

visage the creation of a European observatory with large telescopes. It took a decade of careful maneuvering through the complexities of European politics before his efforts were crowned with success in 1962 with the founding of the European Southern Observatory. ESO has central facilities near Munich and a large observing facility in Chile.

Through his own research and that of his numerous students, Oort's influence has been far reaching. He received many honors, but perhaps the highest was the epitaph written by Subramanyan Chandrasekhar in a telegram to the Dutch Academy: "The great oak of astronomy has been felled, we are lost without its shadow."

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Robert E. Marshak

Robert Eugene Marshak died by drowning on 23 December 1992 at Cancun, Mexico. He was 76 years old.

The child of an immigrant fruit peddler and a garment worker, Bob Marshak was throughout his life driven not only by intellectual curiosity and brilliance but also by an unquenchable quest for social justice and personal recognition. His career was informed by immense achievement but also punctuated by occasional controversy and disappointment.

At Columbia University Marshak majored in philosophy and mathematics, graduating in 1936. As a graduate student at Cornell University, from 1936 to 1939, he did pioneering work in astronomy, especially in the field of white dwarfs, with Hans Bethe. After receiving his doctorate, he joined the faculty at the University of Rochester, but like so many outstanding physicists he left to join the Manhattan Project. During World War II he served at Los Alamos, where he invented a variational method for the crucial neutron diffusion problem in nuclear matter. His work also included a theory of radiative diffusion heat waves; they are now generally known as Marshak waves.

Marshak's major research in particle physics, and undoubtedly his most important contribution to physics, came after his return to Rochester in 1946. In 1947, together with Bethe, he published the now canonical two-meson hypothesis with the correct assignment of the spins to

explain the then-puzzling phenomena seen in cosmic-ray events. This hypothesis, which in 1946 was independently advocated by Shoichi Sakata and Takeshi Inoue in Japan, clarified the prevailing confusion by distinguishing the weakly interacting muon from the strongly interacting pion, which Hideki Yukawa had postulated to account for the strong nuclear force.

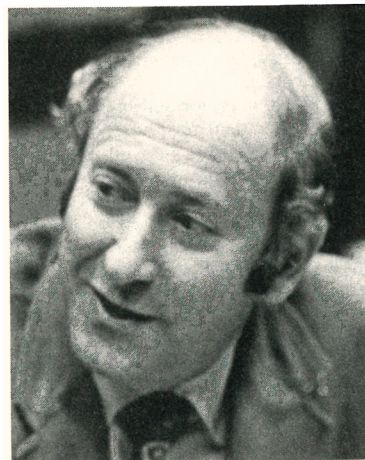
The Rochester cyclotron produced pions on nuclear targets in December 1948, allowing researchers to determine the pion's spin and parity. In 1951 Marshak suggested that one could determine the spin of the positive pion π^+ experimentally by comparing the cross sections for the reactions $pp \rightarrow \pi^+ d$ and $\pi^+ d \rightarrow pp$ and invoking the detailed balancing principle, which in its turn is a result of the time-reversal invariance of strong interactions. Immediately after this proposal, experiments done by R. Durbin, H. Loar and Jack Steinberger at Columbia University, as well as by Donald L. Clark, Arthur Roberts and Richard Wilson at Rochester, confirmed the spin to be zero.

The current state of knowledge of pion physics formed the subject of Marshak's book *Meson Physics*, published in 1952. He also edited a series of books dedicated to developments in contemporary physics, among which *Introduction to Elementary Particle Physics* (1961), by Marshak and a former student, E. C. George Sudarshan, was one.

In possibly the first application of broken symmetry to particle physics in terms of reduced matrix elements, in 1957 Marshak, Susumu Okubo and Sudarshan obtained a magnetic moment sum rule involving Σ -hyperons. During the same period Marshak and his students Peter Signell and Ronald Bryon showed how the inclusion of a spin-orbit contribution to the nuclear force (the Signell-Marshak potential) gave a dramatically improved explanation of the nucleon-nucleon scattering data.

Marshak's major achievement at Rochester was to establish, with Sudarshan, the universal V-A weak interaction theory in 1957. The theory, which emphasized the importance of chiral invariance, was also formulated by Richard Feynman and Murray Gell-Mann. It was the starting point of the present standard unified electroweak theory of Sheldon Glashow, Abdus Salam and Steven Weinberg.

In 1958 Marshak (together with Okubo, Sudarshan, W. Teutsch and Weinberg) introduced the notion of the isospin- $\frac{1}{2}$ weak current with suc-



Robert Marshak

cessful applications to K-meson decays, although the structure was naturally built into the standard theory. Marshak's subsequent research on strong, weak and electromagnetic interactions at Rochester culminated in the book *Theory of Weak Interactions in Particle Physics* (1969), coauthored with Riazzuddin and Ciaran P. Ryan.

In his time at Rochester Marshak was one of the great research guides, in the tradition of Arnold Sommerfeld and Bethe. He had many students and was host to numerous visiting physicists from all over the world. He served as physics department chairman for 14 years, and his enthusiasm, insight and guidance made the department a leading research center of high-energy physics.

In 1970 Marshak became the eighth president of the City College of New York, at a time of wrenching transition for the venerable institution. Having for many decades provided the means of intellectual advancement and social mobility for the city's poor but bright and motivated children of immigrants—an astounding number of well-known American physicists went to CCNY—the college was then, as a result of open admissions, called upon to serve a larger, less well-prepared population. At the same time, though less known to the general public, City College was striving to become a graduate research institution in physics and other science and engineering fields.

Marshak succeeded in improving about a dozen departments at CCNY, physics prominent among them. However, Bob's most visible and sometimes most controversial achievements came with the new programs he established: a Center for

the Performing Arts, an Urban League Studies Program and, most significantly, the Center for Biomedical Education.

All these acts of creation were carried out in an atmosphere of ethnic strife and agitation, as well as political and economic assaults against City College. (Free tuition was abolished in 1975.) Motivated by his social conscience and sympathies, Bob was extraordinarily responsive to all demands, striving mightily and in part successfully to supplement and replace lost public funds with funding from private sources. Nevertheless frustration and bouts of ill health took their toll, as did undoubtedly the deprivation of not doing physics. So at the age of 63 Marshak again became a full-time physicist.

In 1979 Marshak accepted a position as a Distinguished Professor at the Virginia Polytechnic Institute and State University. He resumed research in particle physics, working on various modern subjects such as the preon model (involving possible substructures of leptons and quarks), grand unified theory with possible neutron-antineutron oscillations, consequences of both local and global gauge anomalies in the gauge field theory, and the strong *CP* problem in quantum chromodynamics. Just before his death he completed the manuscript of *Conceptual Foundations of Modern Particle Physics*.

Pursuing physics full-time never stopped Marshak from doing other public service work that for most people would itself have been full-time. In the early 1980s the principal beneficiary of Bob's energy and activism was the American Physical Society. He had been on the APS council and the executive committee in the 1960s, and soon after his retirement from CCNY he was elected APS vice president; he became president in 1983.

One of Marshak's accomplishments was the design and approval of the Cooperative Chinese-American Program in Condensed Matter, Atomic and Optical Physics, which is now seen by those familiar with it as a major achievement and contribution of APS. He also led APS in statements on nuclear arms control.

Other leadership roles played by Marshak included his initiatives in the reestablishment of relations with scientists in the Soviet Union and Eastern Europe, the founding of the Rochester Conference and the seminal role he played in the creation of the International Centre for Theoretical Physics in Trieste, Italy.

With Bob Marshak's death, one of

our time's great physicists and practical dreamers is no longer with us.

HARRY LUSTIG

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Dawon Kahng

Dawon Kahng, a physicist, electrical engineer and research leader, died on 13 May 1992 at the age of 61. He was internationally known for his semiconductor device research and inventions, including the first demonstration of the basic element of today's metal oxide-semiconductor integrated circuit technology, the silicon-silicon dioxide MOS field-effect transistor. At the time of his death he was president of the NEC Research Institute in Princeton, New Jersey.

Dawon was born on 4 May 1931 in Seoul, Korea. He graduated from Seoul National University and entered Ohio State University in 1955. As part of his PhD research under Milton Boone and Marlin Thurston, Dawon investigated physical phenomena related to oxide masking, including the diffusion of impurities into silicon through SiO₂. He received his PhD and joined Bell Telephone Laboratories in 1959.

This was a period of intense effort on silicon surfaces and interfaces, both to improve the existing bipolar transistor technology and to make possible a practical FET device. Although the principles of a MOSFET and inversion-channel (enhancement mode) operation were largely understood, still missing, despite considerable searching, was an ideal insulator of sufficiently low interface state density and dielectric loss, with high enough dielectric strength to allow control of the channel with feasible gate voltages.

Dawon, in collaboration with Martin Atalla, fabricated a MOSFET using a gate insulator formed from high-quality SiO₂ grown *in situ* by a new, high-pressure steam oxidation process. They demonstrated transistor action, operated the device in several modes and reported the results in June 1960. Dawon later confirmed that the performance was consistent with first-order theory. This was the first successful operation of the modern MOS transistor and a major milestone in semiconductor technology.

Dawon made numerous other con-

tributions to semiconductor physics and devices. In 1962-64 he demonstrated for the first time that Schottky barriers obeying the Bethe thermionic emission law could be reproducibly fabricated from Si and GaAs, and he verified the image-force lowering of the barrier. In collaboration with Martin Lepselter, Dawon showed that one could make practical and reliable Schottky junctions with many choices of metallurgy—for example, silicide-silicon junctions. In 1967 Dawon invented a field-effect memory device in which charges were injected across an insulator from silicon onto an isolated gate. This floating-gate memory, which Dawon demonstrated the same year in collaboration with Simon Sze, was the first nonvolatile silicon memory device and opened the way to read-only memory technology. In 1967 he and his colleagues demonstrated efficient electroluminescence from thin-film, wide-bandgap semiconductors in which rare earth ions were impact-ionized by hot electrons, a process they called Lumocen. Dawon continued research on the Lumocen concept throughout his life. As supervisor of a ferroelectric semiconductor group, he contributed to the understanding of field-dependent dielectric properties of ferroelectric semiconductors. His subsequent research was in the area of electronically reprogrammable memory cells, silicon MOS device physics and high-performance silicon VLSI circuits.

In 1987-88, after joining NEC as a consultant, Dawon played a central role in organizing the NEC Research Institute, which conducts long-term basic research in the physical and computer sciences. His plans for the institute included innovative policies encouraging collegiality, collaboration and invention. He served the institute as president from its founding in 1988 and lived to see his plans become a reality.

Dawon envisioned computers with powers of inference and cognition approaching human capabilities. A demanding research leader, he insisted that research be unconventional and that it combine scientific excellence with the potential for pointing the way toward applications. His strategic view of research was coupled with a remarkable intuition in evaluating individual projects. He made an indelible personal impression on his colleagues. Dawon continued creative scientific work and invention to the end of his life.

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