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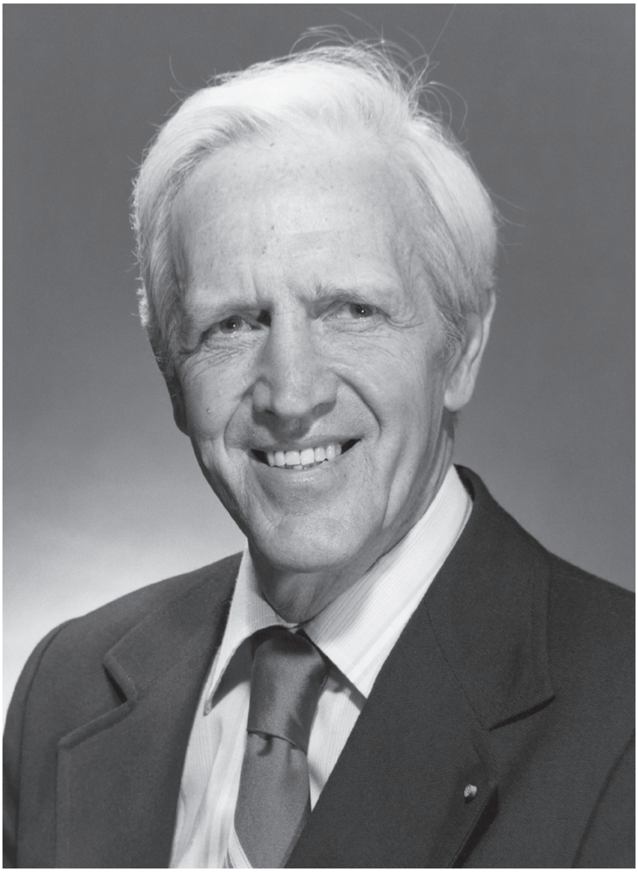

C C Cutler

C. CHAPIN CUTLER

December 16, 1914–December 1, 2002

BY PING KING TIEN

THE ECONOMY WAS IN a depression between 1929 and 1934, and the country went to World War II between 1941 and 1945. C. Chapin Cutler built his character and his strength in those chaotic years. He led a successful career of research in communication science for more than four decades. His inventions in radio, radar, signal coding, imaging, and satellite communications earned him more than 80 patents, numerous awards, and a worldwide reputation. Shortly after he received the Alexander Graham Bell Medal from the Institute of Electrical and Electronics Engineers (IEEE), Cutler said in the spring 1992 issue of the *WPI Journal,* "I don't think I'm really that smart. I just think my imagination got turned on at an early age and that gave me tremendous motivation."

Cassius Chapin Cutler was born on December 16, 1914, in Springfield, Massachusetts. He was the son of the late Paul A. and Myra (Chapin) Cutler. He was raised in a small town environment and was educated in the public school systems of western Massachusetts. His resourcefulness and ingenuity had their roots in his youth and later in his education at Worcester Polytechnic Institute.

In 1929, radio was very popular with young people. At age 14 Cutler played with elementary crystal receivers and his grandfather's three-tube radio, mostly listening to the air broadcasts. Radio technology was still a mystery to him. When school started that fall, he went to the library to look for books on radio. Later he met his friend Larry Reilly. Reilly gave him a copy of *Radio Craft* magazine containing an article, "The Junk Box Radio." Cutler later wrote in his journal, "This, I believe to be the most crucial event of my life."

"That's how I started," he said, "I built the junk box radio receiver, using parts from a defunct broadcast set. I screwed the parts onto a pine board and used a single old vacuum tube. I salvaged even the wire and the solder from the old radio and used my dad's soldering iron heated on the kitchen stove." After the radio was built he heard "dit, dit, dit, dah, dit, dit, dah" from a station in Mexico City, and he was forever hooked on radio.

Shortly after, his father took him to a talk given by a visiting scientist from the newly established Bell Telephone Laboratories. The talk was "The Wonders of Radio and Communication." It was a popular talk with demonstrations. The speaker modulated a neon bulb, talked over a light beam, and demonstrated inverted speech. That was when Cutler learned of Bell Laboratories and decided what he wanted to do with his career. Experimentation with electronics soon became his avocation, and he supported his hobby by baking beans and selling them to neighbors.

In the summer of 1933 Cutler graduated from the Springfield Technical High School. His father and mother were determined that he should go to college, but no one in the family had college experience and none of them had any idea of how to enroll. One day in August he was stopped by his neighbor Eddy Milde, then a graduate student and a track star at Worcester Polytechnic Institute (WPI). Eddy encouraged Cutler to apply to WPI and gave him an application form. A week later Cutler visited the campus and was interviewed by Professor Zelotes W. Coombs. Later that day Professor Coombs told him he was accepted provided he did well in the first semester. When Cutler returned to Springfield, the whole family was elated. His Christian Science practitioner, Evangeline P. Walbridge, came for the occasion and said, "The ONE MIND, Infinite Intelligence is yours. Whatever it is your duty to do, you can do . . . God gives the increase . . ." Cutler did not appreciate what she said until much later.

These were the Great Depression years, and there was a problem with finances. The money he saved from selling beans was less than \$100. His mother gave him \$300 from Grandfather Chapin's estate, and his dad obtained a loan from an insurance policy. Cutler had enough to start for the first year: \$135 for room, \$270 for board, \$350 for tuition, and more for supplies. Cutler was excited. Mrs. Walbridge built his confidence by saying, "God supplies all our needs, only requiring that we be worthy."

Cutler soon learned of the "Fuller Scholarship for Yankee Ingenuity." He worked day and night cleaning up his radio station, photographing and writing up the project. He got advice from many. Dorothy Noble helped put the story together and typed the report. He did not win, but he was cited as the runner-up; and, with that in his record, he later received special attention at WPI from professors and employers.

Worcester Polytechnic Institute, established in 1865, was the third engineering school in the United States, after Rensselaer in 1824 and the Massachusetts Institute of Technology in 1861. It is situated inside the city of Worcester, which in the late 1800s became a major manufacturing center, particularly in the machine tool industry.

The founders of the school believed that students should work with various metal and woodworking tools so that they would be familiar with the capabilities and limitations of the manufacturing process. They selected the motto, "Lehr and Kunst," which in German means "learning and skilled art." To prepare future generations of engineers, students were encouraged to discover, to create, to innovate, and to lead. In addition to academic courses, students were encouraged to work with the community and learn to solve practical problems. The institute produced great leaders in government and industry, and Cutler was among them.

The first day in Worcester was memorable. It was a gregarious class of 126 boys. Cutler and his roommate, Earl Curtis, were assigned a room in the new Sanford Riley Hall in the corner of the first floor overlooking the city. Most of the classmates were from the working class or laboring class and not much better off financially than Cutler. To support themselves the students took such odd jobs as cleaning windows, washing cars, shoveling snow, and tending coal-fired boilers. They were typically paid 40 cents an hour. The instructor in English, Paul Swan, ran the College Student Christian Association (YMCA), which was the contact point for the jobs. In addition, the school provided a few scholarships. Cutler earned more than $700 each year, which with the scholarships, was more than enough to cover his expenses.

Students at WPI pioneered in amateur radio as early as 1911. They obtained call sign 1YK, which was later W1YK. The Worcester Tech Wireless Association, later named the WPI Radio Club, is reputed to be the oldest college radio station in the United States, but it was not successful when it first went on the air. Cutler joined the club soon after he became a student at WPI. Partly because he was the only ham with a two-letter call, he was elected as the chairman of the Transmitter Committee; later he was elected vice-president and then president of the club.

One day Cutler went to the electrical engineering department looking for books on radio. He met Professor Hobart H. Newell, a radio pioneer, and Victor Siegfried, a beginning instructor with an advanced degree from Stanford University. Siegfried introduced to him the new *Radio Engineering* textbook by Frederick E. Terman. Much of the text was over his head, but in the library he found *Shortwave Wireless Communication* by Ladner and Stoner. He devoured it eagerly. In the first year at Worcester, whenever Cutler got ahead of his homework, he studied radio.

As the chairman of the Transmitter Committee in the radio club, Cutler was soon charged with the responsibility of getting the radio station on the air. He redesigned the station and the QSL card. In 1936 the club entered the ARRL sweepstakes and ran up a commendable score of 20,451 points. In the meantime the school provided a pair of high-power (100 W) transmitter tubes, which generated a great deal of enthusiasm in the electrical engineering department.

During one Saturday night Cutler operated in a radio contest, in the windowless third floor of the Atwater-Kent Building. When he emerged from seclusion the next morning, he found that it had snowed all night. He immediately found jobs shoveling snow and he worked until five in the afternoon. He was $6 richer but very hungry. That night he ate two dinners and still had almost $5 left.

During four years in college, Nate Korman was Cutler's close friend. They worked together, intellectually challenging and supporting each other. In the second year at WPI they shared a rented room at 47 Institute Road. Both of them intended to major in electrical engineering, but they wanted to learn more about advanced physics and mathematics. With the support of Professor Newell they switched to general science, a major that had almost entirely elective courses. Years later Nate had a successful career at RCA, while Cutler prospered at Bell Labs. Cutler did well in college, and in the summer of 1937 he graduated with distinction (seventh in his class) from Worcester Polytechnic Institute with a degree in general science.

In the summer of 1934 Cutler worked as a chauffeur for Mr. T. Hovey Gage, a lawyer in Worcester, for $105 a month. On Memorial Day weekend he drove Mr. Gage to his summer residence in Maine. It was a 180-mile, eight-hour trip. Top speed was 12 mph on backroads, sometimes dirt roads. On entering Waterford, Maine, on the dirt road from Bridgeton, Cutler observed two very attractive girls on the street in bathing suits, buying fish from the traveling fishmonger. Later in the evening Cutler was invited to a party of young people at the Wilkins Community House, where he met the girls he had encountered earlier. The most attractive girl was Virginia Tyler. At that time he knew he wanted to be close to Virginia Tyler.

During that summer Cutler drove again and again to Maine, where Mr. Gage provided a room for him at a local inn, the Lake House. He swam in the lake and pitched horseshoes with the local boys beside Round's store. Some of the young people had formed an orchestra, The Rhythm Ramblers, which practiced evenings in the community house. Virginia was the pianist and sat facing the side window. The sight of her concentrating on the music, framed by the window, Cutler described as a most attractive scene.

One evening Virginia, Christine McKean, and Cutler were in Waterford village looking for adventure. Virginia suggested that they go canoeing, using the bishop's canoe, the *Mary B*. It was a beautiful night and terribly romantic, flooded with the light of the moon. They played Truth or Consequences (without the consequences). Afterward Cutler walked Virginia home. They stood in front of Round's store, under her living-room window, for a long time talking about anything and everything.

After the graduation from WPI, Cutler's life was very busy. On September 27, 1941, Virginia Tyler and Chapin Cutler were married in Waterford, Maine. They had a beautiful church wedding with Mother, Brother Lee, Sister Natalie, Virginia's family, and most of the Waterford village present (about 100 people). Chapin's Cousin Wilbur was the best man.

After graduation from WPI, Cutler applied for employment at Bell Telephone Laboratories. Job opportunities were scarce in 1937; the economy had not quite recovered from the Depression and the laboratories, to reduce the costs, were open only four days a week. Cutler's interview was at 463 West Street in New York City on the Hudson River waterfront. During the interview he met an erudite fatherly figure, Ralph Bown. Bown had pioneered in military radio communication during World War I and had made his way through the U.S. Army Signal Corp, Western Electric, and into management at Bell Labs. Cutler described his antenna experiments and attempts at WPI to carrier-depressed modulation for communication. Bown was impressed, and they shared the vision that the science of the future was radio.

There were no openings in the research departments in New York City, but Cutler was offered a position at a branch laboratory in Deal, New Jersey. At Deal, research and development was centered on shortwave radio, high-power transmitter tubes, new antenna designs, and ionospheric radio propagation. They were all areas close to Cutler's interests.

The Deal laboratory consisted of six buildings, a few shacks, and outhouses scattered over a 360-acre field. The buildings were overshadowed by 150-foot steel towers, wooden antenna poles, and mysterious antenna arrays. The main building built before 1920 had recently been renovated for shortwave radio experiments in preparation for telephony across the seas. Other buildings included a machine shop, a garage, a classic “Harvey” farmhouse, and two temporary wooden frame structures that housed the shortwave and the longwave laboratories. There was a tennis court, a picnic area, and a softball field in a grove of giant maple trees. The site was on prime fallow, roughly mowed farmland, with Whale Pond brook running though the center.

Cutler’s subdepartment head and later department head was John C. Schelleng, a veteran of the Army Signal Corp. Schelleng was well known for his paper on ionospheric radio propagation. Cutler’s close associates were J. Peter Schafer, their supervisor; James Wilson McRae, a recent Ph.D. graduate from Caltech; and Thomas G. Morrisey, who was Cutler’s age and just as eager.

Cutler and McRae shared an office and half of the transmitter lab on the second floor of the main building. Initially they were assigned to design a high-power transmitter at 23 MHz using 25-kW experimental tubes supplied by Sid Ingram in New York. They used a feedback amplifier configured as the transmitter stage, which required a delicate balance between the stray capacitances.

Cutler called his first invention the “self-neutralized amplifier” because it balanced the internal tube capacitances, plate to cathode and grid to plate, against each other to prevent capacitive feedback. The grid and cathode were driven by the signals opposite each other in the optimum ratio. It proved to be stable, gave sufficient radio frequency feedback, improved linearity, and provided reasonable input impedance. One day Mervin Kelly, then director of research and later vice-president, came to Deal for a visit. Cutler showed him the transmitter, and Kelly said, “Oh, you are the one who invented the new amplifier.” Cutler was thrilled.

One day Schelleng told Cutler, "Do what you want. You don't have to check with me. Tell me about it only when you want to." He gave him complete freedom, with full confidence that important results would be forthcoming. It was the culture and the wisdom of the management that made Bell Laboratories renowned worldwide, and the best place for research.

After gaining experience on the 25-kW transmitter tubes, Cutler and McRae embarked on another adventurous project: the development of a 200-kW transmitter to operate at frequencies switchable from 4 MHz to 23 MHz with feedback over four stages of amplification. The objective was to provide 12-channel, single-sideband, multiplex telephony between the United States and England. They worked for two years until 1940, when Bell Labs was diverted into military work in preparation for war.

In 1940 Schelleng asked Cutler to work on the proximity fuse. The idea was to install a radio circuit in an explosive shell that would be shot from the ground toward an enemy airplane. The circuit would sense the proximity of the airplane and send a signal to the ground to detonate the shell. Cutler designed the circuitry and tested the fuse at Aberdeen Proving Ground in New Jersey and Indian Point in Maryland. The project was shortened by the success of a self-contained triggering circuit.

Late in 1941 McRae and Cutler were asked to design and build waveguide plumbing for an X-band aircraft antenna. They received lots of advice. The world's waveguide inventors and experts, George Southworth, Arnold Brown, and Archie King, were still at Holmdel, and Sergi Schelkunoff was only a phone call away. Cutler successfully built waveguide elbows, rotating joints, and connectors.

At that time one had to build one's own testing gear, including power supplies. McRae wanted to test the waveguide circuitry and the antenna as a full working assembly. The antenna and the waveguide feed were designed at the facility in Whippany, New Jersey. McRae built the assembly according to their design and mounted one antenna on the second floor of the main building and another in a remote location.

They were able to measure the directivity pattern and field intensity versus elevation angle and azimuth. They obtained good pattern in the E plane or in the H plane but had to adjust the structure between measurements. The beam width was about three degrees as required, but side lobes were one-tenth as strong as the main beam in one plane or the other, not close to the one-half percent power level required. Cutler hastily constructed more apparatus for measurements of amplitude, phase, and polarization of the radiation from the antenna feed. He tried various configurations of the assembly. Nothing seemed to work.

In the midst of this work McRae was called to Washington to guide the Army Signal Corps into the new age of radar. (Years later he returned to the labs as the department head, director, and vice-president.) Cutler was left alone with the antenna project.

"Late in the night, abed," Cutler wrote in his notes, "it all came together in my mind. In the morning, I slapped my vision together with copper foil, solder and sealing wax, and I had quite a different horn structure and a good radiation pattern. I slimmed down the waveguide and channeled the energy into two relatively narrow slots on each side of the guide. I called it the Waveguide Splitting Head. By varying its shape and size, I found a simple way to match the impedances."

It was indeed a novel, ingenious design of the antenna feed. The two slots were located exactly half a wavelength apart. The radiations from the two slots reduced the energy in the side lobes and reinforced the energy in the main beam. He used a screw in the splitting head to adjust field distributions in the two slots. It was simple, and it was reliable.

The waveguide antenna system, dubbed the "Cutler feed," was produced by the thousands and was aboard every Allied bomber in the latter part of World War II. Overnight Cutler became known as a radar expert and was consulted on various antenna designs. In the meantime he invented a variety of antenna feeds, including the corrugated waveguide, which years later was used in microwave devices. When radar was unveiled to the public in 1945, an artist's rendition of the Cutler feed appeared in the August 20 issue of *Time* magazine. By then Cutler had the fame, a beautiful family, and a job he loved.

In March 1944 with the war winding down, they began to work off the huge backlog that had accumulated in the telephone plant. AT&T announced a crash program to build an intercity microwave relay system from New York to Boston for both television and telephone signals. The system involved the construction of a series of radio relay stations about 30 miles apart with 3 MHz of bandwidth, in 4 GHz channels. They selected the close-spaced triode for the repeater amplifier.

Returning to Deal from the wartime assignment, Schelleng invited Cutler to listen to a presentation by John R. Pierce, who was going to describe the traveling wave tube (TWT) that he had learned about in his recent trip to England. The TWT was invented by Rudolph (Rudi) Kompfner in England. It was a major breakthrough for microwave circuits. The bandwidth of a triode was limited by electron transit time, and interelectrode capacitances. In the TWT, amplification was obtained by the extended interaction between propagating waves and a beam of electrons. It eliminated virtually all the bandwidth limitations. At that time Schelleng and Pierce thought the TWT would be the next generation of repeater amplifiers.

Cutler was asked to study the circuit problems of the TWT and to move his laboratory to the newly constructed research center in the suburb of Murray Hill, New Jersey. Most of the activities in New York City had already moved to Murray Hill as the operations of Bell Labs rapidly expanded during the postwar period. The TWT faced several difficult technical problems, and there was a flurry of activities designed to overcome them. Pierce started the analysis and Cutler started the measurements. For years TWTs were made in a specialized shop where it took weeks to construct a single tube. Cutler longed to be able to make his own tubes. He studied vacuum systems and built his own pumping station. It was not easy. "I never did get the station clean enough for the oxide cathode," he wrote in his notes, "but I do not need to." He used a thoriated tungsten cathode button heated white-hot by electron bombardment from another electrode in the tube. The wonderful thing was that in a matter of hours he could open the vacuum chamber and change the parts.

Calvin F. Quate joined Bell Labs in 1950 and Rudi Kompfner in 1951. By then Cutler was promoted to department head reporting to Pierce, who had been newly promoted to director. With his analysis Pierce deduced that noise on the electron beam due to thermal emission of electrons should appear as waves on the beam. It was not obvious at the time that anything as random as noise could propagate in the form of waves. Cutler and Quate set up an experiment to verify Pierce's theory. They projected an electron beam through the center of a toroidal resonant cavity in the newly designed pumping station. The cavity could move along the beam. They measured noise level excited in the cavity and found the waves predicted by Pierce. That was the famous Cutler-Quate experiment.

Herwig Kogelnik wrote in his notes, "When I first learned of Chap Cutler, I was still in graduate school in Vienna. It was in the late 1950's and my PhD thesis blended in the Vienna group's effort to reduce the noise in traveling wave tubes. This was the widest band amplifier for microwaves known at the time and many groups all over the world were trying to improve the performance. Our bible for this work was the famous and fundamental Cutler/Quate experiment described in a 1950 *Physical Review* paper. Little did I know at the time that Chap would be my first Director at Bell Labs."

The Cutler-Quate experiment was well received in the science community because of its fundamental nature. After that experiment, the names Cutler and Quate were linked and frequently interchanged. In conference gatherings Cutler was often mistaken as Mr. Quate.

In Murray Hill Cutler lunched frequently with William M. Goodall, who at the time was digitizing prefiltered TV signals using pulse coding modulation up to seven or eight bits per sample. His paper in the *Proceeding of the Institute of Radio Engineers* described the first successful experiment for digitizing TV signals. Because each picture amplitude sample was very much like the preceding one, Cutler thought that if only the difference in signal amplitudes were coded, it would require only a fraction of eight bits per sample; thus, the saving would be substantial. Cutler concluded further that if one quantized the difference between quantized signals, some of the quantizing error would be compensated and one would get a more accurate representation. Based on those ideas Cutler invented differential pulse code modulation (DPCM). Through the years many coding schemes were derived from his pioneering work on DPCM. Today predictive coding is used in digital TV transmission, fax machine, and medical imaging systems. With this background in signal coding and imaging, he extended his work to pulse heterodyne radar, stereoscopic radar, and stereothermography. In 1957 he was invited by Professor John R. Whinnery to spend a semester as the Visiting Mckay Professor at the University of California, Berkeley.

Cutler was promoted to assistant director of electronics research in 1959 and director in 1963. While Cutler was assistant director, Kompfner was the director and Pierce was the executive director.

The advent of the Russian satellite, *Sputnik,* in 1957 generated in Bell Labs a great deal of activity and enthusiasm for rocketry and spacecraft guidance and control. Pierce wrote a classic paper on the potential of Earth satellites for communications. Cutler wrote a technical memorandum, "A Space Vehicle Communication System." With Pierce's approval Cutler organized an ad hoc committee to study the components that would be necessary for a long-life radio repeater in an orbiting satellite. They had frequent meetings that paved the way for the Telstar experiment, which was soon followed by Project Echo.

Early in 1958 NASA was planning to orbit a 100-foot-diameter aluminized Mylar balloon, proposed by William J. O'Sullivan, as a method to measure the density of the atmosphere in near space. NASA was receptive to the idea of performing a passive communication experiment in space using O'Sullivan's balloon for the reflector. Suddenly Project Echo was underway. The experiment required that they set up a transmitter-receiver station at Bell Labs in Crawford Hill, New Jersey, and an identical station at the Jet Propulsion Laboratory Earth Station in Goldstone, California. The balloon would orbit in low altitude with regular passes over North America. Radio signals would be sent from one station into space, reflected by the balloon, and received by the other station. Dozens of people were involved at Bell Labs, at JPL, NASA, and NRL. William C. ("Bill") Jakes was appointed project manager with full authority, and Cutler was an active participant in all of their operations.

By mid-1960 they had a commercial 60-foot-diameter paraboloidal transmitting antenna, a novel 20-foot horn-reflector receiving antenna, and a 10-kW Varian Klystron tube for the transmitter for each ground station. The newly invented maser was used for the first time as the low-noise amplifier.

On August 12, 1960, *Echo 1* was launched into space. They planned to transmit and receive a recording of President Eisenhower's voice during the first pass of the balloon. It was a day filled with excitement. Jakes wrote in his notes for the occasion:

> We were all up in the middle of the night, well before launch time to get everything running and checked out. Of particular concern was the 2390 MHz receiver on the horn antenna. To provide the most sensitivity possible it was equipped with a maser preamplifier which had to be cooled by liquid helium to a few degrees above absolute zero. Liquid helium is tricky stuff, so we were on edge when the helium was transferred to the maser, but all went well. To provide the tracking of the antennas we arranged to get several possible drive tapes keyed to different starting times to allow for any variations from the planned launch. When the word came of the actual launch, we scampered around to get the tape close to that time, and hoped that it would be good. Goldstone acquired the balloon at the right time after launch and we were really excited that the balloon was apparently in the right orbit. Shortly after that, our man in the tracking telescope van beside the Control room excitedly yelped that he saw the balloon not far off track and began to apply directional offsets to bring us in. I checked with Goldstone to see if they were ready to receive from us at 960 MHz. They said yes so I told Cutler to start that tape of Eisenhower's recording.

"I remember starting the tape with my own fingers," Cutler said later in the WPI Journal, "It was probably the most exciting period in my life, because everything had to be done on the second. We had to have that antenna pointed exactly right, because this thing is whizzing from horizon to horizon in just 20 minutes." Goldstone reported back, "It was coming in loud and clear." There were excited cheers from those in the control room. They had succeeded with the first experiment in space communication! After Project Echo and the Telstar experiment, the world was suddenly ready for commercial satellite communications. The federal government created a semipublic corporation, the Communications Satellite Corporation, as the sole owner of this business.

Cutler gloried in physical activity, was a Boy Scout leader, and loved taking his children on adventures, teaching them survival skills and the virtues of the compass. Cutler hiked and skied with many family members and friends. He hiked much of the Appalachian Trail with his childhood friend Gus Blow. He also climbed Mt. Rainer with hiker Milt Boone. His most strenuous and remarkable hike was to the top of the Matterhorn with a Swiss team. Most winters he spent skiing on the slopes of New England, often near the vacation property he acquired in Waterford. In addition, he and Quate took many adventurous trips together.

Quate first met Cutler at a conference in Ithaca, New York, while he was a graduate student. "It was the start of an association that lasted throughout our career," Quate said. "Our friendship was formed with hiking in the summer and skiing in the winter. The ski trips were mostly in New England, the Catskills, Bromley, and the trails of Stowe. The hiking trips were scattered across the country." Quate recalled:

> In Montreal, we walked on Mt. Tremblant. In Maine, we walked about 3 miles to reach Chimney Lake and then climbed to the top of Mt. Katahdin.

To reach the peak at 5200 feet, we had to traverse the Knife Edge, which is a narrow rock ridge, steep and unfriendly on either side. On another trip in California, we planned to hike to the top of Mt. Banner. We started in Agnew Meadows, walked to Lake Ediza and on to a campsite near Shadow Creek. The next day we traversed a snow packed chute leading to the saddle between Ritter and Banner. From there we climbed to the peak of Mt. Banner. The return was far more difficult and took much longer than we had planned. With lightning striking the peaks, the storm was imminent and we realized that we had to stop for the night regardless of terrain. We slept that night on a slab of solid rock in the open fully exposed. That was a night to remember!

Equally memorable were their later trips in the Grand Canyon and in Paria Canyon.

In 1959, while Quate was still at the Labs with Cutler, Quate was tapped as a vice-president of the Sandia Corporation in Albuquerque, New Mexico. Sandia was then run by Western Electric under contract to the U.S. government. In 1961 Quate left Sandia to join the faculty at Stanford University as a professor of applied physics and electrical engineering. In 1975, while Quate and his students were working on the acoustic microscope, he invited Cutler to spend time at Stanford.

The acoustic microscope was a novel device. It operated on the same principles as the optical microscope except that acoustic waves at microwave frequencies were used instead of visible light. The image from the microscope was taken with a single on-axis spherical lens with limited numerical aperture. Cutler wanted to circumvent the limit imposed by the small numerical aperture of the single lens; he suggested a multibeam arrangement with several off-axis lenses distributed over a wide angle. The wavelets emerging from the lenses acted constructively to form a coherent beam with a large numerical aperture according to the Huygens' principle. The difference in the images with and without Cutler's arrangement was striking.

Later, at a three-level meeting at Bell Labs that included the vice-president, directors, and department heads, Sol Buchsbaun, then executive director, made a ceremonial speech. He presented Cutler with a framed certificate showing acoustic microscope pictures of onionskin before and after Cutler's innovation. The certificate had been framed and sent by Quate.

Cutler was the director of electronics systems research from 1963 to 1971, and the director of electronics and computer systems research from 1971 to 1978. Over the years hundreds of scientists reported to him. He hung the organization chart upside down in his office to remind himself that those at the bottom of the chart were the important ones. After a successful career lasting more than 40 years, Cutler retired from Bell Labs in 1979 to become a professor of applied physics at Stanford University, where he continued to work on acoustic imaging.

Cutler was a member of Sigma Xi, a fellow of America Association for the Advancement of Science and of the IEEE. He served as the chairman of the IEEE Awards Board (1975-1976) and as the editor of *IEEE Spectrum* (1966-1967). He was awarded an honorary doctor of engineering degree by the Worcester Polytechnic Institute in 1975; he received the Robert H. Goddard Distinguished Alumni Award in 1982. Cutler was elected to the National Academy of Engineering in 1970 and the National Academy of Sciences in 1976. He received the Edison Medal of the IEEE in 1981, the IEEE Centennial Medal in 1984, and the Alexander Graham Bell Medal in 1991.

C. Chapin Cutler passed away on December 1, 2002, in North Reading, Massachusetts, at an age approaching 88. He is survived by his wife, Virginia; son, C. Chapin Cutler, Jr.; daughter, Virginia Raymond; and grandchildren, U. Tyler

Raymond, William C. Raymond, Virginia L. Raymond, and C. Chapin Cutler III.

Those of us who knew Cutler well can still think of the warm moments we shared with him and his family. Kogelnik recalls that soon after he joined Bell Labs, there was a budget crisis and no purchasing orders could be signed. He desperately needed a current-controlled power supply to drive a laser. Cutler, at the time a director with about 100 Ph.D scientists in his group, approached Kogelnik before he could complain, with a large wooden board on which he personally had assembled a current-controlled power supply using old vacuum tubes. The power supply worked well.

Quate remembers one of their hiking trips with Cutler, when they traveled to the Colorado Rockies to climb Mt. Alice. It proved to be a trip 18 miles in length with a gain in elevation of 4,810 feet. Their evening meal of chicken soup was prepared by a wonderful lady in the next campsite. After the meal Quate tried to stand and discovered that his legs and thighs were gripped with severe cramps. He could not move. Cutler stood behind him, lifted him up on his feet, and said, “Now walk, walking will cure you.” Cutler was right.

My wife, Nancy, and I were graduate students at Stanford University. We were married in 1952. Shortly after, we moved to New Jersey and I joined Bell Labs. It was a difficult transition for us, from the carefree university environment to the reality of a corporate life in a country that was still foreign to us. Cutler and Virginia were mentors to our family, providing warm, parenthood care. Knowing me well, Cutler said, “When PK is frustrated, he speaks Chinese.” One year we had to go back to Hong Kong for a visit. Virginia took care of our two daughters, Emily and Julia, when Julia was only a few months old. Virginia pulled out a large drawer from the chest and emptied it to make a bed for Julia.

As I finish this memoir I recall and admire his passion to discover and his unbounded energy for work. He will always be a role model cherished by all of us who work in science and engineering.

I WAS ASKED by Professor Andreas Acrivos to write this memoir for the National Academy of Sciences and was overwhelmed by the help I received. Most of the materials were collected from Cutler's personal notes supplied to me by the family. Several pieces were written by his close associates, Quate, Jakes, and Kogelnik. Searching through his old records, Professor John R. Whinnery found a nine-page text written by Cutler on his early experiences at the labs. Kogelnik retrieved a collection of e-mail messages between Cutler and Nick Sauer discussing the lab at Deal. Roger N. Perry, Jr., provided the information about Worcester Polytechnic Institute back in the 1930s and 1940s. Professor Bruce Wooley made Cutler's files at Stanford University available. Gary Boyd and Susan Feyerabend helped to locate Cutler's old papers left in the lab. I have also obtained files from the Lucent Archives and the IEEE History Center. My daughter edited the English of the first draft. Quate edited the final version of the text. I want to thank in particular Patricia A Tier, who assisted me in every phase of this project.

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