division of IBM, and since 1979 he has been an IBM Fellow at the Thomas J. Watson Research Center, Yorktown Heights, New York.

Harold E. Edgerton (MIT) was recognized for "the invention of the electronic stroboscopic flash and for finding a multitude of applications for it within science, technology, and industry." Edgerton received his DSc in electrical engineering from MIT in 1931 and joined the MIT faculty the following year. In 1966 he was made an Institute Professor in the electrical engineering department. Although officially retired, he remains active in that department as a senior lecturer.

Edwin H. Land (Rowland Institute for Science) received the medal for "the invention, development, and marketing of instant photography." He was director of research and president of the Polaroid Corporation from 1937 until 1980, and chairman of the board from 1937 until 1982. In 1967 Land received the National Medal of Science, the Presidential award given for pure science, for discoveries in the field of polarized light and other achievements. Since 1981 Land has been a scientist and the director of basic research at the Rowland Institute, in Cambridge, Massachusetts.

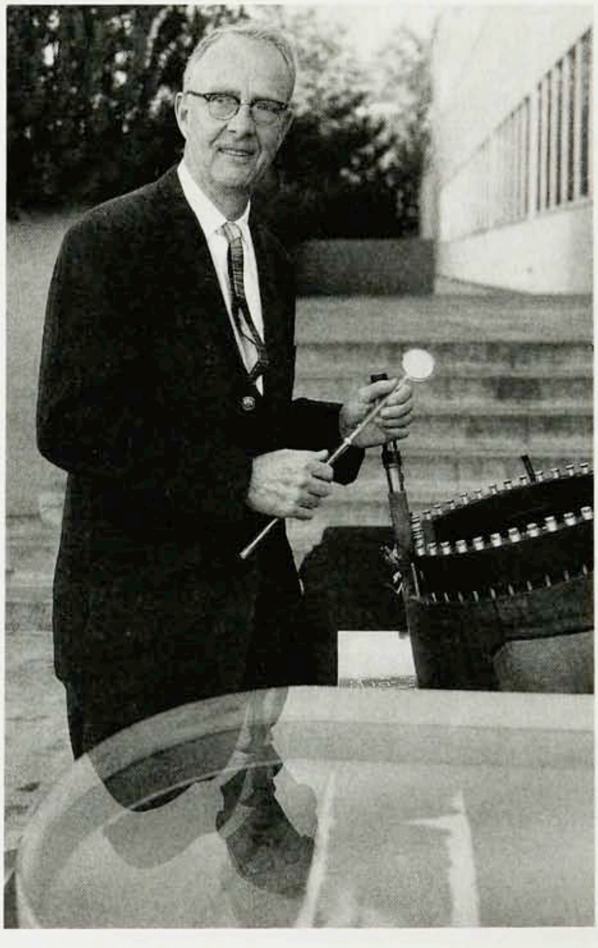
Raymond Damadian (FONAR Corporation) and Paul C. Lauterbur (University of Illinois, Urbana-Champaign) received technology medals for their independent contributions in "conceiving and developing the application of magnetic resonance technology to medical applications including whole body scanning and diagnostic imaging." Damadian received his MD from the Albert Einstein College of Medicine in 1960. From 1967 until 1978 he was on the faculty of the State University of New York's Downstate Medical Center, and since 1978 he has been president and chairman of the FONAR Corporation, Melville, New York, a leading manufacturer of magnetic resonance body scanners.

Lauterbur received his PhD in chemistry from the University of Pittsburgh in 1962. From 1963 until 1985 he was on the chemistry faculty of the State University of New York at Stony Brook. Since 1985 he has been on the faculty at the University of Illinois, Urbana–Champaign, as a professor of medical information science, chemistry, biophysics and bioengineering, a professor in the Center for Advanced Study, and director of the biomedical magnetic resonance laboratory.

OBITUARIES

Luis W. Alvarez

With the death of Luis W. Alvarez on 1 September 1988, the world lost one of its truly great experimental physicists. Luie, as he was known to all, manifested every one of the talents one associates with experimental physics: inventiveness, quantitative design of experiments, experimental skill and inspired interpretation—and excellent intuition. Luie was not a detailed analyst; although acquainted with theory he did not view the purpose of experimental work to be either to verify or to disprove theoretical prediction. He developed strong convictions as to what was or was not important and what was right and wrong. In making these judgments he tended to disregard the intermediate, and in so doing classified the work of his colleagues as deserving either the highest praise or no attention at all.



Luis W. Alvarez poses with some of the liquid hydrogen bubble chambers he developed. In his hand Alvarez holds the primitive two-inch glass chamber, with which he first explored hydrogen bubble chamber technology.

Luie's work was divided into several distinct periods, with little overlap. Just this phenomenon—shifting from one type of activity to the next—reveals his habit of sharply dividing activities into those that were worth doing and those that were not, at any given time. Alvarez's work spanned an enormous range of topics and an equally large range of methodologies. Some of it was individually done, "small" science and investigation, yet much became "big" science involving large collaborations. He was always generous in giving credit and public prominence to collaborators and students.

Luie started his career at the University of Chicago as a student of chemistry but quickly shifted to physics. Although his thesis dealt with an optics problem, his most important contribution was based on


2 NSEC/CM
10 VOLTS/CM

the adaptation of the then emerging Geiger counter technology to cosmic-ray physics. Under the general direction of Arthur H. Compton, and working largely in Mexico, he carried out an experiment on the "east–west effect" seen in cosmic rays. This work showed for the first time that cosmic rays carry an excess of positive charge.

After taking his degree Luie became a prominent member of Ernest Lawrence's Radiation Laboratory at the University of California, Berkeley. This early period, starting in 1934, was possibly the most concentrated creative epoch in Luie's work with respect to contributions to pure physics. He discovered K capture of atomic electrons as a β-decay process. He measured the characteristics of tritium decay and determined the stability of helium-3. He studied scattering of slow neutrons on many substances including *ortho-* and *para*-hydrogen, and thereby contributed to the knowledge of the spin dependence of nuclear forces. In a classic collaboration with Felix Bloch of Stanford University, Luie combined his experience with slow neutrons with Bloch's expertise in nuclear magnetism to determine the magnetic moment of the neutron. Each one of these papers constituted a major advance in experimental nuclear physics.

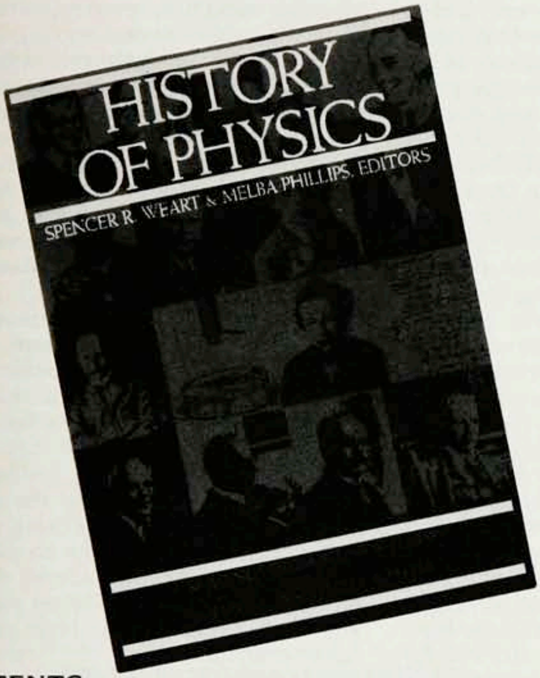
Then the war started, and Luie joined the Radiation Laboratory at MIT. Here his inventiveness and "hands on" ability in designing and building equipment became a major force in shaping many of the devices that laboratory contributed to radar. In time Luie became the head of a special section dedicated to original inventions (in contrast to the other sections, which were organized to work on specialized components).

Luie's contributions were many; we will mention only a few prominent ones. He designed the airborne radar called VIXEN, dedicated to the detection of enemy submarines. At that time, the endurance of submarines underwater was low, so they had to spend a fair amount of time on the surface. Luie designed VIXEN so that the intensity of the transmitted radar signals would vary roughly as the cube of the distance between transmitter and target. The consequence was that as the airplane carrying the transmitters and antisubmarine weapons approached the target, the signal as seen by the target (obeying an inverse square law) would decrease, while the signal as seen by the radar receiver (obeying an inverse fourth-power law) would increase. Thus the skipper of the submarine would be fooled into assuming that the attacking aircraft was receding rather than approaching, while the radar operators received an increasing signal-to-noise ratio.

Luie also worked on early-warning systems and ground-based radars. He was the inventor of the phased-array radar, in which a beam is steered electronically rather than mechanically. Perhaps his most lasting contribution was the invention, development and demonstration of the Ground Controlled Approach radar. Consisting of a ground-based transmitter and receiver that give information on the path of a landing aircraft, GCA enables a ground-based pilot to "talk down" an aircraft to a safe landing under adverse conditions. Luie was involved personally in critical demonstrations of this technology to military "brass" both in the United States and in Great Britain. In the British demonstrations, he helped guide aircraft crippled in combat over Germany, and manned by tired and, frequently, injured crews, to landings theretofore thought impossible. GCA continued to be used throughout the war, and later became the principal tool that made it possible for US aircraft to land at a rate of two per minute during the Berlin blockade. Luie received the highest aviation award given by the US government—the Collier Trophy—for these achievements.

Notwithstanding the strict compartmentalization of information during the war, Luie maintained some communication with the atomic bomb project. When room for invention in the radar work had diminished, Luie joined the nuclear project at the University of Chicago, where he enjoyed the inspiration of working with Enrico Fermi and where he contributed innovations to instrumentation of the early nuclear reactors. However, his work on nuclear weapons did not really come into its own until he and his family moved to Los Alamos. There he worked initially with the explosives division and made seminal contributions to the timing mechanisms that synchronized the detonation of the various lens elements of the implosion device. At the request of Robert Oppenheimer he then pursued yield assessments of the first three nuclear explosions by measuring their shock waves through telemetry. Luie personally directed this activity all the way from design and initial tests to final use, and he participated in the Hiroshima mission himself. The device used in the Hiroshima bombing consisted of a condenser microphone-modulated

Experience history...Einstein's genius...Poincaré's creativity...the physics community's perseverance during the Great Depression...the drama of Goudsmit and Uhlenbeck's discovery...



HISTORY OF PHYSICS

Edited by Spencer Weart and Melba Phillips

With an array of accomplished contributors including seven Nobel Prize winners, this collection of reprinted *Physics Today* articles deepens your appreciation of modern day physics.

Bringing to life the exciting achievements of recent generations, this fully illustrated volume provides insights into the scientific process, as well as the people and events behind the dramatic progress and inspiring discoveries.

With over 300 photographs and illustrations, HISTORY OF PHYSICS is a valuable library reference, a useful supplementary text for a wide range of courses, and stimulating leisure reading for both physicists and informed general readers.

CONTENTS

BEFORE OUR TIMES

INSTITUTIONS OF PHYSICS

SOCIAL CONTEXT

BIOGRAPHY

PERSONAL ACCOUNTS

PARTICLES AND QUANTA

AMERICAN INSTITUTE OF PHYSICS

375 pp. • $8\frac{1}{4}'' \times 11\frac{1}{4}''$ • Softcover • 1985 •
ISBN 0-88318-468-0 • LC 85-70236 • $25.00
(20% discount available to members of AIP Member Societies)

Send your order with payment to:
American Institute of Physics
Marketing Services
335 East 45 Street
New York, NY 10017

Amex, Visa & MC accepted:
To place your credit card order,
call 1-800-AIP-PHYS;
In New York State,
call 212-661-9404

transmitter, dropped by parachute, that sent a telemetry signal to one of the airplanes participating in the raid. With official approval Alvarez wrote a letter to the well-known Japanese physicist Ryokichi Sagane, who had worked at Berkeley before World War II, and attached it to the battery case of the shock-wave telemetry package. The letter informed Sagane of the nature of the nuclear weapon and requested that he communicate the relevant facts to the Japanese high command. This letter was recovered by the Japanese and delivered; the telemetry device is still on view in the Hiroshima Memorial Museum. This episode constitutes a truly original means of communicating with the enemy.

Along with many of his colleagues, Luie contemplated what research to pursue upon returning to academic life. In Luie's case this meant giving thought to new concepts of accelerator construction for nuclear physics based on the use of wartime technologies and equipment. Thus his main contributions immediately after the war were in the accelerator arts rather than physics research. The decision to build the Berkeley linear accelerator was based on Luie's realization that the cost of linear accelerators scaled directly with energy, while the cost of existing cyclotrons varied as the cube of the energy. Also contributing to the decision was Luie's expectation that the vast quantities of surplus ground-based radar equipment would provide "free" radiofrequency power sources for a linear accelerator. Thus resulted the first practical linear accelerator, the 32-MeV proton machine at Berkeley, built under Luie's direction. This machine has remained the standard for proton injectors all over the world, notwithstanding that the basic premises on which it was conceived proved incorrect: The invention of phase stability by Edwin McMillan and Vladimir Veksler, applied to the proton synchrotron, changed the scaling law for high-energy proton machines from cubic to linear, and most of the surplus radar gear had to be replaced with more suitable, dedicated equipment.

Luie also invented the tandem electrostatic accelerator, in which negative ions are accelerated from ground potential to a foil maintained at a high positive electrostatic voltage. The foil then strips the negative ions into positive nuclei, which are accelerated back to a target at ground potential. This method not only doubles the available beam voltage but maintains both the ion source and target complex at ground potential. Another of Luie's inventions was the microtron, an accelerator in which the pathlength of successive orbits is increased by one wavelength of the rf power source. (He never reduced this idea to practice, but others did.)

During the Korean War, Alvarez's accelerator design skills were put to the test by the pressure that developed at Berkeley to contribute to the production of fissionable materials. At that time, Lawrence and Alvarez had concluded that the US was threatened by a cutoff of supplies of uranium, which came largely from overseas. They decided that it would become necessary to "breed" plutonium from either unseparated uranium or uranium depleted in the fissionable isotope U^{235}. Initial plans, later rejected, called for the construction of a fast reactor in the Berkeley hills. These plans were abandoned in favor of breeding plutonium using the neutrons produced by spallation from the impact of high-energy proton or deuterium beams on high-atomic-number targets. After such neutron yields were measured in the synchrocyclotron beam at Berkeley, a prototype accelerator was built under Luie's direction at Livermore, the site Lawrence had selected for the reactor initially planned. The prototype, a deuterium linear accelerator, used the basic principles of the 32-MeV machine but was scaled up vastly in size and average beam current by operating at much lower radiofrequencies. Housed in a 60×60-foot tank, it produced 7-MeV deuterons at an average current of $\frac{1}{4}$ ampere. After its completion it was used for some time for nuclear physics research, but its original purpose disappeared after uranium supplies within the US increased. The plans for a 1-gigawatt production accelerator were abandoned.

With the exception of his participation in proton–proton scattering with the 32-MeV accelerator and some cosmic-ray work using a balloon-borne solenoid, Luie's direct immediate post-war participation in physics research did not match that of his early productive period at Berkeley. This situation was dramatically reversed when he became acquainted with Donald Glaser and his invention, the bubble chamber.

In 1954 the Bevatron came into operation at the Radiation Laboratory in Berkeley, and Luie turned his attention to experiments in particle physics. Lifetime measurements were his first focus of interest: He carried out an emulsion experiment on τ mesons and later a counter experiment designed to measure lifetimes of the various K decay modes.

During the early days of the Bevatron, Luie's contributions to particle physics were threefold. In 1953, right after Glaser announced the invention of the bubble chamber, Luie began research on the construction of a chamber using hydrogen as a working fluid. As soon as he and his team had demonstrated that hydrogen could be used as a working fluid in a laboratory bubble chamber, Luie began construction of a gigantic, 72-inch hydrogen bubble chamber. The important breakthrough here was that he demonstrated that a metal box with glass windows (the so-called dirty chamber) would work just as well as Glaser's small, clean, glass container.

Luie's second major contribution during this period arose from his realization that the old-fashioned projection tables used with cloud chambers would no longer suffice for the large numbers of events that one observes in helium and hydrogen chambers. He spearheaded the construction of automatic scanning and measuring equipment (the so-called Frankensteins) whose output data would be stored on punched cards and then evaluated on large electronic computers.

Luie's third major contribution was the large number of important physics discoveries he and his coworkers made using the tools he had developed. They discovered the Y^* (1385 MeV)—the first new resonance—and then in rapid succession the K^* (890 MeV)—the first meson resonance—the ω^0 meson and many others. These discoveries represented a major step forward in the physics of particle states, leading to the "eightfold way" and eventually to quarks. In fact, Murray Gell-Mann, the leading figure in those theoretical developments, was in close touch with Luie and his group throughout this period.

The techniques Luie and his group developed were rapidly taken up by many physicists all over the world. During the 1960s large bubble chambers were developed at Brookhaven National Laboratory, at the Rutherford Laboratory in England, at CERN in Switzerland and at the Ecole Polytechnique in Paris. Though these chambers differed in design from Luie's, the confidence that large chambers could be built and the belief that they were essential for particle physics research come directly from Luie's work.

The same is true for the automatic measuring machines and, in particular, the accompanying computer programs that reconstruct the events in

space and calculate the kinematical parameters that fit the data. Such programs have been accepted, either outright, with various modifications, or as models, by all physicists engaged in the analysis of bubble chamber pictures. They have also been adapted to reconstruct events in drift chambers and other modern electronic detectors. The Monte Carlo methods Luie's group developed for event simulations and detector efficiency calculations have become a major industry, and are used universally by both experimenters and theorists.

The contributions Luie's group made using the 72-inch bubble chamber continued for well over a decade, and were a major factor in establishing the new spectroscopy of hadrons. In typical Alvarez fashion he observed that the productivity of that chamber was limited by the repetition rate of the Bevatron, rather than by fundamental engineering limits. When the Stanford Linear Accelerator Center developed hadron beams of higher energies and higher repetition rates than were available at the Bevatron, he initiated a re-engineering of the chamber to use that opportunity. He transferred the Bevatron's machinery and much of its operating staff to SLAC, where they received a new lease on life. In taking this action, Luie put the interests of science ahead of institutional and personal interest. The discoveries made with the large hydrogen bubble chambers earned Luie the Nobel Prize.

Paradoxically, Luie's participation in high-energy physics went "full circle." He recognized that Glaser's invention could be exploited only by converting Glaser's small chambers to large, reliable machines, building massive analytical devices and organizing large operating teams: Luie's bubble chamber effort is often cited as the decisive step to "big science." Yet in his later years he expressed a strong dislike of big science and returned to a variety of individual activities including inventions and technical detective work. Much of this work excited the public imagination. Luie searched for hidden burial chambers in Egyptian pyramids using cosmic-ray muons. He studied the events surrounding President Kennedy's assassination by examining the effects of shock waves on Abraham Zapruder's camera and carrying out experiments on the terminal ballistics of bullets in human brains (simulated by melons). He invented lens systems of variable focal length by superimposing appropriately shaped laminae of glass.

His most dramatic application of physics to other fields came with his work bearing on the extinction of species, which he himself considered the most important scientific achievement of his career. (See Alvarez's article in PHYSICS TODAY, July 1987, page 24.) Together with his son Walter, a geologist, Luie discovered an unusually high concentration of an isotope of iridium at the geological boundary between the Cretaceous and Tertiary formations. In association with his colleagues working in radiochemistry at the Lawrence Berkeley Laboratory, Luie determined that this iridium was of extraterrestrial origin and had presumably reached Earth via a meteoric impact. Luie extrapolated that such a massive impact would have raised so much dust into the atmosphere that it would have produced worldwide darkness sufficient to impede biological processes. This he associated with the disappearance of the tiny marine organisms known as foraminifera, as well as dinosaurs and other species, between the Cretaceous and Tertiary periods. While there is little argument about the correctness of the association of the iridium layer with the impact of an extraterrestrial boloid, the details of how this event might be connected to extinctions are still in dispute. Many paleontologists maintain that Alvarez's hypothesis cannot by itself give a satisfactory picture of the Cretaceous–Tertiary extinctions.

Whatever the verdict on this controversy turns out to be, Luie's discovery has induced major changes in thinking about geological and evolutionary processes. Detailed examinations of the soil chemistry of the Cretaceous–Tertiary boundary and other geological strata associated with mass extinctions have been made worldwide. Some studies have correlated apparent periodicities of major extinctions with the frequency of occurrence of meteoric impacts. Luie's findings have triggered interest in the "nuclear winter" phenomenon, which associates danger to life with the dust and soot raised into the atmosphere by nuclear explosives.

Luie's productive life has had its share of controversy, triggered primarily by his attitude that at any one epoch scientific questions have only one best answer and that those who do not accept that verdict are largely wasting their time. Thus when, through his work, the hydrogen bubble chamber became the most productive tool in discovering new hadronic states at high energy, he felt that high-energy physics resources should be almost totally concentrated on bubble chamber work. This caused conflict between Luie and those of his colleagues at the Lawrence Berkeley Laboratory who did not feel that science should be conducted under such a principle of absolute priority. During the period when Lawrence and Alvarez tried to rededicate the resources of the Lawrence Berkeley Laboratory to breeding uranium, not everyone was persuaded that the emergency requiring this action existed. The debate between Luie and the disbelievers in his theory of mass extinctions has at times been acrimonious.

Luie had an amazing knowledge of the entire literature of physics, and he exhibited the opposite of the "not invented here" syndrome: When he felt that others had attacked a problem responsibly, he would not attempt to modify their technique just to prove he might have a better way. For example, when at Los Alamos Luie agreed to assess the yield of nuclear explosions using shock-wave measurements, he ascertained from then-classified reports that Wolfgang K. H. Panofsky had already developed instrumentation he could adapt to that purpose, and he used those devices.

Luie Alvarez, like most academic physicists, immersed himself in military technology during World War II. Unlike many of his academic colleagues he pursued such work intensively (if intermittently) throughout his life. His scientific standards remained high throughout, and he justified his work as the means to peace. He disapproved of SDI. Luie was part of the first wave of US scientists to visit nuclear facilities in the Soviet Union in 1956. He was deeply moved by the occasion and argued that nuclear explosives had made war a thing of the past.

Luie Alvarez was an extraordinarily gifted experimental physicist, an inventor, an investigator and a strong individual who maintained the highest standards of truth in inquiry. The world is poorer without him.

GERSON GOLDHABER
Lawrence Berkeley Laboratory
Berkeley, California
WOLFGANG K. H. PANOFSKY
Stanford Linear Accelerator Center
Palo Alto, California

Ralph P. Johnson

Ralph P. Johnson died 11 February 1988 in Los Angeles at the age of 78. A fellow of The American Physical Society, his career included numerous contributions to physics as well as responsibilities in industry and government.

After completing his undergraduate work at the University of Richmond and receiving his MS from the University of Virginia in 1932, Johnson went to MIT, where he earned a PhD in 1936. Working in physical electronics under Wayne Nottingham, he and William Shockley developed the cylindrical electron microscope for studying electron emission from filaments. The microscope provided the first direct measurements of the variation of electron emission and adsorption with crystallographic orientation. Their paper on this work was the first scientific publication by either author.

Johnson was on the research staff at the General Electric Research Laboratories in Schenectady, New York, from 1936 until 1943. There he continued studying the surface physics of metals and built an electron diffraction camera of his own design. A short study of stereoscopic vision led to an imaginative psychophysics paper titled "Believing Is Seeing." In 1937 he co-authored with Frederick Seitz a series of three review articles in the *Journal of Applied Physics* on the emerging field of solid-state physics. These articles, which stressed how quantum mechanics and band theory offer a unified approach to widely differing types of solids, have been recognized for their seminal influence on the solid-state physics community (see the article by Spencer R. Weart in PHYSICS TODAY, July 1988, page 38). The American Physical Society made him a fellow in 1941.

In the early years of the war Johnson worked on phosphorescent materials for radar applications. In 1943 he joined Lauriston Taylor at the Operational Research Group of the US Tactical Air Command in England, where his efforts were di-

Ralph P. Johnson