MEMORIAL RESOLUTION

OSCAR BUNEMAN
(1914 - 1993)

Oscar Buneman, Professor Emeritus of Electrical Engineering at Stanford University, Fellow of the American Physical Society, and a significant contributor to the fields of plasma electrodynamics, fundamental electromagnetic theory, and numerical analysis, died in his sleep on January 24, 1993. He was 79.

Buneman was born September 28, 1913, in Milan, Italy, to German parents. He grew up in Hamburg, Germany, where he received a classical gymnasium education at the Johannaeum and completed two years of university work. He was imprisoned by the Nazis for political resistance in 1934; upon his release in 1935 he went to Manchester University in England, where he received a B.Sc. in mathematics and an M.Sc. in applied mathematics (for a study on nonlinear differential equations). With the outbreak of war in September 1939, he was interned in Canada with other foreign nationals. Professor Thomas Gold of Cornell University writes, "He was a marvelous companion in those trying times. He was one of the very few non-Jewish refugees from Nazi oppression in the camp. Evidently he had strong principles and saw the Nazi hell that was being created. He and [Sir Herman] Bondi were the prime movers in the camp university and I certainly learnt a lot more from them than I would have had I remained in Cambridge for those nine months." In 1940 Buneman completed a Ph.D. supervised by Douglas Hartree.

For the next three years Buneman did postdoctoral research with Hartree on the theory of the magnetron. The magnetron had been brought into spectacular operation at Birmingham by Boot, Randall, and Sayers, but its theory was not fully understood; it was, in fact, a mystery. With support from the Admiralty, Hartree initiated the simulation of particle orbits in large numbers by numerical iteration on his differential analyzer. Although the analyzer was a primitive analog computer, the seed of many algorithms now in use on supercomputers was sown at this time by Hartree and his colleagues, who included Phyllis Lockett and David Copley as well as Buneman.

While programming the Manchester differential analyzer, Buneman discovered the bunching of particles in a cavity magnetron; the "Buneman potential" that exists in a frame of reference corolating with the particles; and the diocotron instability. He initially used a relaxation technique developed by Southwell to relate the electromagnetic field to the updated particle distribution by solving Poisson's equation, but the technique was slow.

The fusion physics of the 1940s offered new opportunities for the numerical analysis of particles and fields. In 1944, as a member of the British mission to the Manhattan Project at Berkeley, Buneman worked on ion optics for the calutron isotope separation device. In 1945, he transferred to the Canadian reactor project and in 1946 returned to England to work on neutron diffusion, multigroup models, and Fermi age models at the Atomic Energy Research Center at Harwell. He remained there until 1950.

During the next 10 years, Buneman was a member of Peterhouse College, Cambridge, a lecturer in mathematics at the university, and a solo sailplane pilot with the Gliding Club. As computers grew in power, he retained his interest in numerical methods through continued contact with Hartree. He also published on fundamental classical electrodynamics under the influence of P. A. M. Dirac.

It was at Cambridge in 1959 that he discovered the Buneman instability that develops in two interpenetrating ion streams; his paper in Physical Review led to his acknowledgment as the founding father of the particle simulation of plasmas. While visiting Stanford in 1959 he was stimulated by Tor Hagfors, a visitor from Norway developing the theory of ionospheric backscatter from fluctuations, to work out a new instability involving plasma electrons frozen by the earth's magnetic field in the presence of ions able to drift across the field. Independently discussed by D. Farley, this instability is frequently invoked in the current literature of auroral and equatorial electrojets.

From 1960 until he reached emeritus status in 1984, Buneman was a Professor of Electrical Engineering at Stanford University, working on laboratory applications of plasma physics to crossed-field microwave devices, stability analysis, and other phenomena. He supervised, jointly with Professor Gene Golub, the dissertation of Roger Hockney, who later became a key figure in numerical plasma physics and who, with J. W. Eastwood, dedicated a book on computer simulation using particles "To Oscar: Founder of the Subject."

In the 1960s Buneman returned to Poisson's equation and developed a fast direct solver with Hockney using a spatial grid in two dimensions that made two-dimensional electrostatic simulation attractive and economical and eventually superseded the method of summing Coulomb interactions. The method uses cyclic reduction for which Buneman introduced a stable algorithm. For a program currently running on Cray supercomputers Buneman used his own version of the fast Hartley transform, writing the computer code directly in Cray assembler language to gain speed.

Radiophysicists in Stanford's electrical engineering department introduced a new and enduring dimension into Buneman's theoretical activities. The Buneman instability proved to have significance for electron streaming in the magnetosphere and led to collaboration with T. F. Bell on whistler theory and with L. R O. Storey, the founder of whistler physics. A Buneman publication on density fluctuations in plasma whose electrons and ions are at different temperatures proved relevant to the unexpectedly strong backscatter then being detected from the outer ionosphere.

The solar wind and its theoretical discussion dating back to Chapman and Ferraro next engaged Buneman's attention. As more and more data from observation clarified the time-variable topology of the solar-particle stream's interaction with the earth's magnetosphere, the more intractable the theory seemed. With a series of collaborators, among them K. -I. Nishikawa, T. Neubert and D. S. Cai, Buneman developed a three-dimensional electromagnetic particle simulation code (TRISTAN) for Cray supercomputers that showed the dramatic kinematics of formation of the bow-shock, the magnetospheric cavity, the magnetotail, and other features known from observation and reproduced the transient behavior associated with the flapping of the solar wind sheet. Ultimately he simplified the self-consistent field approach to the point where all of the particle behavior could be deduced directly from Newton's equations of motion (in the relativistic form of Lorentz) supplemented only by Maxwell's equations and not requiring Poisson's equation or magnetohydrodynamics. The divergence of the current density, determined directly from knowledge of charge motion, allowed the current density itself and thus the new local electric and magnetic fields to be determined. He called this the local method and considered it to be the most suitable algorithm for the recent massively parallel computers like the Connection machines. Buneman lectured at the 1st to 4th International Schools for Space Simulation (1982, 1985, 1987, and 1991) and as recently as April 1991 he was demonstrating the fruits of his technique in the form of a computed movie at the meeting in Kyoto, Japan and transferring his transportable code to young space scientists by direct coaching on the local supercomputers. His lectures were regarded as most helpful and his enthusiasm inspiring; TRISTAN has since been used for studies of the dynamics of artificial clouds, whistler waves driven by electron beams, and current loop coalescence.

Buneman maintained an interest in nuclear fusion through interaction with Anthony Peratt at Los Alamos National Laboratory and others at Lawrence Livermore National Laboratory, publishing notes from time to time in *The Buffer*, organ of the National Energy Research Supercomputer Center. TRISTAN was used at Los Alamos to study high power microwave generation and the dynamics and radiation properties of plasmas with cosmic dimensions.

Buneman taught various courses in electrical engineering at Stanford, giving them an inimitable mathematical and computational flavor; he also taught courses cross listed with the computer science department. As the trend to improved high-level languages advanced, Buneman stressed the continued need for meticulous attention to microprogramming. The power of his TRISTAN code is a testimony to the effectiveness of combining basic knowledge of electrodynamics with an intimate understanding of machine fundamentals. Buneman thoroughly enjoyed the digital world. In his last year he improved on the standard algorithm for constructing a pixelized straight line and worked on half-tone graphics. It had been thought that the fast Hartley transform could not be generalized beyond one dimension because the kernel was not separable. During one week in 1986 three different methods were discovered, of which Buneman's was the most elegant and involved a procedure now known to his colleagues as "oscarization." He followed up his discovery by publishing on three, four, and n dimensions.

Professor Hockney writes, "'Oscar Buneman will be remembered with affection by a long line of graduate students, now spread throughout the world, not only for his personal kindness, but also for the inspiration he brought to regular research discussions. He was often difficult, indeed impossible, to keep up with, and each meeting would bring up a new and interesting research topic. The problem for the student was always to concentrate on one topic long enough to produce a thesis. It was a privilege to have been his student, and to know that we are carrying on from his pioneering work in computational physics and numerical analysis."

Even as an emeritus professor, Oscar Buneman's door was always open and he was most generous with help to colleagues and students. He loved the outdoors, spending as much time as possible with his family in the mountains and sun. He liked sleeping in the open (even at home), swam regularly, and, until late 1992, was a familiar sight in very brief shorts and an ancient crash helmet, riding his racing bicycle to his office. He was to have given the keynote address at the meeting of the IEEE Plasma Physics Society in Vancouver, BC this summer. He will be very much missed by his colleagues.

Buneman is survived by his wife, Ruth, of Los Altos, California; a sister, Gertrude, of Hamburg, Germany; and sons Peter (Philadelphia), Michael (Frankfurt, Germany), Kelvin (San Francisco) and Paul (Mountain View, California).

Professor Ronald N. Bracewell, Emeritus
Professor Robert A. Helliwell, Emeritus
Professor Allan M. Peterson, Emeritus