

Nondeterminacy and a Calculus for the Derivation of Programs.” In 1976, he published his monograph *A Discipline of Programming* (Prentice-Hall), in which he defined the “weakest precondition” semantic model for the total correctness of a nondeterministic sequential programming language.

By 1984, Burroughs had merged with Univac, and Edsger decided to return to academic life as a professor and Schlumberger Centennial Chair in Computer Sciences at the University of Texas at Austin. There, he continued to practice his techniques for formal derivation of programs and algorithms, which he published in a series of handwritten manuscripts that were duplicated and distributed by post to his friends. His work was often developed in his weekly graduate seminar, the Austin (or Eindhoven) Tuesday Afternoon Club. He also applied his constructive techniques to the derivation of elegant mathematical proofs—for example, in geometry and number theory. This was the way he had hoped computer science would repay part of its great debt to mathematics.

Edsger’s many elegant algorithms and his point of view about programming have had a subtle but extremely significant influence on the development of computational physics. Some of his algorithms, such as the one for finding the minimum spanning tree, are in daily use. Others, such as smoothsort, are used only occasionally, but to great effect. Probably more than any other individual, Edsger was responsible for giving the world of computational physics a solid notion of what an algorithm is, how a powerful algorithm can change the research landscape, and why the best algorithm might not be the first one that comes to mind.

Edsger was a perfectionist, pursuing the traditional academic ideals of knowledge for its own sake. The quality of his lectures was the result of meticulous preparation (and avoidance of overhead projectors), and his commitment to personal help for his students went far beyond the call of duty. He gave as much careful thought to details of his personal life as he did to the problems of science and made a conscious lifelong choice of his handwriting, his fountain pen, and his clothes. He decided that the best kind of hat was that worn in Texas, and his chosen form of necktie was the Texas clasp. He did not think it incongruous to wear these accessories above short cotton pants, ankle socks, and open sandals. In this attire, he would travel around the state parks of Texas in his recreational vehicle, which he affec-

tionately, and wittily, named the “Touring Machine.”

He deplored the managerial, political, and commercial pressures that afflict the academic world today, and he did not hesitate to protest against them in his most trenchant style of writing and speaking. He was a master of epigram (now called a sound bite). When hard-pressed by criticism that his kind of research was not relevant to the problems of the real world, he replied by defining the problems of the real world as those that remain when you refuse to apply their known solutions.

Tony Hoare

*Microsoft Research
Cambridge, UK*

Robert Edmund Apfel

Robert Edmund Apfel, widely known for his work in physical and biomedical acoustics, died of cancer on 1 August 2002 in New Haven, Connecticut.

Bob was born on 16 March 1943 in New York City. Both his parents were artistically inclined and instilled in him a love for the fine arts. Even though he became a world-class engineer, he maintained an active and participating interest in the theater, wrote poetry, and was involved broadly in science education.

In 1964, Bob earned a BA in physics from Tufts University, where he first developed an interest in acoustics. For a senior thesis project, he combined his love of music with science by studying the acoustics of an auditorium that sorely needed improvement. His efforts attracted the attention of Ted Hunt at Harvard University, who once remarked, “Here was this undergraduate from Tufts trying to scrounge equipment from my lab to do an acoustics experiment—I figured with those kinds of skills, he’d be a great graduate student!” Thus, in the fall of 1964 he was off to Harvard to work in Hunt’s lab. He would later earn his MA in physics in 1967 and a PhD in applied physics in 1970.

At Harvard, Bob set himself immediately to the task of understanding acoustic cavitation, a challenge that he pursued for much of his professional career. Using an ingenious technique that he later dubbed “acoustic levitation,” he designed an experiment that would measure the tradeoff between elevated temperature and acoustic pressure in determining the onset of boiling in superheated drops. The drops were made small enough so as to exclude the ran-



Robert Edmund Apfel

dom contamination of inhomogeneous nucleation sites (dirt!), and he thus was able to determine the limit of superheat in a variety of liquids. Soon afterward, *Nature* and *Scientific American* published his fundamental work on the properties of liquids, and the Institute of Acoustics recognized this work by presenting him with its A. B. Wood Medal and Prize in 1971.

That same year, Bob accepted an assistant professorship at Yale University, where he began building a productive laboratory that would undertake research in a variety of topics in physical acoustics. Five years later, he received the Biennial award (now the R. Bruce Lindsay Award) of the Acoustical Society of America (ASA).

The moments when Bob was merely sitting and pondering are few, but in one quiet moment on a beach in Florida, he conceived the idea that became the basis of his neutron detector. He reasoned that if he could make small superheated droplets that contained no nucleation sites, then the droplets would remain in a metastable state for very long periods. Each superheated drop, however, would act like a small bubble chamber (as in high-energy physics particle detectors) if a high-energy nuclear particle passed through it. When the superheated drop was nucleated, a sharp acoustic pulse would be generated that could be easily detected with a transducer. Thus, he had invented a sensitive and stable nuclear particle detector, which he patented in 1979, and which formed the basis of his company, Apfel Enterprises, founded in 1980.

Bob’s technical interests were quite broad. Together with a number of his students, he investigated the potential bioeffects of medical ultra-

sound and discovered that, under certain conditions, diagnostic ultrasound machines could produce acoustic cavitation. That work was important enough for the US Food & Drug Administration to require that every diagnostic ultrasound machine used in clinical practice have an output label describing its "mechanical index," or its capacity for producing cavitation. He also studied the oscillations of drops in microgravity.

Bob's creativity was not limited to pure scientific research. While giving a lecture on relativity to undergraduates at Yale, he discovered a unique method for deriving Albert Einstein's time-dilation formulas, and subsequently wrote "Inferences from Considering the Twin Paradox," published in 1985 in the *American Journal of Physics*. And, after a dinner at which he had demonstrated how to make a wine glass sing and his fellow acousticians had challenged him to explain how it had happened, he wrote another article entitled "Whispering Waves in a Wine Glass" for the journal. Although he taught in the mechanical engineering department at Yale, he also delivered lectures to architects and wrote a primer called *Deaf Architects and Blind Acousticians* (self-published). He ed-

ited Hunt's book on *The Origins of Acoustics* (Yale U. Press, 1978) and worked together with Hunt's son, Tom, to establish the Hunt Fellowship of the ASA. Bob also wrote a screenplay, books on creativity, works on the nature of our humanity, and poetry.

At Yale, Bob served in a number of leadership roles: several times as chair of the mechanical engineering department, as chair of the Council of Engineering, and as director of external affairs for the faculty of engineering. He also developed innovative undergraduate and graduate programs by forging links between industry and academia.

An active participant in the ASA, Bob chaired the society's technical committee on physical acoustics during the late 1970s, served on the original long-range planning committee, and in 1996 completed a term as president. Perhaps his greatest accomplishment in the society was the creation, in 2000, of a fully electronic journal, *ARLO (Acoustics Research Letters Online)*. For his continued leadership in the ASA, he was awarded the society's highest honor, the Gold Medal, two months before he died. Although weakened by cancer and a recent operation, he attended the meeting in person and delivered a moving acceptance speech.

Active beyond academia, Bob raised money from industry and Yale for the New Haven public schools' science fairs and for classroom computers. He also studied voice and was an amateur baritone. Every few years, he gave concerts whose programs included lieder by Franz Schubert, French love songs, English ballads, and songs by Leonard Bernstein and Aaron Copland. His periodic efforts to enlist fellow acousticians to sing during social hours at ASA meetings were a continued source of delight to many.

Although Bob most often considered himself an acoustician, those of us who knew him thought of him as an extremely gifted scientist and talented leader who would have brought distinction to any field he chose. Thus we acousticians are privileged to have had him as a colleague.

Lawrence A. Crum
University of Washington
Seattle

Karl Leslie Brown

Karl Leslie Brown, a versatile applied physicist at SLAC, died of heart failure on 29 August 2002 at a hospital in Stanford, California.

Karl was born in Coalville, Utah, on 30 September 1925 and was awarded all his degrees in physics by

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