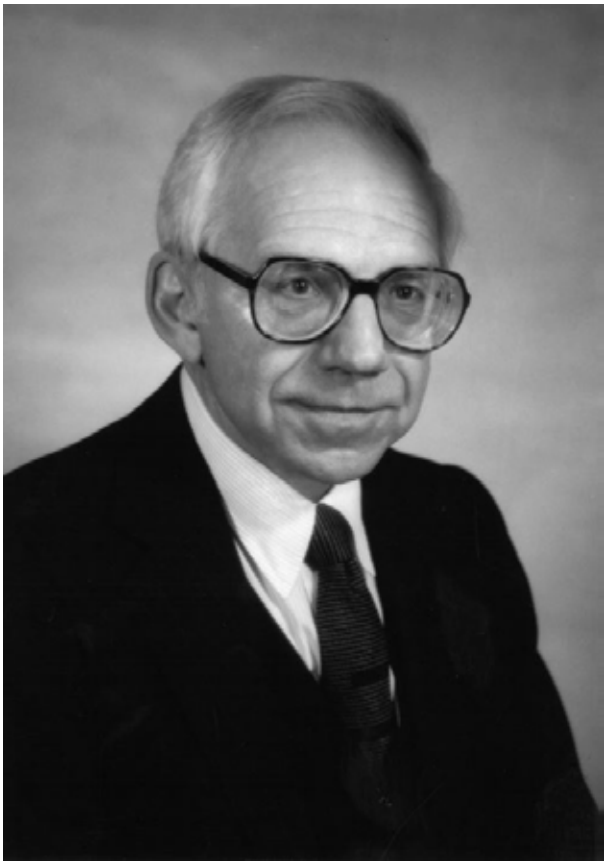

Leo L. Beranek

LEO L. BERANEK

1914–2016

Elected in 1966

"Applied acoustics."

BY TIM J. MELLOW
SUBMITTED BY THE NAE HOME SECRETARY

LEO LEROY BERANEK, a renowned acoustician, teacher, philanthropist, leading light of hi-fi sound, and cofounder of the internet-pioneering company Bolt Beranek and Newman (BBN), died October 10, 2016, at the age of 102. He was a pillar and major contributor to the field of noise control engineering.

Leo was born September 15, 1914, in Solon, Iowa, to Beatrice and Edward Beranek. It was at the age of 14 that he was introduced to the brand new field of electronics when the family moved to Mt. Vernon, Iowa, where his father joined the family hardware business that sold radios, which required installation, service, and repairs. While at Mt. Vernon High School, Leo took a correspondence school course on radio technology and repair, which led to his becoming Mt. Vernon's "Radio Man." This set the stage for his extensive use of electrical circuit analogies in his later acoustical work.

After graduating from high school with highest honors in 1931, Leo was accepted at Cornell College in Mt. Vernon. Because the family business was hit hard by the Depression,

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George Maling made important contributions to this tribute. A fuller biography is available from the Acoustical Society of America (http://acousticalsociety.org/sites/default/files/Leo_Beranek.pdf).

he had to take a year off to fund his tuition by working for Collins Radio, a manufacturer of transmitters, and doing farm work during the summers. During this time, he also played drums in dance bands and tympani in the college symphony orchestra. He received his bachelor's degree in mathematics and physics from Cornell in 1936, missing Phi Beta Kappa by only a tenth of a point.

He now faced the challenge of obtaining a scholarship to enable him to attend graduate school. His lucky break came as he strolled down Mt. Vernon's Main Street on August 16, 1935. He came across a Cadillac with a Massachusetts license plate parked at the curb with a flat tire. He offered help, and it turned out that the driver was Glen Browning, a former instructor in engineering from Harvard with a successful radio manufacturing business in Winchester. Leo had just read his paper on the Browning tuner in the library that morning. The two struck up an instant friendship. Glenn gave Leo the names and addresses of two people at Harvard, one for admissions and the other for scholarships, and instructed him to use his name as a reference.

Leo's application for the scholarship to Harvard was successful. After receiving his MSc in communication engineering and physics at the end of his first year with nearly all As, he was offered a job as a research assistant to Frederick V. Hunt at the Cruft (later Electro-Acoustic) Laboratory. The pay enabled Leo to go from subsisting on two meals per day to three.

To help Hunt develop a means for playing the newly developed 12-inch vinyl records, which needed a much lower-weight pickup, Leo was tasked with setting up a listening studio and designing the playback equipment. This included a 20 watt tube amplifier and a multicell horn loudspeaker with a large exponential horn woofer to showcase the improved sound quality of vinyl compared to 78 rpm shellac disks. By the end of the academic year, they had achieved their goal of reducing the weight of the phonograph pickup from 60 to 2 grams. With the huge reduction in surface noise—and the increase in playing time from 3 to 23 minutes per side—vinyl revolutionized the way people listened to music.

During the 1938–39 academic year Leo worked with Hunt and fellow PhD student Maa Dah-You to verify experimentally (and to extend) the theory of sound in rectangular enclosures, presented in the book *Vibration and Sound* by Philip M. Morse (American Institute of Physics; 2nd edition, 1991), with and without damping material applied to one of the walls. This research made it possible to predict the resonance frequencies (or eigenfrequencies) from the dimensions of the enclosure and led to Leo's first paper, "Analysis of Sound Decay in Rectangular Rooms," published in the *Journal of the Acoustical Society of America* in July 1939. This was followed in June 1940 by a second paper, "Acoustic Impedance and Sound Absorption," in which the acoustic impedances of commercial acoustic materials were measured, typically using Leo's personally designed apparatus. These data had not previously been available and, in a contemporary paper, Morse wrote that, because of Leo's results, "it is now possible to demonstrate the adequacy of the theoretical connection between the acoustic impedance of the material and its physical properties, on one hand, and the absorption coefficient as employed in usual practice, on the other."[1]

Leo received his doctorate and in 1940 took his first job at Harvard as an instructor in physics and communication engineering, which involved teaching and upgrading laboratory apparatus. He demonstrated his natural diplomacy skills, asking the other instructors for their views before offering his own.

He was soon recruited to lead a team in a National Defense Research Committee project, with Morse and Hunt as chair and vice chair, respectively, of the supervisory committee. The Army Air Corps urgently needed a lightweight acoustical material to deaden propeller noise in their bombers, which they believed was causing pilots to become overfatigued.

Leo considered that a good sound-absorbing material would have a large internal surface area against which viscous

[1] Morse PM, Bolt RH, Brown RL. 1940. Acoustic impedance and sound absorption. *Journal of the Acoustical Society of America* 12(2):217–227.

flow losses would occur. One possibility was to adapt glass-fiber wool used in heat insulation, but the fibers were too large. He then came up with the idea that making the fibers smaller in diameter and increasing their number would reduce the weight more rapidly than increasing the total surface area. The Owens-Corning Fiberglass Company was willing to experiment with this and after a couple of months produced a new material called Fiberglas AA in which the diameter of the fibers was one-tenth that of a human hair. It is widely used in passenger airplanes to this day.

Another focus of the project was to improve the intelligibility of speech in headsets used by pilots and crew by improving both noise immunity and the high-frequency response, to make it easier to discern consonant sounds such as "th," "sh," "t," and the like. Within a year of the United States entering World War II, the new ANB-H-1 headset was standard in the aviation services.

The next military project would be instrumental in making the D-Day landing a success. The Allied Army wanted to set up a decoy, known as the "ghost army," to trick the German army into thinking that there would be a landing at Pas-de-Calais (as part of Operation Fortitude). Further decoys would also be used on the continent after the landing. These involved the use of inflatable rubber tanks and other military equipment together with large loudspeakers to produce their sounds, which would be audible 15 miles away.

To select the best loudspeakers for the task, a new kind of testing facility was required. The speakers would be too loud for testing outdoors in inhabited areas, but they needed to be tested in soundproof conditions without reflection, simulating outdoor conditions. Leo designed one of the first chambers to provide such conditions, using thousands of glass fiber wedges on the walls, and described it as so quiet that "you could hear the blood rushing through your ears." He even coined the term "anechoic chamber," which has entered the dictionary.

After working on another project to improve communication systems in the combat information centers aboard Navy ships, especially with respect to equipment, sound engineering, and

selection and training of operators, Leo was awarded a John Simon Guggenheim Fellowship in 1945, which enabled him to write *Acoustic Measurements* (John Wiley & Sons, 1949). He had received the R. Bruce Lindsay Award the previous year for his published papers.

Leo left Harvard in 1947 to become professor of communication engineering and technical director of the Acoustics Laboratory at MIT. The course he taught there formed the basis of his famous 1954 book *Acoustics* (McGraw-Hill), the first to show the electrical, mechanical, and acoustical parts of a transducer on a single analogous circuit, making it easier to understand a transducer visually.

Electrical circuit theory could be applied to predict the transducer's performance. Subsequent writers such as Neville Thiele and Richard Small took Leo's work a stage further by applying modern filter theory, which enabled a loudspeaker to be engineered to give a chosen frequency-response shape. Leo was particularly proud of the fact that Edgar Vilchur used *Acoustics* as the starting point for his invention of the "acoustic suspension" principle, which led to smaller loudspeakers with a good bass response.

In 1948 Leo, together with his fellow MIT professor, Richard Bolt, founded Bolt Beranek, which became BBN in 1950 when they were joined by Richard's former student Robert Newman. Their first contract was to provide acoustical consultancy for the United Nations Assembly Hall in New York. They were told that the loudspeakers had to be mounted behind the podium, which could have led to a feedback problem with the microphones in front of them. Leo selected loudspeakers and microphones made by Altec and designed to have uniform amplitude and phase responses that avoided such problems.

BBN worked on a number of auditoriums over the next decade, including some with "difficult" shapes. These included the Aula Magna concert hall of the Universidad Central de Venezuela (1953), MIT's Kresge Auditorium (1954), the Grace Rainey Rogers Auditorium in the Metropolitan Museum of Art in New York (1954), the Northern Alberta Jubilee Auditorium in Edmonton (1955), the Binyenei Ha'Uma concert hall and

convention center in Jerusalem (1956), the Culture Palace at Tel Aviv (1957), and the Tanglewood Music Center in Lenox, Massachusetts (1959).

Leo realized early on that it wasn't the number of people in the audience that determined the reverberation time (RT) but the total seating area. This explained why so many concert halls, such as the Royal Festival Hall in London, had shorter RTs than their acousticians had calculated.

After being asked to provide acoustical consultancy for the David Geffen Hall (then known as Philharmonic Hall) at New York's Lincoln Center, BBN surveyed 54 concert halls and opera houses, mainly in Europe, to establish the relationship between the acoustical properties and the size and design of the auditorium. Leo interviewed musicians and conductors and visited the halls. He concluded that the best shape was that of a shoe box with no more than 2,400 seats. The results of the survey went into his 1962 book *Music, Acoustics and Architecture* (Wiley), which contained descriptions of how the concert halls sounded as well as photographs, plans, and a wealth of technical data.

Unfortunately, after a press campaign to increase the number of seats, the Lincoln Center building committee instructed the architects to increase the seating capacity to 2,760—the same as that of the Carnegie Hall that the David Geffen Hall was intended to replace. The architect, Max Abramowitz, wouldn't allow BBN to debate the changes with the committee members and so Leo was powerless to prevent them. Horizontal side balconies were replaced with steeply sloping ones with bowed fronts to cram in more seats. Panels above the audience that Leo had suggested should be adjustable were fixed. To save money, the walls and ceiling were smooth instead of having irregularities to diffuse reflected sound. To make matters even worse, the row of panels nearest the stage were hung six feet too low by mistake. Thus the sound on opening night wasn't what Leo had intended and reviews were mixed. Despite some bad publicity and an absence of follow-on work in concert halls for nearly three decades, Leo always had the full support of the acoustical community.

At MIT during the 1950s Leo was also involved in research on noise in heating, ventilation, and air conditioning (HVAC). He resigned from his professorship in 1958 to work for BBN full time, although he continued as a lecturer at MIT until 1981.

BBN did much research into noise in working spaces that helped to establish current international standards. The work extended to transport, with the design of exhaust mufflers and sound deadening for the Convair Aircraft Company in 1954.

In 1956 Pan Am wanted to fly its new Boeing 707 jet airplanes from Idlewild (now John F. Kennedy International) Airport, claiming they were no noisier than the company's propeller airplanes. But their measurements didn't account for the fact that, while the overall amount of noise may be the same, the human ear is more sensitive to the predominantly higher-frequency sounds produced by the jet engine. Aware of a lawsuit at Newark Liberty International Airport brought by angry residents, the Port of New York Authority wanted to avoid a repeat at Idlewild.

Using psychoacoustic research, BBN came up with a new metric to measure noise, the perceived-noise decibel (PNdB), which is now part of International Civil Aviation Authority standards. Consequently, noise over populated areas was restricted by the Federal Aviation Administration (FAA) to 112 PNdB, which meant that mufflers had to be fitted to the engines and takeoff procedures modified. Leo saw this as one of BBN's most important achievements because of its impact on the quality of life near airports.

In 1959 BBN received contracts from NASA for control of sound and vibration in space vehicles. All this work, complemented by industrial summer courses on noise control that Leo organized at MIT, culminated in two of his books, *Noise Reduction* (McGraw-Hill, 1960) and *Noise and Vibration Control* (McGraw-Hill Higher Education, 1971).

Early on, Leo had been thinking that computer systems could be used to amplify human labor and so hired J.C.R. Licklider in 1957. "Lick," as he liked to be called, was a first-rate psychologist with physics training and experience in computers. After a few months he requested that BBN purchase a

Royal-McBee LGP-30, costing $30,000. When Leo asked what he proposed to do with it, Lick replied with the prophetic words "I don't know, but if BBN is going to be an important company in the future, it must be in computers." Leo had enough faith in Lick to go ahead.

By 1960 BBN had progressed to the very first production of PDP-1 by DEC, which led to several lucrative software contracts. After hiring MIT professors John McCarthy and Marvin Minsky, BBN was able in 1962 to demonstrate time sharing among three remote operators to the public for the first time. Then in 1968 BBN won the contract from the Advanced Research Projects Agency (ARPA) of the Department of Defense to develop the ARPA Network (ARPANET), predecessor of the internet, to connect large computers at leading universities and laboratories.

As Neil Armstrong's famous words "one small step for man" and the Concorde supersonic passenger jet made the headlines in 1969, the first message sent between two packet-switched computers in different cities went almost unnoticed. Yet the internet has had a far greater impact on the world today than either human space travel or supersonic passenger flight.

On October 3, the first message sent from the University of California, Los Angeles, to the Stanford Research Institute (now SRI International) read "LO"—the first two letters of "log in"—before crashing. But history was made. According to Leo, the fastest-growing use of ARPANET turned out to be email, although it was originally intended for sharing the use of processors, rather like server farms in the cloud today. BBN initiated the use of the @ symbol in email addresses.

That same year, Leo resigned as president of BBN (he continued as a director until 1983) to concentrate on the bid by Boston Broadcasters Inc. (BBI), of which he was president until 1979, to obtain an FCC license to run what became WCVB-TV Channel 5 Boston. Although BBI had won the bid earlier in 1969, there was a legal challenge by rival bidder WHDH. BBI won the appeal and began broadcasting on March 19, 1972. WCVB's news programs soon became the most watched in Boston and Leo received the Abe Lincoln Television Award in 1976.

Leo chaired the board of overseers for the Boston Symphony Orchestra in 1977 and then the board of trustees from 1983 to 1989, during which time he organized fundraising to turn around a dire financial situation. He remained a life trustee and has been honored with the Beranek Room in Boston Symphony Hall.

In 1989 he was invited to be the acoustical design consultant for the Opera House of New National Theater, Tokyo. Leo incorporated a horn comprising two curved surfaces, one above and the other below the proscenium, to amplify the soloists' voices so that they wouldn't be drowned out by the orchestra in the pit below as in most other opera houses. The venue receives glowing testimonies from leading musicians who perform there. Five more commissions from Japan followed, including Tokyo Opera City, which was the most challenging because of its distinctive pyramid-shaped roof. It was hailed by the *New York Times* on April 18, 2000, as an acoustical "miracle."

Leo's books and many papers on auditorium acoustics have furnished designers with a comprehensive list of metrics to evaluate sound quality. His last paper, "Concert Hall Acoustics, Recent Findings," was published in April 2016.

He was a member of the executive council during a difficult time for the Acoustical Society of America (ASA). A group complaining about a lack of autonomy had broken away to form the Audio Engineering Society (AES). Leo set up a committee, with R. Bruce Lindsay as chair, that recommended the creation of the current "technical sections," which solved the problems. Leo was elected ASA president in 1953 and inaugurated in 1954. In 1971 he won the AES Gold Medal and in 1975 the ASA Gold Medal.

He was also an organizer and the charter president of the Institute of Noise Control Engineering of the United States of America, established in 1971, and he participated in the founding of International INCE in 1974. He served on the board of the INCE Foundation, which recognizes and rewards technical excellence in noise control engineering education and provides financial support for undergraduate and graduate

students, educators, and authors judged to be outstanding in the field of noise control engineering.

Elected a fellow of the American Academy of Arts and Sciences in 1952, he served as president from 1989 to 1994. As a member of the National Academy of Engineering, he served on the Membership Committee (1966–68), Council (1970–71), Committee on Public Engineering Policy (1966–72), Marine Board (1966–71), and Aeronautics and Space Engineering Board (1966–71 and 1973–76).

In 2002 President George W. Bush presented Leo with the National Medal of Science in Engineering, "For his leadership, dedication, and contributions to the art and science of acoustics; for cofounding one of the world's foremost acoustical research and consulting firms…." In 2013 he was awarded the Founders Medal of the Institute of Electrical and Electronics Engineers (IEEE).

Ironically, despite having been so influential in the hi-fi revolution, when asked what sound system he had at home, Leo replied, "I have nothing against recorded music. In Boston, we have a great orchestra and a great concert hall so I, and my wife, do our listening there.… [F]ive speakers in one living room sounds deadly."

In addition to working hard, he found time to go skiing and attend concerts. To those who knew him Leo was an organizer, good at motivating people, honest, approachable, and informal, with an infectious smile. He had a passion for the subject of acoustics that made it seem more like fun than work, and in 2008 published his autobiography, *Riding the Waves: A Life in Sound, Science, and Industry* (MIT Press).

He was married to his first wife, Phyllis (née Knight), from 1941 until she died in 1982. He married Gabriella Sohn in 1985 and is survived by her, sons James K. Beranek of Cedar Rapids and Thomas B. Haynes of Chicago, and granddaughter Antonia Hsu Haynes.

He is greatly missed.