

Leo Beranek's Contributions to Noise and Vibration Control

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The background story behind passage of the Noise Control Act of 1972.

Introduction

Both authors have had the opportunity to know and work with Leo Beranek for more than 60 years, and to share with him at least one of his many interests—the field of noise and vibration control (Figure 1). In this article, we describe Leo's early interest in the field—mainly adapted from his autobiography, *Riding the Wave* (Beranek, 2008).



Figure 1. Left to right, George Maling, Leo Beranek, the late Ken Eldred and Bill Lang at Ken's 70th birthday party in East Boothbay, Maine. Summer, 1999.

Then we describe the activities related to noise during his time at MIT, and a few interesting noise problems solved at Bolt Beranek and Newman Inc. (BBN). Leo's time at MIT was followed by the publication of *Noise Reduction*—a text which was followed by a series of books on noise and vibration control. Leo was also involved in the launch of two periodicals, the passage of the Noise Control Act of 1972, and, more recently, the development of a national noise policy.

The Harvard Years

As mentioned above, the authors have depended on Leo's autobiography for information on his noise control activities in the early years, and for a few interesting noise control problems solved after the formation of BBN in 1948. Leo was a graduate student of F.V. Hunt at Harvard University and took his first course in acoustics under Hunt, using as a textbook the 1936 edition of *Vibration and Sound* written by Philip Morse at MIT (Morse, 1936). Leo's doctoral thesis on acoustic impedance led to an interest in the sound absorptive properties of materials. This caught the interest of Morse who later was asked by the government for assistance with lowering the propeller noise levels in the cockpits of aircraft. Leo became involved in what we believe was his first noise control project, Harvard's first government contract, and the development of very thin fibers which could be used

• BBN, Inc., opens first branch office, Los Angeles, CA (Jan 1956)

• BBN Inc., headquarters moved to 50 Moulton Street, Cambridge

• Lecturer, MIT Summer Programs (1958-1981)

• BBN Inc., adds man/machine, signal processing, computing and psychoacoustics activities with Leo's hiring of J.C. R. Licklider and Karl D. Kryter (1957)

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1959

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for a lightweight sound absorptive material (Beranek et al., 1944). More details may be found in the article by Hanson in this issue.

Today, the anechoic room is a very well established environment for the determination of the noise emissions or sources. Leo's development of these rooms came about because of a government need to test very high intensity sound sources—then thought to be an effective battlefield weapon. The main problems were the sound absorptive properties of the room lining and the shape of the sound absorbers. The shape issue was settled by the development of the wedge and the testing of many designs. The work was published in JASA (Beranek and Sleeper, 1945), and remains relevant to the design of acoustical wedges used in today's anechoic testing chambers.

On to MIT

In 1946, Leo became an associate professor at MIT and the technical director of the MIT Acoustics Laboratory under director Richard Bolt. It is important for one of us (George), and to Leo's future work, that Leo became a teaching assistant to Ernest Guillemin who was an expert in network theory and is said to have been a brilliant teacher. In the summer of 1951, Leo was asked to teach Guillemin's course on introductory electric circuit theory. George entered MIT as a junior and transfer student from Bowdoin College, and that course was George's first introduction to MIT and Leo Beranek. Among others, George joined David Keast and Norm Doelling who had transferred from Amherst. Leo's teaching and his hospitality outside the classroom were very much appreciated. The experience was valuable because, in 1953, George took Leo's course 6.35 *Acoustics* where the emphasis was on electrical, mechanical, and acoustical circuits (in combination) and their application to microphone and loudspeaker design. The class worked through notes which, the following year, became his book, *Acoustics* (Beranek, 1954).

According to his autobiography, Leo's main research interest at MIT was related to heating, ventilating, and air condi-

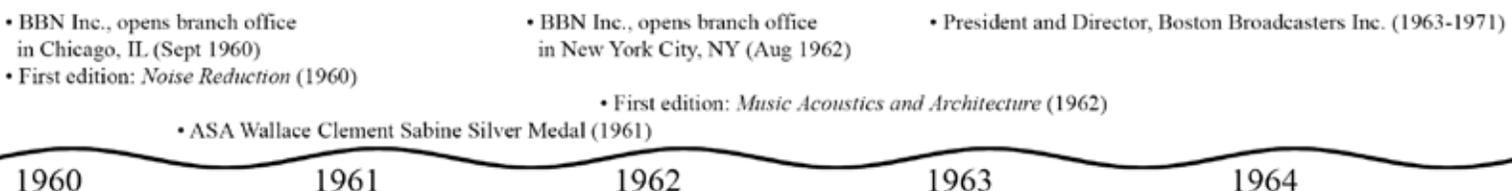
tioning equipment (HVAC). This may have been because of his work with Dick Bolt in the design of the United Nations headquarters in New York, or it may have been because he recognized the importance of HVAC systems in the post-war building boom. In any case, Leo had a laboratory with a fan noise setup, and George was one of the many students who did laboratory experiments using the apparatus. That work led George to a lifelong interest in fan noise, its measurement, and its control.

After nearly a decade as Associate Professor of Communications Engineering, Leo left MIT in 1958 to devote his full energies to his rapidly evolving acoustical research and consulting firm Bolt Beranek and Newman, Inc. He did return to MIT for several years thereafter as a lecturer and director of his popular MIT summer program on acoustics and noise control.

Bolt Beranek and Newman

When Professors Bolt and Beranek formed their consulting business in joint partnership, their first office was in the MIT Acoustics Laboratory housed in a building constructed for temporary usage during World War II on the back corner of the MIT campus fronting on Vassar Street (Building 20). The first two employees of the firm were Sam Labate and the other author of this article, Bill Lang. This office was temporary because although MIT encouraged its faculty to engage in outside consultations, it was inappropriate for employees of a consulting firm to be working at that time on the MIT campus. As a consequence, the firm was moved to a small office at 55 Brattle Street in Harvard Square, Cambridge. This is discussed in the article by Walden in this issue.

The office on Brattle Street only contained two drafting tables, a cabinet for drawings, and two or three filing cabinets. The firm stayed at this location for about a year and it then moved to another location in Harvard Square at 16 Eliot Street, overlooking the transit system subway car storage yard (now the site of Harvard University's John F. Kennedy School of Government). It was during this period that BBN's consulting on the acoustical design of the United



Both authors have had the opportunity to know and work with Leo Beranek on noise control for more than 60 years.

Nations headquarters in New York City was completed, as were a number of projects that were an offshoot of the work initially done at the MIT Acoustics Laboratory. The firm expanded with the addition of architect Bob Newman and Jordan Baruch as partners. Adding Bob broadened the scope of the firm, and the name was changed to Bolt Beranek and Newman Inc. Jordan was Leo's first doctoral student. BBN remained at the Eliot Street location for several years and then moved from Harvard Square to Moulton Street in the Fresh Pond section of Cambridge. A photo of the Moulton Street building appears in the article by Walden.

According to Leo's autobiography, three BBN noise abatement projects stand out. In 1950, the government had a large supersonic wind tunnel at the NASA Lewis Flight Propulsion Laboratory in Cleveland, Ohio. Continuous 24-hour operation of the facility was essential for development of military aircraft jet engine systems. Leo describes the noise when it was turned on: "The noise sounded like a series of thunderous explosions, even at distances of five to ten miles away." Needless to say, noise abatement was required. Leo's first design of a model muffler and then design and construction of what was said to be the world's largest muffler turned out to be successful.

In 1954, an airplane, the Convair 340, was hard to sell because of the interior noise in the passenger compartment. Leo and a younger colleague, Edward Kerwin, worked on a solution to the problem using a unique system of engine mufflers and sound absorptive blankets in the passenger cabin, exterior shell, and window construction. More details are in the article by Hanson in this issue. (The late Ed Kerwin and George were fraternity brothers at MIT. Ed spent many productive years as a "Principal Scientist" in the Physical Acoustics Division of BBN.)

An issue with lasting implications arose in 1956 when the Port Authority of New York had to make a decision about bringing in Pan American Airways Boeing 707 into Idlewild airport (now JFK) at the beginning of the jet age. Port Authority policy was that jet airplanes could be no noisier than current propeller planes. A major problem arose because

the measurement methods of the time led to equal noise whereas subjective reactions indicated that the jet airplane was considerably noisier than the propeller airplane. Leo was deeply involved in the issue, and psychoacoustic studies by Karl Kryter led to the development of a new noise metric, perceived noise level. Hanson and Fidell discuss this subject in more detail in their article in this issue.

Publications on Noise Control

Leo's contributions to the Acoustical Society of America are detailed in another article in this issue by Charles Schmid, recently retired executive director of the Society. From a noise control perspective, it is important to recognize Leo's contribution to the ASA-published magazine, *Noise Control* (<http://goo.gl/1GFrF1>).



Figure 2. Leo as ASA president and founder of *Noise Control* magazine, 1955.

The first issue of the magazine came out in January, 1955 when Leo was president of ASA (Figure 2 and article by Charles Schmid). Leo recounted the establishment of the new periodical during his term of office as President of ASA in 1954-55. The Secretary of ASA was Wallace Waterfall, who served in that capacity from the founding of the Society in 1929 until 1969. In 1954, before Leo assumed the Presidency of ASA, he mentioned to Wallace that very few

papers on noise were published in *JASA* because the noise papers submitted to the editorial staff were deemed to be too practical. Wallace suggested that Leo undertake the publication of a new magazine by ASA entitled *Noise Control*. With Lew Goodfriend as the editor, the first issue of the magazine appeared in January 1955, and the magazine continued publication through Leo's term as ASA President and for five years thereafter. The ASA Executive Council then saw the need for a new magazine with a broadened scope and launched *Sound, Its Uses and Control* (<http://goo.gl/df6Mjl>).

• BBN Inc., opens branch office in San Francisco, CA (1967)

• Chief Scientist, Bolt Beranek and Newman, Inc. (1969-1971)

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According to Leo, also while he served as ASA President, the Executive Council recognized the needs of specialists within the ASA for in-house organizations which would represent their interests. This led in 1960 to the establishment of Technical Committees, including the Technical Committee on Noise, within the ASA. This is described in more detail in the article by Schmid.

Most of Leo's book *Acoustics* (Beranek, 1954) is devoted to basic acoustics and electro-acoustical issues. Noise control is, however, the major subject of chapter 11 and its predecessor chapter 10 which covers sound transmission through walls and between enclosures, both important subjects in noise control. A significant portion of chapter 11 is devoted to noise criteria, a favorite topic of Leo's, and was based on his research in government facilities and BBN's extensive consulting in building projects.

Arguably, a breakthrough in his noise control publications came in August of 1953 when Leo organized the first of a series of Special Summer Programs on Noise Control—a cooperative effort between BBN and MIT which featured lecturers from both institutions. One hundred and twenty individuals attended the first two-week course. The course was repeated in 1955 and 1957, and the course material presented became the text for *Noise Reduction*, edited by Leo and published in 1960 (Beranek, 1960). Chapter 1 in the text presents some interesting history and a long list of references. Several chapters, including one on criteria for noise and vibration in buildings, were written by Leo and the others by experts, mostly with a connection to BBN. Aside from the very valuable technical information on noise control, the book set a pattern as a text edited by Leo with his own contributions in addition to contributions by recognized experts in the field. *Noise and Vibration Control*, published in 1971 (Beranek, 1971), followed the same pattern. In addition to authors from BBN, a number of authors from other institutions provided a broad view of noise control. Eventually, INCE/USA acquired the publication rights to the book (Beranek, 1988), and it is still available in paperback (<http://www.bookmasters.com/marktplc/00726.htm>). Leo and István Vár then collaborated to edit a new book, *Noise and*

Vibration Control Engineering which was first published in 1992 (Beranek, and Vár, 1992). A new set of authors contributed to a second edition (Vár and Beranek, 2006). Although there have been many other books, handbooks, and handbook articles on noise control written in past years, this series beginning with *Noise Reduction* stands out as a major contribution to the noise control literature.

The Founding of INCE/USA

Some years after 1970, Leo wrote: "Bill truly conceived the idea of an Institute of Noise Control Engineering. In the late summer of 1970, Bill came to my home in Winchester, Massachusetts and asked me whether I would be interested in joining him in establishing such an institute. The idea being that we could establish a place where noise control engineers could be certified, we could hold regular meetings to disseminate new research and practical developments in noise control, and we could enhance the literature through a technical journal. We discussed the proposition in great detail and then decided to go ahead."

The key player for ASA during this period was Wallace Waterfall. Leo and Bill recognized that Wallace's position regarding the development of INCE/USA would be the Society's position, so we made sure that Wallace was completely informed on plans. As Leo was a past president of ASA and Bill was a past chairman of its Technical Committee on Noise, we pledged to Wallace that everything would be done to foster a continuing close relationship between the ASA and the proposed new organization. The new organization would be formed as a "business league" under Section 501(c)(6) of the U. S. Internal Revenue Code, while the Acoustical Society was a 501(c)(3) organization, chartered as a "scientific and educational organization." The idea was brought before the leading noise control engineers of that day through a workshop held at Arden House in Harriman, N.Y. in January of 1971. Bill took primary responsibility for the organization of this workshop—the birthplace of INCE/USA. Leo became its charter president. Two decades later, Leo assisted with the birth of the INCE Foundation which, to this day, is very active in the support of noise control education, stu-

- INCE Charter President (1971-1973)
- Audio Engineering Society, Gold Medal Award (1971)
 - First edition: *Noise and Vibration Control* (1971)
 - President and CEO, Boston Broadcasters, Inc. (1971-1979);
FCC-licensed owner and operator of TV Station WCVB-TV Channel 5, Boston, MA

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minor activities, the EPA was essentially out of the noise control business—although the law remains today in the United States Code as 42U.S.C.65.

Leo and Bill collaborated to try and restart action on noise policy. They organized an ad hoc committee, the Peabody Group (the first meeting was held in Peabody, Massachusetts in November of 2000). Another meeting was held that year and a third meeting took place in 2001. The Group consisted of noise control specialists with varied interests and they prepared several recommendations. Then followed a series of papers published in *Noise Control Engineering Journal* (e.g., Beranek and Lang, 2003; Finegold et al., (2003). One recommendation was that the National Academy of Engineering (NAE) become involved in noise policy. The NAE did become involved, and the National Academies Press published an NAE report titled “Technology for a Quieter America” (TQA) in 2010 (Maling, 2010), see <http://goo.gl/orNPs2>. A second NAE report titled “Protecting National Park Soundscapes” was also published (Fleming, 2013), see <http://goo.gl/6Frb4N>.

An *ad-hoc* follow-on committee is currently working with several government agencies on noise policy, and Leo is a member of the TQA Advisory Board. The committee has published two reports, one on motorcycle noise (Lang and Wood, 2014) and one on noise barriers and quieter pavements (Wood et al., 2014). A third report on noise policy and noise control engineering in manufacturing facilities is being written.

The EPA has shown no current interest in being the lead government agency for noise control and today many agencies with noise issues are stressed by limited funds. The development of a comprehensive national noise policy remains elusive.

Acknowledgments

The authors are very grateful to have known Leo Beranek for many years, Bill since 1947 and George since 1951. One common interest not mentioned above is the determination of the sound power of noise sources. Leo wrote a chapter on this subject for one of his books (Beranek, 1971), and

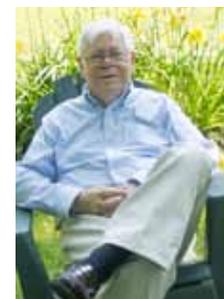
invited us to do the chapter in 1992 (Beranek, 1992). This subject has been important throughout our careers, and we are grateful for that opportunity. Another common interest which runs through the above text is professionalism in noise control engineering. Leo has been very supportive of our activities in this area, and we owe a great deal to his support in our collective efforts to improve the situation with respect to environmental noise control, both nationally and internationally. Thank you, Leo, for all you have done for us.

Biosketches

William W. Lang has served as president of the Noise Control Foundation since 1975. At the IBM Corporation from 1958 to 1992 he had corporate responsibility for the design of low-noise computers. He has been involved in international noise control engineering as a founder of the Institute of Noise Control Engineering (USA) and International INCE and is a member of the National Academy of Engineering.

He has authored more than 50 technical publications and has edited two books. He earned an M.S. from the Massachusetts Institute of Technology and a Ph.D. in physics and acoustics from Iowa State University.

George C. Maling, Jr. is a Fellow of ASA, and has served as chair of the Technical Committee on Noise and a member of the Executive Council. He received ASA's Silver Medal in Noise in 1992. He is also a past president and managing director emeritus of the Institute of Noise Control Engineering, and served for 39 years as editor of *Noise/News International* and its predecessor, *Noise/News*. He has also served as president of the INCE Foundation. He is a member of the National Academy of Engineering, and, in 1999, received the Rayleigh Medal from the Institute of Acoustics (UK).



• Director and Consultant on wide area networks, Wang Laboratories Inc. (1980-1986)

• National Council of Acoustical Consultants, Honorary Membership Award (1982)

• BBN Inc. awarded AIA Institute Honor (1984):

"pioneering acoustical consultants who in 35 years have almost singlehandedly invented an entire profession by creating an awareness of acoustical considerations in design and by integrating technical solutions based on scientific principles with architectural and artistic concepts"



Leo at his office at 16 Eliot Street, Cambridge

Two Early Lessons From Leo

While at the BBN offices on Elliot Street in Cambridge, Leo Beranek, busy as he was as President and CEO of a rapidly growing BBN and simultaneously serving as President of the Acoustical Society of America, led periodic seminars for the BBN staff. I vividly recall two lessons I learned from Leo's seminar discussions which have remained with me throughout my acoustical consulting career now for just over 60 years.

Lesson 1: Teach our clients all we know about the acoustical problem at hand. We must always offer top notch consulting and research services and we owe our clients the very best advice we can give them to enable their making decisions on the project. We advise and our clients decide!

Lesson 2: Share our knowledge with our professional colleagues through technical papers presented at meetings and in publications in accordance with the mandate of the Acoustical Society to "spread knowledge in acoustics and to promote its practical applications."

I have observed Leo Beranek applying these principles in his work since my early days at BBN and throughout his long and productive professional career. I have attempted to do likewise in mine.

William J. Cavanaugh

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wcavanaugh@cavtoci.com

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• Principal, Leo Beranek, Acoustical Design Consultant (1986-present):
primarily consulting and research activities on projects in Japan from 1986 thru 2001

• President, American Academy
of Arts and Sciences,
Cambridge (1989-1994)

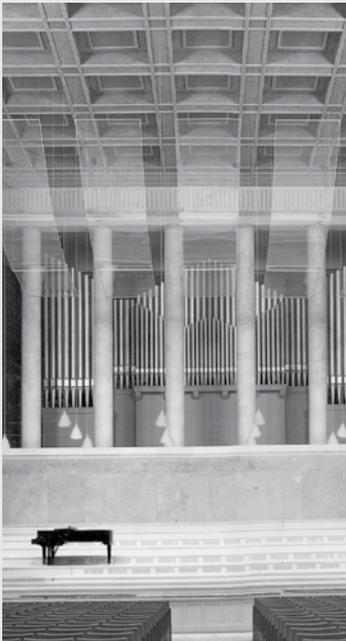
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The Herkulessaal in Munich, Germany, visited by Leo Beranek in 1959, is known as the first concert hall with free hanging reflectors above the stage.

Many Thanks!

As a young scientist in September 1959, I presented a paper at the International Congress on Acoustics (ICA) in Stuttgart, Germany. I was very pleased when I learned that the well known scientist Dr. Leo Beranek from BBN, whom I did not know personally, had listened to my presentation.

During the ICA, field trips had been organized to visit interesting acoustical objects or places. I traveled by railway from Stuttgart to Munich for presentations at the Herkulessaal and the Cuvilliés-Theater. Leo came into my compartment and that is when I got to know him personally. I told about my ideas and my plans and my problems managing a new acoustics consultancy office in Germany. This was the starting point of our more than 55 years of friendship. Leo became aware that we physics- and mathematics-people were proficient in acoustics but had little idea about commerce. We could not get a loan from a bank, which was absolutely necessary for growing; but Leo said: “money is not a problem” and offered that BBN could take a share of 45% (US \$15,000) of the registered capital. So, due his support, in 1962, Müller-BBN GmbH started on its way to becoming a very successful consulting company. Thank you Leo!

Leo became a director of the company. Every year, prior to the shareholder’s meeting, Leo would check up on us and our bookkeeping and our management decisions. Thank you, Leo!

After the yearly Müller-BBN shareholders’ meeting in Munich, we sometimes went to Switzerland for skiing. Leo had a Swiss skiing-instructor-certificate and was an extremely good skier. I was a German skiing-instructor. We skied together on quite steep slopes near St. Moritz, both looking to see who could come down the slopes first. After these sporting interludes, we discussed business decisions. Thank you, Leo!

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An Offer I Could Not Refuse...

In the summer of 1958, as a newly minted assistant professor of mechanical engineering at New York University, I attended Stephen Crandall’s course on Random Vibration at MIT. Shortly after returning back home I received a letter from Bolt Beranek and Newman, which I had not heard of before. The letter was rather long and informal, written by BBN’s president, Leo Beranek. He invited me to come to Cambridge for an interview, described BBN, and extolled the living conditions in the Boston area. Having lived in New York City for five years, I was rather leery of solicitations and my first reaction was to ignore this invitation – in particular, I felt that no president of a significant company would take the time to write such a casual and loquacious letter.

However, my wife Goldie persuaded me to go for the interview and I agreed reluctantly, thinking that at least I would be able to take a free trip to see Cambridge and Cape Cod. Well, the interview with Leo and others was much different than I had expected, and I received an offer I couldn’t refuse. The rest, as they say, is history. I had 37 productive years at BBN before retiring from there and moving on to Acentech (which had evolved from the BBN’s architectural and environmental acoustics consulting group). I will always be grateful to Leo and BBN for introducing me to the broad field of acoustics and for enabling me to make my small contributions to our art and science.

Eric E. Ungar
Retired, BBN (1959-1996)
Senior Scientist, Acentech (1996-)
Principal Scientist, Acentech Incorporated

• First edition: *Noise and Vibration Control Engineering* (co-authored with István L. Vér) (1992)

• ASA Honorary Fellow Award presented at the Wallace Clement Sabine Centennial (June 1994)

• Completion of Hamaryku-Ashi Hall, Tokyo (1994)

On Knocking Heads with Leo

During the summer of 1950 I was a teaching assistant for Richard Bolt who was a visiting professor in the Physics Department at UCLA. Bolt was a dynamic lecturer and enthusiastic promoter of my going to graduate school at MIT and then working for the newly formed consulting firm of Bolt and Beranek. Bolt asked me to come to the next ASA meeting where I could meet Leo.

The ASA meeting was held in Balboa Park in San Diego and we arranged for a meeting with Leo outside during a break in one of the technical sessions. Leo was waiting for us; we started to sit down on a log bench, Leo on one side, Bolt on the other, with me in the middle. At the same time, both Leo and I looked down at the bench to brush away the leaves before sitting and promptly banged our foreheads together as we turned and sat. What a way to meet your future employer! We had many subsequent wonderful opportunities to knock heads together over many years.

William J. Galloway
Retired, BBN Los Angeles
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Circuit Model

I first learned that vibrating electromechanical systems could be analyzed by associating mechanical elements (springs, masses, levers) with common electrical components (inductors, capacitors, ideal transformers) when I purchased in 1959 the new acoustics text by E. Kinsler and A. R. Frey (Chapman and Hall, lt., 1950).

Even so, I did not appreciate the scope and power of equivalent circuits to represent electro-mechanical systems until I used Leo Beranek's new text Acoustics (McGraw Hill, 1954) to teach the engineering Acoustics course in the electrical engineering department at the University of Minnesota in 1956. It was this experience that made me realize the power of an equivalent circuit model to not only represent topology of the physical system, but also to provide a graphical procedure for its dynamical analysis through the regular rules of ordinary circuit theory (combining elements on series and parallel, depending on whether they share a common velocity or force).

Leo Beranek's reputation and accomplishments in architectural, electro-, and physical acoustics are outstanding, but I cannot overlook his other outstanding accomplishments in basic electrical engineering.

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Guidance From a Friend

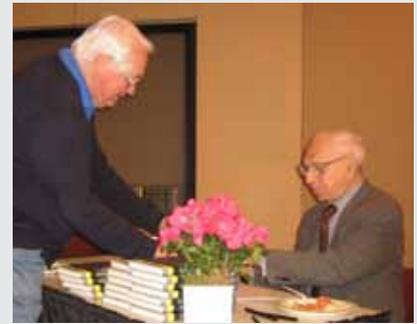
I was drawn to BBN by associations with Leo, Ira Dyer, Dick Lyon, Eric Ungar, and other BBN'ers whom I had met at ASA meetings that I attended as a Naval officer seeking to understand how to improve sonar systems.

Upon graduation from Harvard, I shared two characteristics with Leo - we both grew up in Iowa and we both shared the same PhD thesis advisor, Prof. F. V. Hunt.

Leo suggested that my wife Mary and I should move to Winchester where he and his late wife Phyllis lived. We did so, and they introduced us to friends in Winchester. Leo and Phyllis also introduced us to the bear steak dinner at the Harvard Faculty Club.

Leo was Chief Scientist of BBN when he left BBN to manage the CH 5 TV station in Boston - John Swets and I took his title. I retired this year from BBN with this same title, after 50 years that were launched with guidance from Leo Beranek. Though I did not help Leo to found the company, I worked there longer than he did.

Jim Barger
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Retired, Chief Scientist BBN Technologies
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Dick Lyon with Leo at book signing for "Riding the Waves" in 2008

• Completion of Town Concert Hall, Mitaka, Japan (1995)

• First Edition: *Concert Halls and Opera Houses: How they Sound* (1996)

• Completion of Tokyo Opera City Concert Hall (1997)
• Completion of National Theater Opera House (1997)

• INCE, First Distinguished Noise Control Engineer Silver Bowl Award (1996)

• Honorary Life Trustee, Cornell College, Mt. Vernon, IA (1997)

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