Walter M. Elsasser

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the betatron oscillations of the particles in the ring small, so that a substantial fraction of the injected particles were stably captured.

By 1965, using the Stanford linear accelerator as the injector, he had storage rings running with large enough circulating currents to do the first colliding-beam physics experiment. The experiment, done in collaboration with Burton Richter and others, was a measurement of electron–electron scattering at a center-of-mass energy of 600 MeV, far higher than any fixed target experiment could achieve. The results showed that electrons behave like structureless point charges down to distances of the order of 10^{-14} centimeters. After this demonstration that storage rings actually worked, high-energy physicists all over the world hastened to build their own.

With the benefit of hindsight we can find one serious mistake in O'Neill's 1956 letter. He grossly underestimated the possible improvement of high-vacuum techniques: He claimed that a storage ring could hold a beam with a lifetime of a few seconds. If he had said hours instead of seconds, nobody would have believed him. It took 20 years before storage rings with lifetimes measured in hours became routine. By that time, having taught the world how to do high-energy physics, O'Neill had moved on to other things. His 1968 proposal to use an electron–positron storage ring accelerator as a K-particle factory, with the energy tuned to sit exactly on the narrow phi resonance at 1020 MeV, has begun only recently to receive serious attention.

In 1965 O'Neill became a full professor at Princeton, where he remained until his retirement in 1985. He enjoyed teaching and devoted much of his time and energy to doing the job well. In 1969 he was responsible for teaching Physics 103–104, the basic introductory physics courses. He decided to reform the courses radically, replacing the traditional problem exercises with "learning guides," which led the students step-by-step to a deeper understanding of what they were doing. The reform was an immediate success, and the learning guide system is still used in Princeton courses today. When O'Neill was concocting problems to put into his first learning guides, the students had recently been watching the Apollo missions on television, and so he emphasized applications of elementary physics to people and things in orbit and on the Moon. These orbital problems were popular with the students. At the end of the term,

Gerard K. O'Neill

O'Neill asked the class to write a term paper about a human habitat in space, calculating the requirements of mass and energy and propulsion for a viable settlement. The students responded enthusiastically to this too.

After reading the term papers, O'Neill was infected with their enthusiasm and wrote a paper of his own, "The Colonization of Space," which was published in 1974 in PHYSICS TODAY. Thereafter space colonies remained one of his main interests. In 1978 he and his wife, Tasha, founded the Space Studies Institute, a privately funded organization that supports technical research on the science and engineering of space activities. The institute successfully built a working model of a mass driver, a device invented by O'Neill for cheap and efficient movement of materials from the Moon or an asteroid into orbit.

It was characteristic of O'Neill to combine far-reaching visions with practical work in the machine shop. All his inventions, whether in high-energy physics, space technology or high-speed trains, were worked out in real hardware models with meticulous attention to detail. When, as usually happened, experts in the fields that O'Neill invaded raised objections to his ideas, he had always thought of the objections first and found ways to answer them. Some of his commercial ventures failed for financial and political reasons. Not one of his inventions failed for technical reasons.

O'Neill founded the Space Studies Institute with the intention of introducing a new style into the world of space technology. His purpose was to organize small groups of people to develop the tools of space exploration independently of governments and to prove that private groups could get things done enormously cheaper and quicker than government bureaucracies. And to bring his vision of the free expansion of mankind into space to a wider public, O'Neill wrote books. His first book, *The High Frontier* (William Morrow, 1977) has been translated into many languages. It established O'Neill as spokesman for the people in many countries who believe that the settlement of space can bring tremendous benefits to humanity and that this is too important a business to be left in the hands of national governments. In 1985 the US government recognized his status as an advocate of the private sector by inviting him to serve on the National Commission on Space.

O'Neill's third career, as an entrepreneur, began with the Geostar project in 1983 and was in full swing up to the day of his death. His final venture, the high-speed train system, which he called VSE (for velocity, silence, efficiency), was started during his last six months. The basic idea of VSE is to build a train network like a telephone network, with all trips nonstop, the stations widely distributed, and the switching system transparent to the users. Unlike other high-speed train systems, VSE is designed to outperform commercial airlines—in velocity by a factor of 5, in silence by a factor of 100, in efficiency by a factor of 10. Like other O'Neill inventions, it will have to wait a long time before the world discovers how sensible it is.

I was privileged to be a close friend of two great men, Richard Feynman and Gerard O'Neill. I was often struck by the deep similarity of their characters, in spite of many superficial differences. Both were indefatigable workers, taking infinite trouble to get the details right. Both were effective and enthusiastic teachers. Both were accomplished showmen, good at handling a crowd. Both had good rapport with ordinary people and abhorred pedants and snobs. Both were uncompromisingly honest. Both were outsiders in their own profession, unwilling to swim with the stream. Both stood up against the established wisdom and were proved right. Both fought a fatal illness for the last seven years of their lives. Both had spirits that grew stronger as their physical strength decayed.

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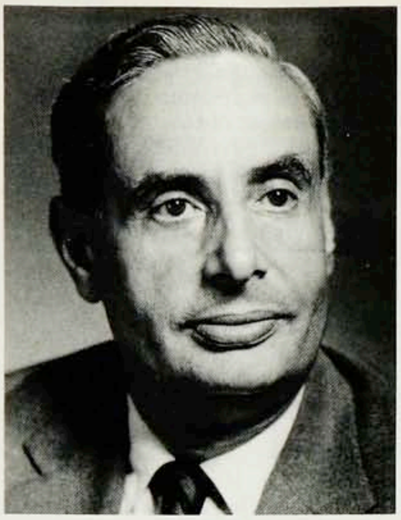
Walter M. Elsasser

Walter M. Elsasser, one of the most versatile and gifted scientists of this



Walter M. Elsasser

century, died on 14 October 1991 at the age of 87.

Elsasser began his career in theoretical physics as an undergraduate with Arnold Sommerfeld in Munich. He went on to graduate work with Max Born and James Franck in Göttingen in 1924. There he recognized that some puzzling experimental results obtained at Bell Telephone Laboratory in New York were in fact the first demonstration of the matter waves proposed by Louis de Broglie in 1924. Elsasser left Germany in 1933 with the advent of the Hitler regime and continued his theoretical work in the Paris laboratory of Frederic Joliot. Theoretical calculations led him to the concept of magic numbers that determine the stability of the atomic nucleus. Others later expanded Elsasser's ideas into the shell model of the atomic nucleus. While in Paris, Elsasser befriended the physiologist and philosopher of biology Theophile Kahn. From his discussions with Kahn, Elsasser was eventually led to the idea that it is intrinsically impossible to order the phenomena of life exhaustively in logical and mathematical terms. The attempt to find a suitable logical structure for understanding the living state was to occupy much of his attention for the rest of his life.

In 1936 Elsasser settled permanently in the US, where he was associated sequentially with Caltech (1936–41), the US Army Signal Corps (during World War II), the University of Pennsylvania and the RCA laboratories in Princeton (1945–50), the University of Utah (1950–56), the Scripps Institution of Oceanography (1956–62), Princeton University (1962–67), the University of Maryland (1967–74) and Johns Hopkins University (1974–91). In all these wanderings, his official activities were connected with the physical sciences and included work in meteorology, atmospheric radiation, plate tectonics and terrestrial magnetism. He made basic contributions in all these fields, as he had a talent for eliminating the accessories and getting at the fundamentals of a problem.

Elsasser was perhaps best known for his work on dynamo theory for the origin of magnetic fields in planets and stars. In a series of papers published from 1945 to 1950, he demonstrated how a metallic fluid dynamo can be self-sustaining for indefinite periods of time as a result of ordinary electromagnetic induction. He demonstrated mathematically how the kinetic energy of the fluid motion in the Earth's core can be converted to electromagnetic energy. Elsasser identified a positive feedback process in which energy is exchanged between two components of the magnetic field: the poloidal field (the part extending to the Earth's surface and beyond) and the toroidal field (the part contained within the core). He proposed that convective motion of the fluid is the agent in the exchange process.

Elsasser also derived an important formula for predicting the strength of magnetic fields in celestial objects. By balancing Coriolis and Lorentz forces acting on the conducting fluid, he concluded that the Earth's dynamo is characterized by a particular value of a dimensionless parameter—now called the Elsasser number—that includes the magnetic field strength, the electrical conductivity of the core and the rotation rate of the Earth.

When the concept of plate tectonics revolutionized the geological sciences in the 1960s, Elsasser analyzed how stress diffuses across tectonic plates, thus explaining the phenomenon of postseismic deformation observed in seismically active plate boundary regions, such as the San Andreas fault zone, following large earthquakes.

Besides his memoirs, Elsasser published four books over three decades beginning in 1958, all of them in biology. He felt that immense complexity was an intrinsic characteristic of the living state, even in the simplest organisms, and that biology required a logic suitable to such complexity. By the time he wrote his third book, *The Chief Abstractions of Biology*, in 1975, he felt it necessary to escape completely from the preoccupation with reductionism and mechanism that characterizes conventional biological science. Elsasser developed a set of postulates for a holistic theory unique to organisms, which supplemented rather than replaced the reductionist approach. He concentrated his attention on the behavior and function of the intact cell or organism, rather than on the molecular constituents and biochemical mechanisms. He based his theory on the intrinsic molecular heterogeneity that characterizes even the simplest cell, combined with the ordering effect of the intact living organism. Nature selects the actual molecular states of living organisms from the immense number of such states possible under quantum mechanics. However, the existence of choice in reproduction renders complete prediction of causal chains from physical law impossible.

Elsasser's proposals were made during the heyday of molecular biology, and molecular biologists tended to ignore them. His response was to create a theoretical foundation for a new way of understanding many old problems, such as dauermodifications (adaptive changes in organisms), embryological development and cancer. He believed that simplicity is not a hindrance but a help. His postulates have recently borne fruit in the demonstration that cells of higher organisms, when separated from one another in culture, exhibit great heterogeneity for many characteristics and that selection among the varying phenotypes gives rise to long-lasting changes in the heritable behavior of all cells. Although Elsasser was pessimistic about the early acceptance of his ideas by biologists, recent experimental verification should speed the process.

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Henry Hurwitz Jr

Theoretical physicist Henry Hurwitz Jr died in Schenectady, New York, on 14 April 1992, after a long fight with cancer. He was 73.

Hurwitz received a BS degree in physics from Cornell University in 1938 and a PhD in physics from Harvard in 1941. His thesis was in quantum mechanics. After a period as an instructor in physics at Cornell, he joined the Manhattan Project at Los Alamos, where he worked with Edward Teller in Hans Bethe's theory group.

In 1946 he joined the General Electric Research and Development Center in Schenectady, where Kenneth Kingdon was setting up a group