue for GI. M/A-COM also later sold the government piece. We were doing quite a bit of government work. By that time probably a third to a half of what we left was still work done for the government.

Although we built a lot of error correcting equipment for the government, the most important government product was the first microprocessor-implemented digital satellite modem, called a dual modem. Irwin Jacobs waxed lyrical on that more than I. The dual modem was built for the U.S. Air Force starting in the mid-'70s. It became a production program by the very late '70s and continued well into the '80s and '90s. It's still being built by a company that later bought the Linkabit Government Division. Initially, the dual modem was for the Air Force Satellite Communication Program. It was something the Air Force could use from a command post to communicate with a fleet of bombers, B-52s, FB-111s and so forth. Among other things, it sent the Emergency Action Message, which has never been sent, thank God. However that was its purpose. Rockwell originally built that product in the '60s and early '70s. Although it was digital transmission, it was very much an analog implementation and was essentially an FM modem.

The Air Force realized they needed to modernize, especially to introduce more security, and thus spread spectrum came into the picture. We built a spread spectrum modem. It had to be dual, that is it had to be backward compatible to the previous mode, and it had to have intelligence. We implemented a microprocessor not on a single chip, but out of standard merchant chips. By then there were highly integrated memories and some early signal processors and we made a little computer out of this type of components. It was really a RISC machine that implemented all the algorithms to do the spreading, modulation, coding, decoding, etc.

It took us about three years to convince the Air Force that (a) this was feasible and (b) that this little company called Linkabit could do it. We wound up building thousands of these dual modems. After the Air Force, we designed them for the Navy and the Army, each of which had their own capabilities or requirements. The Army modem became a tri-modem rather than a dual modem. There is a company in San Diego called Titan that bought the government systems division of M/A-COM that had been Linkabit's and they're still building those things. To a large extent that work is what made Linkabit, probably more so than the work done with coding. Linkabit was an R&D company that did a limited amount of manufacturing. Once Linkabit was acquired by M/A-COM we became larger. In the spring of 1985 Irwin Jacobs and I quit within a week of each other. After taking it easy for all of two or three months, we started Qualcomm in July of '85. A number of people immediately joined us. We didn't know exactly what we would do. I had been teaching. I formally resigned from UCLA in '75 after I had moved to San Diego in '73 and become a full-time Linkabit employee, but I stayed on at UCSD as an adjunct. In '85 while between companies, UCSD gave me a regular appointment on a part time basis because I felt I wanted to do other things as well. For roughly the next ten years I was a quarter time professor. I stayed with the UC system for a total of about thirty-one years, although only ten years of that was full time. I was keeping a little busy doing that, but when this opportunity came up with the same guys I had worked with at Linkabit, actually the cream of the crop, it was too much of an incentive to resist joining. Irwin Jacobs will say we started in his den, but in fact I wasn't there because I was traveling in Europe on a very nice cruise. I got back in mid-July. By then we had a palatial office over a cleaners shop, at least 3,000 or 4,000 square feet. We had already contracted for a building on Sorrento Valley Road, but it wasn't yet ready. We still own that building. Qualcomm had a much faster start than Linkabit, where we had started in a dentist's office on the edge of UCLA.

I'll quickly give you the Qualcomm story. It started out with about seven people and a secretary. We didn't have commercial work in mind on day one. We went after moderate size government work, and did one sizable data link contract. That was a Joint Services program, Army/Navy/Air Force, for test ranges. They needed very fast telemetry and messaging back and forth between airplanes, tanks and other moving platforms. Then we did a number of satellite programs. One satellite program was for what was then Ford Aerospace, now Loral, and another one was for Hughes. By the late '80s the DOD budget was depleting. There was a really interesting project we worked on in multiple satellite low earth orbiting. Globalstar and Iridium are the descendants of this concept. But this was for the military. That program was axed due to budget reasons and because Aerospace Corporation didn't like the concept. They were oriented only to geosynchronous satellites.

Before Qualcomm was even formally founded, I received a call from a fellow who was working for a company called OmniNet that was trying to do satellite position location and messaging for the transportation industry. It's a very long story, but ultimately OmniTRACS came out of that. OmniTRACS is a two-way satellite communication system.

Morton: Is that the one truckers use?

Viterbi: Yes. There are currently 300,000 trucks, about 260,000 in North America and the rest distributed especially in Europe but also throughout Mexico, Brazil, Korea, Japan, Malaysia, and now also China. Europe has about 25,000 or 30,000 trucks using the system. That was a long haul, and I'll cut it short. It took about a year to develop a prototype, but that prototype was only one way, from the satellite down, or I should say from the hub to the satellite to the trucker. It was not going the other way, because there was another company called Geo Star that had it going the other way. Our customer, OmniNet, was trying to get together with Geo Star but could not.

Then we went for **both** directions. What was interesting about it was that everyone else was trying to use L band and processing satellites, but we used Kl.c. band, which is the 12 and 14 Gigahertz band. There was very little L band. If you wanted a processing satellite you had to have your own package aboard, whereas using a non-processing satellite with Kl.c. band there was plenty of supply. Among other things, there had been some launched for a direct satellite broadcast service in the '80s that didn't take off. Therefore our customer was able to lease direct satellites fairly cheaply.

It was quite an achievement to develop that product. It involved a lot of signal processing and a very clever antenna with a directional antenna control that would move as the truck moved and always faced the satellite. That was largely Irwin Jacobs' conceptual approach along with some very good development work done by others at Qualcomm. It all came together in early '88, but just about then our customer was going broke. Our only option was to buy them out for stock. That was a very expensive proposition, but it turned out fine because that business did well in the long run.

We got one outstanding customer, Don Schneider of Schneider National. At that time he had about 10,000 trucks. Schneider probably has 15,000 to 20,000 trucks today. Our business built up from there. Even after Schneider we had a dip, because there wasn't another Schneider around. We went after J.B. Hunt, but Hunt was not as receptive and waited several years before coming on board.

OmniTRACS was finally starting to be profitable. We certainly hadn't recovered our investment, but our revenue now exceeded the cost to operate and build up the system. Today at least 90 percent of the companies with over 1,000 trucks are using OmniTRACS, and it's a very successful business.

Then one of our really clever guys, Klein Gilhousen, came in and said, "We're using CDMA. We're using spread spectrum for that system." I forgot to mention the most important thing, which is why we used CDMA and why we were able to use these low cost satellites when no one else could. Low cost satellites weren't really meant for mobile use. The FCC license in Ku band was only for use with fixed satellites and fixed transmitter/receivers, while for mobility L band was supposed to be used.

However there was a footnote in the regulations that said secondary users could be mobile. A secondary user can use a satellite, but only if there is no interference. Satellites tend to be about 2 degrees of arc apart from one another, and mobile terminals are very small and therefore have a big antenna aperture on the order of 6 to 12 degrees, so they splatter their signal up to the other satellites, therefore naturally interfering. Conversely, they're wide open so that other satellites interfere with these terminals and they have no recourse. There is no recourse either way. If others interfere with secondary users, that's just too bad. If secondary users interfere with others, they're off the air.

We had to convince the FCC that we could build a system that wouldn't interfere, and that was a big struggle. However the FCC is very liberal with experimental licenses, and they gave us a license for something like 600 trucks and no more on an experimental basis. It took at least a year and a half to convince the FCC that we weren't interfering. Then they gave us a license for 20,000 trucks. Today we are licensed for about 300,000 in the U.S. and are going to go up to about half a million, and we've never had a case of interference. Our mobile transmitter send one watt spread over the full transponder, which is about 24 Megahertz wide, so that our signal looks like noise. We're way down in the noise.

Another aspect in relation to our competition is that when a satellite is leased it is leased from a provider like GE satellite. They coordinate. Unless the next satellite over is transmitting full blast TV, if it's just a VSAT we can live with it. It looks like interference but it's spread spectrum, since in the process of despreading the desired signal back to the original narrow band, the other signal becomes spread and looks like noise. In any case, we made commercial spread spectrum real by loading up with tens of thousands and ultimately hundreds of thousands of users.

Then Klein Gilhousen came in one day and said, "Why can't we use this for cellular? There's lots of interference there." That made sense to me. I had presented a conference paper to an IEEE Communications Workshop in '82 saying, "This spread spectrum might apply well to cellular," but no one was listening, and it wasn't a thrust of M/A-COM Linkabit. When Klein made that proposal I said, "That sounds familiar, but you've got a power control problem. You have got to assure that no one is swamping out your signal."

One of the first things that Klein, Irwin, Butch Weaver and I worked on was power control. We came up with a really clean and neat way of combining what we call open loop and close loop power control, and it worked very well. At first no one believed us except Pac Tel Cellular, which is now Vodaphone Air Touch. Pac Tel listened and got Bell Atlantic, NYNEX, and Ameritech to listen. They all made investments in us on the level of a million dollars. That is a tiny amount now, but it was a significant amount back then. They helped us pay for development and we were off and running. I won't give you the whole CDMA story. I can give you three papers on the subject.

Morton: That would be great. The transition to cell phones from the satellite and the tracking makes a lot of sense to me. I also see Qualcomm's name on an e-mail product called Eudora.

Viterbi: Yes. That was an interesting coincidence. As I mentioned, both in the old company and even more so at Qualcomm, we were Intranet oriented well before the Internet or Intranet explosion, and we developed our own e-mail product. We found that the University of Illinois' supercomputer lab had a guy name Steve Dorner who had written this program, and we licensed it. Ultimately we hired the guy. He still lives in Champagne-Urbana and works full time for us. A fellow named John Noerenberg was the Qualcomm software engineer for e-mails, and I think it was his idea to market it.

We commercialized it a little bit at a time. Initially we sold it for $25, a nominal amount. We had two versions. One version was Eudora Light, which we gave away over the net. The other version was Eudora Pro, which we sold. Before we knew it, there were 10 million users of the combination of the two. Every government lab and every university seems to use it. Even in Europe I am asked if Qualcomm is the one that makes Eudora, I say, "Yes. It's a sideline. Our main business is cellular phones and satellite systems."

Morton: Has Qualcomm made money on that, or do most people use the free version?

Viterbi: It's been tremendous and relatively cheap publicity. Initially we made a little bit of money. We started marketing it for real and lost money. Then it went through a kind of quiescent period. Eudora 4.2 is really quite good. Now you can easily find all the old messages that you've thrown away and things like that. We're now on a new kick towards supporting the product through advertising in what's really e-commerce. People can have Eudora free provided they accept ad messages. That is being alpha tested and will soon be beta tested. Technologically it makes sense. Whether it makes sense as a business is not certain. It could really take off, but if it doesn't that's okay because it's not our main business.

Morton: The federal government has one way or another benefited your various companies a great deal over the years.

Viterbi: No question.

Morton: What's your opinion on federal spending on research and development and purchases?

Viterbi: I'm a member of Clinton's Presidential Information Technology Advisory Committee, and we just put out a report six months ago urging the government to continue doing basic R&D. Not application oriented research, but fundamental research. There's no one to develop the transistor equivalent of the twenty-first century. Research that brought ARPAnet and the Shannon Information Theory fueled our information economy, which is the fastest growing segment of our economy. Fundamental research also developed the transistor and radio astronomy. This kind of research is not going to be carried on by industry because shareholders won't allow it. GE and RCA gave up on pure research thirty years ago. Bell Labs and IBM gave up on pure research about five to ten years ago. None of them are doing really basic research. If they are, it's minuscule.

As for where it should be done, I think it possibly should be done in the universities. They are geared for it. CEOs can't face their shareholders and say, "I am creating shareholder value by doing research that may or may not have an impact ten years from now, and I probably won't commercialize it." That is the position in which IBM found itself, and certainly AT&T found itself in that position even more. In the past AT&T could afford to keep Bell Labs doing pure research because they were a monopoly. There was a lot of foresight there, and there were no constraints. AT&T shareholders could be guaranteed their 7 percent, which might have been 7½ percent if there hadn't been a Bell Labs, but they were in no position to complain.

Morton: How do you get past the objection that, as a head of a big company, the federal government is funding research that threatens your own? What if they are trying to invent the next generation of wireless communications?

Viterbi: If you're not enough fleet of foot to take advantage of it, you don't belong. Then you have no right to be a foremost and successful company. If you are talking about the coach manufacturer being put out of business because somebody came up with the internal combustion engine, that's old think. Nobody has a right to say that today.

We're doing some very innovative things such as a system for high-speed wireless access to the Internet, a product that we will be announcing in a major way in a week and a half. We are getting up to 2 megabits per second, the equivalent of DSL and cable modems in a wireless manner. We're using cellular frequencies on the order of 1½ Megahertz of bandwidth getting 2 megabits per second transmission rate. It's quite a challenge, and I think our guys have demonstrated capability. That's very good advance development. It's also good applied research. However it is not fundamental, basic research. It's something that we hope will be a major commercial success in two years.

Basic research is something that's purely speculative and may be typically five to ten years out before any application is developed. Five years is optimistic. Ten years out is more realistic. We should do it for our national good. After all, what do we have that the rest of the world doesn't have? We have a very good higher education system and a rather weak secondary education system. It's an enigma how it is that we can have the best university in the world that everybody wants to come to and have a rather weak K-12 program. The answer is absurd. Because all the rest of the world wants to come to study here, we admit some percentage of them, probably less than 10 percent of the applicants, and they maintain our quality of higher education. I gave that as a commencement speech at Berkeley.

Morton: That's asking for trouble.

Viterbi: One faculty member told me it was a very controversial theme. All the parents of the students, partly because I said if someone is graduating from Berkeley Engineering they're good, were thrilled. Be that as it may, the point I was trying to make is that what gives us a higher standard of living is the fact that we can take the technology that's been built up over the years and rapidly apply it. That is because of the financial backing of venture capitalists, because we're a lot faster than the Europeans, and because we're much more entrepreneurial than the Japanese. The Japanese are fast but monolithic. They often go off in the wrong direction, like the MUSE High Definition TV system, an analog system which was rendered obsolete by digital technology. Digital cinema is another system development here. This is all great for the next decade or so, but what comes next?

Morton: Right.

Viterbi: Everyone else is catching up. Europe seems to be doing it in a strange way. They're tending to close themselves in by having their own standards. They're trying to do what the Japanese did twenty or thirty years ago. The Japanese are no longer doing that. China is another story, but I've gone far enough.