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WOLFGANG KURT HERMANN PANOFSKY
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A Biographical Memoir by

BY SIDNEY D. DRELL AND GEORGE H. TRILLING

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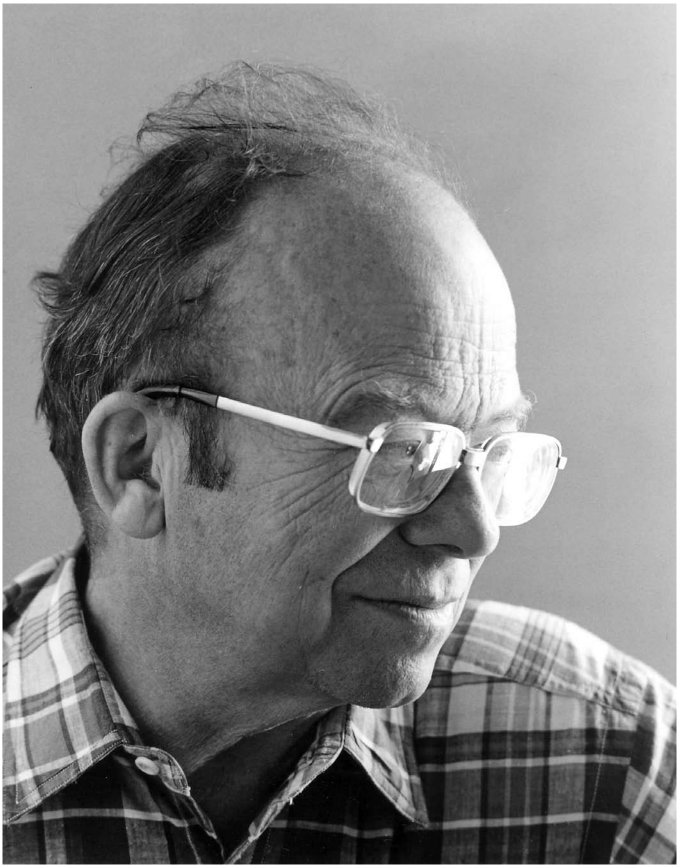

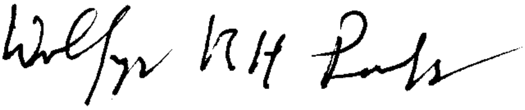

WOLFGANG KURT HERMANN PANOFSKY

April 24, 1919–September 24, 2007

SIDNEY D. DRELL AND GEORGE H. TRILLING

WOLFGANG KURT HERMANN PANOFSKY, a legendary and beloved figure of modern physics, died of a heart attack on September 24, 2007, at his home in Los Altos, California. Known as "Pief," he was renowned worldwide as a distinguished particle physicist, the founding director of the SLAC National Accelerator Laboratory, and a man of integrity who fought throughout his life for arms control in a world heavily armed with nuclear weapons. Never one to avoid a challenge, he was in his office on the day of his death, writing on arms control, questioning technical details of the linear coherent light source (a free-electron laser then being built at SLAC), and looking forward to the impending publication of his memoir, *Panofsky on Physics, Politics and Peace: Pief Remembers* (2007).

Pief was born on April 24, 1919, in Berlin, Germany, and grew up in Hamburg, where his father, eminent art historian Erwin Panofsky, was a professor at the University of Hamburg until he was dismissed in 1934 because he was Jewish. Realizing that their lives and their careers were at risk if they remained in Germany, the Panofsky family emigrated to the United States and settled in Princeton, New Jersey. Pief was admitted to Princeton University at age 15, graduated summa cum laude with a major in physics in 1938, and entered Caltech for graduate work.

Pief's thesis research, under the supervision of Jesse DuMond, was a precision measurement of the ratio of the Planck constant h to the electron charge e. In 1942 he received his Ph.D. and married DuMond's daughter, Adele, a marriage that lasted for 65 years. Though initially classified as an enemy alien, Pief was granted citizenship and clearances to work on military projects, including an improved firing-error indicator, an acoustic device for detecting shock waves from supersonic bullets. His work on the firing-error indicator attracted the attention of Luis Alvarez and J. Robert Oppenheimer who invited him to Los Alamos in 1944 to develop a shock-wave detection device in order to measure the yields of nuclear explosions, including the Hiroshima bomb.

After World War II ended, Pief accepted an invitation from Luis Alvarez to move to the University of California Radiation Laboratory, now formally known as the Lawrence Berkeley National Laboratory, originally to work on proton linear accelerators. He worked first on the design and development of a 32 MeV, 40-foot-long proton linear accelerator, contributing extensively and innovatively to theoretical analyses of beam stability and to experiments aimed at improving the performance of the oscillators powering the proton beam. This machine was constructed successfully, but with the invention of the synchrotron (based on the newly discovered principle of phase stability) extensions to higher energies were never built.

This was a unique and very exciting time at the Rad Lab and the beginning of what are now known as "big science" laboratories. Pief's contributions and leadership soon earned him a faculty position in the University of California, Berkeley, physics department. From 1946 to 1951 he was an assistant professor and then an associate professor. He taught electromagnetism, a field of his special expertise; with Melba Phillips he coauthored a graduate textbook *Classical Electricity and Magnetism* (1955) that was widely used for a number of years.

Pief continued his intensive, very productive experimental research in the study of subatomic particles using the Rad Lab's two accelerators, the 184 inch cyclotron and the 330 MeV electron synchrotron, both with high enough energy to produce pi mesons, as pions were originally called. Pions had been discovered in 1947 in cosmic rays at Bristol, and Berkeley became a unique center of work in this field. Pief, in collaboration with Steinberger and Steller, studied multiphoton production by gamma rays incident on nuclear targets, identified the two-photon decays of neutral pions, and accurately measured their mass. With Aamodt and Hadley he investigated the at-rest absorption of negative pions by protons and deuterons. These measurements helped determine the spin and parity of pions, and more accurate masses for both neutral and charged pions.

This very productive research period was interrupted in 1951 when Pief chose to leave Berkeley and move to Stanford University in protest against a loyalty oath to the United States and California constitutions that were imposed on the faculty and other employees of the University of California. The oath required all employees, as he later wrote, to "affirm their lack of communist contamination." Although he signed it, and had already demonstrated loyalty by working on classified projects for the military during the war, he believed the oath to be wrong in principle. He also became very distressed when he learned that colleagues who had refused to sign the oath were threatened with dismissal and, in some cases, dismissed. He viewed the resulting climate of mistrust at Berkeley to be intolerable. In October 1952 the oath was ruled unconstitutional by the California Supreme Court.

A detailed account of Pief's involvement with the loyalty oath controversy is given in J. D. Jackson's *Physics Today* article.[1]

As a professor of physics at Stanford, Pief was a popular lecturer, patient and accessible. He created the same open, collegial relationship with students that he nurtured later as director of the university's High Energy Physics Laboratory, where he developed its 61-meter-long, 1 GeV electron accelerator into an exceedingly productive research tool. With G. B. Yodh, Pief made detailed studies of pion production by electrons incident on a proton target, including production of the so-called (3/2, 3/2) pion-nucleon resonance. Their experiments were the first to measure high-energy inelastic electron-proton scattering, a process subsequently studied in far greater detail at SLAC, the laboratory that Pief later helped create. With G. E. Masek, Pief made the first observation of gamma-ray conversion into mu+ mu– pairs. One of us (G.T.) was in the audience when Pief gave a Caltech colloquium describing this experiment. After his presentation, distinguished theorist Richard Feynman pointed out that Pief's approach, at higher photon energies, was a good way to discover even more massive electronlike particles, if they existed. As it turned out about 20 years later Martin Perl, working at SLAC, discovered the heavy tau lepton in almost the way that Feynman had suggested; but an all-important difference is that he studied conversions of virtual photons (made in electron-positron collisions at the SPEAR collider [Stanford Positron Electron Accelerating Ring]) into tau-lepton pairs, rather than the conversions of real photons that Pief and Masek had used. Lepton-pair cross-sections for real photons decrease rapidly with increasing lepton mass, whereas for virtual photons they are almost independent of lepton mass at energies well beyond threshold, a tremendous experimental advantage.

Recognizing the scientific value of having electron beams with energies much higher than the 1 GeV so far achieved, Pief joined forces with Stanford colleagues to develop the concept and begin the design and construction of a linear accelerator laboratory capable of producing an electron beam of energy of at least 20 GeV. This project was originally called the Stanford Linear Accelerator Center, or SLAC (and more informally Project M, or the Monster). In 2008 SLAC was renamed the SLAC National Accelerator Laboratory, reflecting the reality that it had developed an array of circular storage rings in addition to the original 2-mile-long linear electron accelerator, and making clear its status as a national laboratory. When authorized in 1961 with a budget of $114 million, SLAC was the largest scientific project of its time.

Getting SLAC authorized and built had many challenging aspects. In the late 1950s high-energy physicists were more interested in extending the particle physics energy frontier by building much higher energy proton accelerators. Protons (~1800 times more massive than electrons) can be accelerated to higher energies than electron beams because they lose much less energy to electromagnetic radiation than electrons with the same energy. In addition, due to their strong nuclear interactions, proton collisions are a more copious source of other subnuclear particles to study. On the other hand, electrons have the important advantage of interacting with nuclear particles through the well-understood electromagnetic force, leading to more selective and easily interpretable phenomena. Time has proved that electron and proton accelerators have both been of critical value in leading to complementary phenomena and observations that, taken together, were essential to progress.

Two additional issues—one political and one based on principle—presented barriers to getting on with the construction of SLAC. The political barrier, which became a *cause célèbre* in the Stanford area, involved the aboveground power line connecting SLAC with the main power line coming down the peninsula from San Francisco to Silicon Valley on Skyline Boulevard. Residents feared that the line would be an ugly scar and fought to have it underground, adding considerably to the cost. Since they were unwilling to pay to have their numerous local power lines put underground, the U.S. government demurred. With a visit by Washington representative Laurance Rockefeller and recognition that the 230 kilowatt line to SLAC would be barely visible in its newly designed incarnation, the matter was eventually settled. The line remains in use today.

A more fundamental controversy arose when Pief, with the support of Stanford University's administration and trustees, rejected the insistence by the Atomic Energy Commission, at that time the original incarnation of what has now become the Department of Energy, that SLAC, like other AEC installations, be subject on an open-ended basis to any regulations imposed unilaterally by the government on grounds of national security requirements. Against strong outside advice that this might endanger the entire project, Pief insisted that any such decision had to be jointly arrived at by the university, which was and still is responsible for building and managing SLAC, and the government. Pief and Stanford stood firm and gained agreement for their position. As in the UC loyalty oath controversy, Pief displayed his deep and enduring commitment to stand strongly and unyieldingly behind the principles important to him.

Construction of SLAC was completed on budget and on schedule in 1966. Under Pief's strong leadership the technical, administrative, and political challenges were overcome. The 2-mile-long linear accelerator met and subsequently exceeded its original design goals. Pief also provided visionary leadership in building a world-class entire research enterprise that continues to flourish 44 years later. He assembled a strong team to design and build the experimental detectors in parallel with the accelerator. Together with a strong theoretical group, that team was ready to produce groundbreaking new research results at turn-on time. During Pief's tenure as director until his retirement in 1984, scientists conducted experiments that led to the discovery of new forms of subatomic matter, including quarks as constituents of protons and neutrons, the J/psi resonant state and its "charm" quark constituents, and the tau lepton, each of which was recognized by the award of a Nobel Prize in Physics, for a total of three Nobels. The successful development and scientific application of electron-positron storage rings at SLAC had major impact on particle physics programs at other laboratories all over the world, culminating in the Large Electron Positron (LEP) collider at CERN.

In the 1950s Pief became heavily involved in advising the Eisenhower Administration on arms control and science policy. For example, in 1958 the Eisenhower administration was preparing to open negotiations with the Soviets toward cessation of nuclear weapons tests. Jim Killian, then science adviser to President Eisenhower, was relying on the President's Science Advisory Committee (PSAC) for the necessary technical studies on the means available to detect weapons tests. There were unresolved technical issues, and he turned to Pief to head up a technical working group to deal with methods of detection of nuclear explosions in space. The issue at that time was the possibility of hiding nuclear explosions. Could exotic tests be concealed by exploding nuclear devices at very high altitudes or in outer space, even concealing tests behind the moon or the sun, as suggested by some scientists? If anyone thinks that particle physicists are clever in inventive creations these days, they should compare their ideas with some of the nuclear test exotica one had to face then.

As Killian wrote in his memoirs, President Eisenhower opened a diplomatic negotiation with the Soviets that year that included the methods and instrumentation for space detection that were recommended by the technical committee chaired by Pief. Subsequently, the negotiators reached an agreement based on the correct technical assessment of limitations and potentials for detecting and identifying high-altitude explosions. Pief himself played a prominent role in that negotiation as chair of the U.S. delegation. This was the first basic step toward the subsequent signing and ratification of an atmospheric test ban treaty several years later during the Kennedy Administration.

The fact that background radiation from atmospheric tests decreased by two orders of magnitude in 20 years following the end of aboveground testing of nuclear bombs by the United States and the Soviet Union, and that the environment in which we live has been so cleaned up from threatening nuclear fallout, derives in no small measure from the success of that technical effort.

During this time, President Eisenhower appointed Pief to the President's Science Advisory Committee for a four-year term that continued through the Kennedy Administration. He contributed to much more work on testing limits that continued for the next 35 years, leading up to the Comprehensive Test Ban Treaty signed in 1996, but not ratified by the United States as of this writing. During the 1970s and 1980s, Pief also was a leader in the fight against the building of ballistic missile defenses, arguing on sound technical grounds, that achieving an effective defense against nuclear warheads was impractical.

This was a cause in which he remained engaged throughout his life. In fact, on the day after his death, an op-ed piece he had just written entitled "Missiles No Defense" appeared in the *San Francisco Chronicle*. Its concluding paragraph reads,

> The above (analysis of defense of the nation against nuclear weapons) shows that the scientific-technical realities and the political actions by the United States and Russia are divergent. What is the reason for this failure? Is it insufficient scientific-technical advice reaching the highest levels of governments? Is it deliberate disregard of such advice by national leaders? Is it simply the inherent conservatism of governments in their ability to change past erroneous decisions? We do not know. One overriding fact remains clear: scientific-technical realities cannot be overruled by political decisions without resulting in grave risks to the nation.

How did Pief manage to combine his Washington responsibilities with his Stanford teaching obligations? Quoting from his memoir,

> [PSAC] met in Washington on the first Monday and Tuesday of each month, and there were many additional meetings of subcommittees, or retreats of the whole committee. Because I had to teach freshman physics on Wednesday mornings, my wife would pick me up from my return flight to San Francisco on Tuesday evenings, drive to the Stanford lecture hall, and work with me to prepare the demonstrations needed for the next day's classes. We then went home, and early on Wednesday mornings, I gave the lectures and accompanying demonstrations, usually to three classes in succession.

Pief was intensely engaged as a member (and chair from 1985 to 1993) of the Committee on International Security and Arms Control of the National Academy of Sciences. That committee produced a number of influential studies on technical national security issues and policies for the U.S. government. It also met frequently with scientists from other nations, most particularly the Soviet Union and China, to raise the level of mutual understanding and trust on nuclear issues of major importance.

In recognition of his wisdom, his devotion to both science and peace, and his stature as a national treasure, Pief received just about every conceivable award that science, academia, and the U.S. government could give. He was elected to the National Academy of Sciences in 1954. His many honors included the Enrico Fermi Award, presented on behalf of the President of the United States by the AEC with the citation:

> For his many important contributions to elementary particle physics; for his leading role in advancing accelerator technology evidenced in the success of the SLAC 20 BeV, SPEAR and PEP machines; for his positive influence on and inspiration of younger scientists; and for the depth and thoughtfulness of advice he has so generously given the United States Government.

Similar words of praise can be found in the citations for the National Medal of Science; the Franklin Medal from the Franklin Institute, "particularly for accelerator design, construction, and successful exploitation"; the Ernest O. Lawrence Award for his fundamental contributions to meson physics; the Leo Szilard Award for his contributions to society through his arms-control work; the Richtmeyer Lecture by the American Association of Physics Teachers; the list goes on, including his election as president of the American Physical Society in 1974.

In addition to achieving membership in the National Academy of Sciences, the American Academy of Arts and Sciences, the Council on Foreign Relations, and the American Philosophical Society, Pief was elected to foreign membership in the Chinese Academy of Sciences, the Academie des Sciences (France), the Accademia Nazionale dei Lincei (Italy), and the Russian Academy of Sciences, in recognition of the valuable advice he provided to their scientific programs. In particular he was heavily engaged in advancing the Chinese high-energy physics program and the construction of the Beijing electron-positron collider.

Tributes to Pief have universally emphasized both his enormous impact on particle physics, and his integrity, humanity, strong commitment to fighting for principles in which he believed deeply, and his tireless efforts to help the world and its government leaders understand the grave new dangers posed by nuclear weapons of such enormous destructive power. This facet was emphasized in the citation for the honorary doctorate awarded to Pief by his alma mater, Princeton University:

> He has led our quest for the ultimate constituents of inanimate nature, using the resources of modern technology to open the realm of high-energy elementary particle physics and to catch glimpses of a fleeting world of "color," "charm," and "strangeness." Knowing intimately the awesome power of the atom, he has counseled us in the arena of nuclear arms, soberly reminding us of the mutually assured destruction that is the most likely outcome of their use.

A simple tribute that encapsulates the widespread admiration of Pief as a citizen of the world came from the theoretical physicist Abraham Pais. As Pais and I (S.D.) sat musing in a bistro near Stanford University in the summer of 1951 shortly after we both first got to know Pief, Pais remarked simply: "That Panofsky—what a beautiful person."

Dr. Panofsky is survived by his wife, Adele Panofsky, and their five children: Richard Panofsky of Rehoboth, Massachusetts; Margaret Panofsky of New York City; Edward Panofsky of La Honda, California; Carol Panofsky of Santa Cruz, California; Steven Panofsky of Ukiah, California; and 11 grandchildren and 3 great-grandchildren.

NOTE

1. J. D. Jackson. Panofsky agonistes: The 1950 loyalty oath at Berkeley. *Phys. Today* 62(2009):43-47.

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