countered Albert Wheelon, a former fellow student at MIT, who arranged for Fred to visit TRW, a company that was taking an early and important lead in spaceflight and space science. Fred soon joined TRW, and eventually he held a variety of management positions related to his central role in the space research activities of that corporation.

He was a principal investigator of plasma waves for the Pioneer 8 and 9 interplanetary spacecraft and a coinvestigator for several instruments on satellites in the Earth's magnetosphere. In studies of plasma phenomena using antennas on the early Orbiting Geophysical Observatory series of spacecraft, Fred was one of the leaders who established the importance of plasma waves in the dynamics of the Earth's radiation belts. His insight and leadership led to the crucial analyses and interpretations of the wave and plasma phenomena associated with the collisionless nature of the Earth's bow shock. Instrumentation on the OGO-5 spacecraft detected the first electrostatic plasma waves found in any collisionless shock.

During the organizational stages of the Voyager project, Fred vigorously advocated the absolute necessity of plasma-wave measurements to provide the data essential for understanding the plasma physics of the magnetospheres of the outer planets. The final acceptance of his arguments by NASA, and his leadership of the plasma-wave teams for both Voyager spacecraft, significantly advanced the scientific successes of the mission. At the time of his death, Fred was awaiting with great expectations the Voyager encounter with Neptune in August 1989. Those of us who worked closely with him on the Voyager project found that many of our recent conversations with him centered on his anticipation of new discoveries from that distant planet.

Fred's leadership in space science extended to an impressive range of national and international advisory committees, where his wise counsel and vigorous approach were frequently sought and rarely ignored. Besides serving on both the Space Science Board and its Committee on Solar and Space Physics, Fred was also a member of the Committee on Solar–Terrestrial Research of the National Research Council. The latter committee selected him as chairman for the interval 1974–79 of the US Committee for the International Magnetosphere Study (1977–79). Fred's wide range of scientific contacts and his scientific understanding proved to be extremely helpful on his frequent trips to Washington to coordinate the extensive ground-based and satellite-based research activities of that study. More recently, Fred served as the chairman of the Panel on Solar and Space Physics for the Space Science Board's major study examining directions for space research in the 21st century.

Of all his accomplishments, Fred was most proud of his success—achieved with the help of Robert Farquhar of the Goddard Space Flight Center—in advocating moving the third International Sun–Earth Explorer satellite from its location at the L1 point (the Lagrangian point approximately 1.5 million km towards the Sun from Earth along the Earth–Sun line) to a trajectory that would make it possible to intercept Comet Giacobinni–Zinner. The ISEE-3 spacecraft was renamed the International Cometary Explorer and was sent off to the first successful encounter of a comet made by a spacecraft, in September 1985, several months prior to the encounter of Comet Halley by an international armada of spacecraft. The media quoted Fred as exclaiming, "We stole it!"—"it" referring to the reconfiguration of the ISEE mission.

In addition to his talents as a scientist, Fred was an able and articulate spokesman for space science. He was exceptionally adept at translating the findings from spacecraft into tangible concepts that the public could relate to. During the Voyager-1 encounter with Jupiter in 1979, Fred was able, with his collaborators, to transform plasma-wave emissions into exotic sounds. Dubbed "the sounds of space" by the media, these were made widely available on records and cassettes that captivated the imaginations of people worldwide.

In short, Fred Scarf possessed a keen insight into physics, a tremendous intuition when faced with the new and unusual, a "jaundiced eye" view of the conventional and a facility in explaining things in a way that anyone could understand. Fred was generous in encouraging others to high accomplishments in many fields of space science.

The US space research program has lost a dynamic leader and creative researcher, and space plasma physics has lost one of its pioneers. Those of us who were privileged to work with Fred have lost a close friend, a trusted adviser and an enthusiastic collaborator.

Lennard A. Fisk
NASA Headquarters
Washington, DC

Charles F. Kennel
University of California, Los Angeles
Stamatios M. Krimigis
Applied Physics Laboratory
Johns Hopkins University
Laurel, Maryland
Louis J. Lanzerotti
AT&T Bell Laboratories
Murray Hill, New Jersey

Martin Greenspan

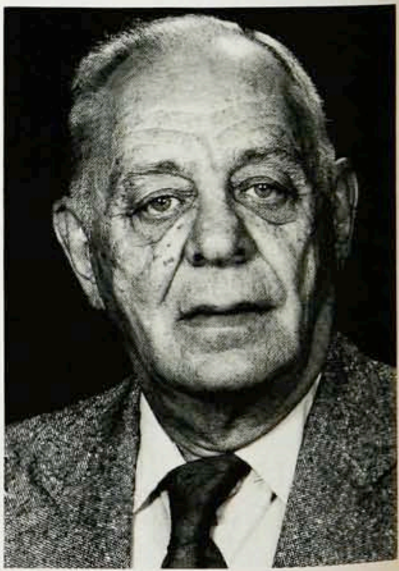
On 31 October 1987, the community of acoustical physicists suffered a great loss with the death of Martin Greenspan following a brave, brutal fight with cancer. Moe, as he was known to his friends, was one of a kind. His outstanding characteristics were concern for his fellowman, wisdom, encyclopedic knowledge and skill in the laboratory. He was a Renaissance man.

Moe was born in New York City on 8 May 1912, attended public school in Jersey City and received a BS from the Cooper Union Institute of Technology in 1934. He joined the staff of the National Bureau of Standards in the autumn of 1935 and maintained this affiliation until his retirement in 1974, after which he served as a consultant.

Until 1946 his work at NBS was in elasticity and strength of materials. Moe performed important theoretical work on the frequently complex stress distributions in civil engineering structures such as rigid knee bents, box girders and perforated plates, for which closely coordinated theoretical and experimental efforts are necessary to assure structural safety.

In August 1946 Moe was invited to join the Sound Section of NBS, where he did work in physical acoustics.

Martin Greenspan



(Twenty years later he would become chief of the section.) His work with section chief Richard K. Cook and Moody C. Thompson Jr on the propagation of sound in rarefied gases is now regarded as classic. Moe showed that the Navier–Stokes equation gave a surprisingly good quantitative account of the attenuation and dispersion of sound in a monatomic gas, down to a wavelength approaching the mean free path of the gas. Moreover, in measurements made at much lower pressures, where the mean free path was significantly greater than the wavelength, he found substantial deviations from the Navier–Stokes predictions. New theoretical many-body results are now judged by their agreement with these data. For polyatomic gases, in which molecular relaxation processes associated with vibrational and rotational modes occur in addition to the translational relaxation, Moe demonstrated experimentally and theoretically how the added degrees of freedom combine to affect acoustic dispersion and attenuation.

In the early 1950s the US Navy realized its need for an automatic device to measure the speed of sound in the sea, particularly as a function of depth. Moe and Carl E. Tschiegg collaborated in the development of an accurate, reliable and rugged instrument, now called an acoustic velocimeter and used worldwide by the US Navy and in industry.

In the 1960s, again working with Tschiegg, Moe turned his attention to cavitation. He and Tschiegg paid special attention to the effects of dissolved gases and of neutron irradiation on the threshold of cavitation. They were able to determine reliably the temperature dependence of the cavitation threshold for degassed, neutron-irradiated liquids. In such liquids, atomic nuclei, recoiling off the neutrons, nucleate cavitation. Moe won worldwide recognition for his preeminence in this field.

In acoustic emission measurements, one hopes that the signal one receives characterizes the event that produced it. But before Moe turned his attention to the problem, signals were so drastically affected by "ringing" that most of the signal merely reflected the normal modes of the specimen and the apparatus. Around 1980, along with Tschiegg and Franklin R. Breckenridge, Moe developed a technique in which, at least for certain acoustic emission events, the received signals were completely free of aberration due to reflections or ringing.

In a relatively recent foray into theoretical acoustics, Moe made a major contribution to the theory of the piston radiator. One might think this a pretty well worked-over problem, but in a 1979 paper Moe succeeded in extending the theory to include exact solutions for cases in which the acoustic pressure and particle velocity vary over the face of the piston.

Moe served on the Acoustical Society of America Executive Council from 1959 to 1962, and he was elected vice president of ASA for 1963–64, and president for 1966–67. He held several additional science-related positions of leadership, with ASA and other organizations. He was an associate editor of the *Journal of the Acoustical Society of America* from 1961 to 1966, and editor of the *Journal of Research of the National Bureau of Standards, Section C, Engineering and Instrumentation* from 1962 to 1973.

It was a delight to observe him at ASA meetings. His presentations at technical sessions had style, good humor, color and clarity, and all had solid scientific content. On the other side of the coin, the technical sessions benefited greatly from Moe's presence in the audience, as he found ample opportunity to raise questions and make comments. (I've attended innumerable sessions where Moe's responses were more important than the paper itself, and often increased its significance.) Moe was a master of "corridorship." Where you found Moe you would usually also find a circle of the young and the old, listening to him telling the way it was—his insights into the subtle issues that were being discussed at the session—or just telling a good story in his inimitable way.

Even though Moe's BS from Cooper Union was his highest academic degree, through his experiments, his expressive and incisive writing and his lectures, he earned an enviable international reputation. His knowledge of acoustics is matched by few people alive today.

This obituary can hardly be ended better than with the words of a young and bright member of the Acoustical Society who wrote a letter supporting Moe's nomination for the ASA Gold Medal, which he received in 1983. The letter began, "Martin Greenspan is the kind of scientist I would like to be," and ended with the following additional tribute: "For the enrichment of the scientific literature, and, equally important, for the enrichment of our lives, Martin Greenspan is pure gold all the way."

ISADORE RUDNICK
University of California, Los Angeles