Delbert Ray Fulkerson

August 14, 1924 — January 10, 1976

Delbert Ray Fulkerson's tragic and unexpected death at the age of fifty-one dealt his many friends, colleagues, and students a severe blow. He was one of the pioneering giants in the development of modern operations research, and his fundamental contributions in network flow theory and combinatorial analysis have had and will continue to have a major and lasting impact on the field.

Over and above his scientific abilities, Ray was a man of outstanding personal qualities. He was warm, kind, and friendly, with great compassion for the needs of his fellow man. He was a person of great integrity, a strong and constant advocate of justice and fair play, but always modest and unpretentious. At the same time he was an active and skillful competitor, whether it was at tennis or kriegspiel or in the dogged pursuit of the solution of a difficult mathematical problem. Those who had the privilege of knowing Ray greatly respected him for his outstanding human attributes as well as for his intellectual talents.

Born in Tamms, Illinois, Ray was the third of six children of Elbert and Emma Fulkerson. Elbert Fulkerson was the high school principal in Tamms, and later in Carterville, Illinois, where Ray attended grade school and high school; the family subsequently moved to Carbondale where Ray's father taught mathematics and served as the secretary of the faculty at Southern Illinois University. Ray's parents, particularly his father, appeared to have had a strong influence on their children: all six graduated from high school as class valedictorians, the three boys earned Ph.D. degrees, and each became a teacher.

In September 1941 Ray enrolled in Southern Illinois University. His studies were interrupted by World War II, and in January 1942 he joined the U.S. Army Air Corps where he received training as a meteorologist. In June 1946 he received an honorable discharge from the Air Corps as a first lieutenant and returned to S.I.U. from which he was graduated, first in his class, in 1947 with a B.A. in mathematics. He received his M.S. and Ph.D. degrees in mathematics at the University of Wisconsin in 1948 and 1951.

Ray obtained his Ph.D. at an ideal time in the history of mathematics. The subject was entering an era of unprecedented growth and prosperity. This period included the time that he was to spend at the Rand Corporation in Santa Monica, California. Ray joined the Mathematics Department of Rand in March 1951. He would spend more than twenty exciting and extremely productive years there during which time he created and developed the field of network flows and made fundamental contributions to combinatorial theory and mathematical programming.

Initially he worked on studies in logistics and systems analysis, particularly on algorithms for the solution of transporation and assignment type problems. When Dr. George Dantzig moved to Rand from the Air Force in June 1952, he and Ray became close personal and professional friends, a relationship that would last throughout the years. The resulting collaboration led in 1954 to Ray's first two published papers: the first written with Dantzig solved the problem of finding the least number of tankers required to meet a fixed schedule, and the second, with Dantzig and Dr. Selmer Johnson, solved a forty-nine-city, "traveling salesman" problem; the latter paper received honorable mention for the 1954 Lanchester Prize given by the Operations Research Society of America (ORSA). The interaction between Fulkerson, Dantzig, and later Dr. Lester R. Ford, Jr., led to some fundamental contributions to mathematical programming. In 1956 they developed a primal-dual algorithm for solving linear programs, and later the Ford-Fulkerson work on the column generation technique for multicommodity flow problems led Dantzig to formulate the decomposition principle for linear programming. The celebrated Ford-Fulkerson book on *Flows in Networks*, which appeared in 1962, was an outgrowth of their earlier collaboration, while Ford was at Rand, on a project to evaluate the capacity of the Eastern European rail network. The original problem they solved had been formulated as one involving network flows. The book contains basic research that extended and generalized their earlier work on this problem and is considered the classic in the field; it received honorable mention for the Lanchester Prize of ORSA and has since been translated into French, Japanese, Polish, and Russian. In 1967 Ray was the recipient of one of the Lester R. Ford Awards of the Mathematical Association of America for an expository paper on flows in networks (the award being named for his colleague's father who was also a mathematician).

After the publication of *Flows in Networks*, Ray's research took a turn toward the pure. He wrote more about "graphs" and less about "networks" and began to work on matroid theory and general blocking systems, an abstraction of the dual notions of flows and cuts in a network. This led him to develop the theory of blocking pairs of polyhedra that served to unify a variety of mathematical results involving discrete phenomona and, later, the concept and theory of antiblocking polyhedra.

While at Rand, Ray maintained a variety of contacts with the business and academic world. He consulted at various times for different industrial corporations. In 1958 he taught what was probably the first course in network flow theory, at the University of California, Los Angeles. In 1963 he was visiting professor at the University of California, Berkeley, and in 1966 at Stanford University. In 1968 he was appointed distinguished visitor at the University of Waterloo, Canada, and in 1971 he returned as visiting professor.

In the fall of 1971, Ray joined the Department of Operations Research in the College of Engineering at Cornell as the Maxwell M. Upson Professor of Engineering and professor of operations research and applied mathematics. In his quiet and unassuming way he quickly became the intellectual leader of the department. He taught a popular sequence of courses in network flows and extremal combinatorial problems designed to bring research students to the frontiers of knowledge in these areas. Ray was a superb and inspiring teacher. He set very high standards for his graduate students as he did for himself; in his relationships with them he was always fair and compassionate. His door was open to faculty and students alike, and he was a font of knowledge in his areas. He was a scholar in the true sense of the word and continued to produce outstanding research at the frontiers of his field.

At the time of his death he was a member of the American Mathematical Society, the Mathematical Association of America, the Mathematical Programming Society, the Operations Research Society of America, the Society for Industrial and Applied Mathematics, and the Institute of Management Sciences. He was a member of the council of the Mathematical Programming Society as well as associate editor of its journal, *Mathematical Programming*. He was also associate editor of the *Journal of Combinatorial Theory* and the *Journal of Optimization Theory and Applications*, and advisory editor of *Mathematics of Operations Research* and of *Networks*. His last major project, a two-volume collection of papers, which he edited for the Mathematical Association of America, took four years to complete. His own published papers and books numbered more than fifty.

A memorial service was held in Ray's memory and honor in the Chapel of Anabel Taylor Hall at Cornell. Alan Hoffman, a close friend and professional colleague of Ray's spoke at this service and closed his remarks concerning Ray's professional accomplishments with the following sentences: "His greatest honor is simply that network flows exists as a subject of such importance that all over the world now and in the future, it is and will be a fundamental tool in economic and industrial planning. It was Ray's great good fortune or perhaps the reward of his talent and energy to create mathematics that contribute to life where art and nature imitate each other." The scientific world has lost an outstanding mathematical research worker, and we have lost a close and warm friend.

Ray is survived by two sons, Guy Emmet of La Jolla, California, and Lee Alan of Santa Monica, California; his former wife, Eleanor, of Santa Monica, California; his mother, Mrs. Elbert Fulkerson of Carbondale, Illinois; two sisters, Mrs. Merle Guthrie of Belleville, Illinois, and Mrs. June Todd of Skokie, Illinois; and two brothers, Richard Fulkerson of Commerce, Texas, and Glen Fulkerson of San Diego, California.

Louis J. Billera, William F. Lucas, Robert E. Bechhofer