Reflections on My Career at Bell Labs

When Prof. Nehorai invited me to contribute an article to this column, I was a bit hesitant to accept his invitation. I do not really have any advice for young aspiring engineers or words of wisdom such as the ones you will find in some of the earlier articles. Also, unlike other writers in this column, I have not managed a large group of scientists. I headed only a very small group (about six) of colleagues for a few years. However, Prof. Nehorai assured me that the “Leadership Reflections” column includes articles that look back on scientific careers and the institutions that nurtured them. So my article is going to be about my career, mainly about my 39-year association with Bell Laboratories.

My undergraduate training was in India, where I earned degrees in physics and electrical communication engineering. I wanted to continue further studies in engineering, but in those days (mid-1950s) no graduate program in engineering was offered anywhere in India. So I decided to go to America for graduate studies. One of the universities that accepted me was the University of Wisconsin, where I earned an M.S. and a Ph.D. In 1954, while I was on the ocean on my way to America, my very first scientific paper (on vibrations of Indian musical drums) appeared in the Journal of the Acoustical Society of America. (Air travel those days was by propeller planes and only for the very rich.) I arrived in New York just about when Senator Joseph McCarthy was beginning to fall from grace.

After finishing my Ph.D. degree at Wisconsin, I briefly worked for industry and at a research institute in India and taught at the University of Toronto, Canada, for a year. In 1962 I joined Bell Labs and worked there until my retirement in 2001. Currently, I am a consultant at Avaya Labs Research.

I must confess that when I joined Bell Labs, I had intended to stay there for just a few years to gain some experience in industrial research and then join academia. The research environment, however, was so attractive that the few years stretched out to 39.

**BELL LABS: AN INSIDER’S VIEW**

I would like to share with you some of the allure and excitement of working at Bell Labs. Much has already been written about the preeminence and stature of Bell Labs as a research organization. But by using examples drawn from my personal experience, I hope to provide a different, more intimate, perspective.

Fortunately, a large part of my career at Bell Labs was during the era that has been called “the glory days” of Bell Labs. I am not sure when that era began—presumably just after World War II. However, the end is easier to identify. Slow erosion started in 1984 when AT&T was broken up, even though Bell Labs itself was still kept in one piece. The erosion picked up speed in 1996 when Bell Labs was split up into a part that stayed with Lucent Technologies and another part that formed the new AT&T Research Lab. And, at least for the area of Bell Labs where I worked, the end came abruptly in 2001 with what I call “an epidemic of encouraged retirement.” But I am getting ahead of my story. Let me tell you about some of the qualities of Bell Labs that made it such that unique place and, wherever possible, to give you some examples from my experience that illustrate these qualities.

One of the first things that impressed me at Bell Labs was the essentially academic atmosphere of the place. That was something I had not anticipated in an industrial research organization. And to add to that, the labs had resources in equipment and support personnel that far exceeded those at a university. Also, top quality computing facilities were available. (By today’s standards, of course, the computing facility at Bell Labs in 1962 is laughable. All computations were done on an IBM 704 computer in batch mode. The computer had a memory of 32 K, and it occupied a large room in the only air-conditioned building on the campus. Programs were punched on Hollerith cards and sent to the computer via mail carts. However, by the standards of the day, the facility was top class.)

Another thing that struck me immediately was the completely free atmosphere. Here were world-famous luminaries by the dozen, who were not barricaded behind outer offices and secretaries. You could just walk up to their
THE IMPORTANCE OF DIVERSITY

Diversity was another remarkable aspect of the labs. The department that I joined was ostensibly concerned with various aspects of speech signal processing, coding, and transmission. Everyone in the department was interested in one aspect or another of speech. But as far as I could tell, almost none of the members of the department joined the lab with prior credentials in that area. There were a couple of electrical engineers, a physicist, a physical chemist, a mathematician, and so on. And yet, together they were able to produce some of the best work in the field. This approach is in sharp contrast to the modern idea of hiring people who would “hit the ground running.”

Another aspect of diversity is worth mentioning. It was the acknowledgement that people have various motivations for doing research. Some (like me) approach it as puzzles to be solved, others to make a fundamental discovery or to make a lasting contribution to society, yet others to invent commercially successful products, and so on. It was recognized that good research can be done with a variety of such motivations.

Freedom to choose the line of research one wished to pursue was one of the most enticing aspects of working at Bell Labs. I can say without hesitation that in my 39 years there, I was not once asked, let alone imposed upon, to work on some specific problem. And I am sure this experience was shared by just about everyone in the basic research part of Bell Labs. The idea was for managers (e.g., department heads and directors) to provide a problem-rich environment and then let individuals decide what they wanted to work on. Some very broad directives obviously existed, and I assume straying too far from them might have been discouraged.

Collaboration among people in very different parts of the labs was encouraged. My collaboration with several members of the mathematics department is an example of this. That collaboration yielded several papers in queuing theory, which was definitely not something of direct interest to the department that employed me. (Incidentally, one of those papers, written in collaboration with David Anick and Debasis Mitra, actually turned out to be cited far more than any of my papers in acoustics or speech.)

Emphasis was on doing good science and creating new knowledge without the immediate goal of practical application. Not all research was aimed at developing products. The thinking was that with several competent people doing research with a variety of motivations in an environment rich with relevant problems, some of the research was bound to result in good products. This attitude started changing slowly in 1984, and there was more and more emphasis on product-oriented research. Some revisionist claims have been made to the effect that research at Bell Labs was always directed towards a product, and the invention of the transistor has been cited as a prime example of this. I do not agree with that assessment. And as far as the invention of the transistor is concerned, I distinctly remember a symposium in honor of the 50th anniversary of its invention. Several scientists who had participated in that activity in the 1940s were at this symposium. And several of them made statements to the effect that the study of semiconductors was presented to them as an area worth investigating with the potential of yielding breakthrough products. However, their charter was to study semiconductors and develop an understanding of their properties, without the specific aim of developing a product.

KNOWLEDGE AND RESEARCH

Here are some examples from my personal experience to illustrate the emphasis on creation of knowledge and the emphasis on long-term research.

A problem of interest in speech science is to determine the continuously changing cross-sectional area along the vocal tract in the process of producing speech. I was made aware of this problem early in my career by James Flanagan. Early procedures for doing this used X-ray movie cameras to record side views of the vocal tract and from them estimate its three-dimensional form. This method is undesirable for several reasons, the most important being the need for prolonged exposure to X rays. Manfred Schroeder suggested using acoustical measurements to determine the shape and derived a method valid when the tract is only slightly perturbed from a uniform cross section. B. Gopinath and I became intrigued by this “inverse” problem and were able to derive a complete mathematical solution. Later, in collaboration with Jeff Resnick and then with Juergen Schroeter, I was able to reduce the method to practice and actually produce movies of the dynamic variations of the vocal tract. This work did find recognition in some areas of the scientific community but turned out not to be too useful for speech work. Yet its scientific merit was appreciated, and the work was supported at Bell Labs for several years.

As an example of emphasis on long-term research, I might mention my work on echo cancellation. In long-distance telephony, echoes are generated at points of impedance mismatch, mainly at the interface between the long-distance network and the local network. Several satisfactory methods of combating these echoes had been invented over the decades since the advent of long-distance telephony. In 1962, however, one week after I joined Bell Labs, the era of satellite telephony was ushered in with the launch of the first communications satellite, Telstar. It was anticipated that satellite communication would ultimately be via geostationary satellites, and these produce round-trip delays of as much as 600 milliseconds. With such long delays, the known methods of dealing with echoes were shown to be quite unsatisfactory. A new method was needed, and John Kelly started thinking about it in the early 1960s. He proposed the device now known as an echo canceler and invited Ben Logan and me to join him in developing it. Anthony Presti and I made the first (analog) prototype of the canceler around 1996. Due to Kelly’s untimely death, I ended up writing the first paper laying out the mathematical properties of the device in 1967. In the 1970s, Debasis...
Mitra and I collaborated in deriving several basic properties of the canceler.

The important thing to note here is that while all this work was being supported, it was not clear if and when a commercial application of the device would be realized. The analog implementation was prohibitively expensive, and integrated circuits were still in the future. However, we were encouraged to work on "impractical" ideas under the assumption that eventually digital technology will make them economically feasible. It took over 15 years for the commercial application of echo cancelers to begin, with the implementation of a canceler on a chip in 1980 by Don Duttweiler and Y.S. Chen. Later, of course, the device was deployed by the millions on the telephone network and yielded more than a billion dollars of revenue to the owners of Bell Labs.

Another example of aiming at a distant future is provided by a more recent application of echo cancellation. During the 1990s, I started thinking about the problem of canceling echoes in a stereophonic teleconference. It turns out that cancellation of echoes in such a multi-channel situation is qualitatively different from cancellation in the single-channel case. In collaboration with Dennis Morgan, Jacob Benesty, and Joseph Hall, I spent a considerable amount of effort on this problem, and we were able to come up with some interesting and useful solutions. Again, this work was encouraged even though no immediate use was expected. More than ten years later there are still no commercial applications of this work. To date it remains a conjecture, although I believe a good one, that eventually most teleconferencing will use stereophonic (in general multichannel) transmission and will therefore require stereo (or multichannel) echo cancelers.

I could give several other examples from my personal work in other areas such as speech recognition and speech synthesis, but the above examples suffice to illustrate my view of Bell Labs' commitment to long-term research aimed primarily at the creation of knowledge.

It may be argued that this attitude towards industrial research was possible only because of the special, regulated monopoly structure of the old AT&T. And it may be argued that to show an annual profit, business value becomes of paramount importance, and industries cannot afford the luxury of such research. There is, I am sure, some truth in both these assertions. However, I believe that it is in the national interest to have a laboratory of this type: a laboratory where industrial research is done in a university-like atmosphere, but where, unlike at a university, the environment is rich with problems of direct interest to industry. Perhaps a national laboratory is the answer. Or perhaps a laboratory run by a consortium of industry could be formed. It is imperative that means be found to set up such a laboratory. It is important that a certain portion of industrial research be done without the emphasis on immediate application. The exigencies of developing products and services create an atmosphere of rapid changes that may be likened to a rollercoaster ride. That can be thrilling, but it is not possible to think about the distant future while riding a rollercoaster. And some amount of relaxed thinking about the future is necessary.