MEMORIAL RESOLUTION

WILLIAM MARTIN FAIRBANK
(1917 – 1989)

William Martin Fairbank, Max H. Stein Professor Emeritus of Physics, died almost instantaneously of a heart attack while out running--an essential activity of his--near his home in Ladera on September 30,1989. He was 72, still extremely vigorous mentally and physically, having been in the laboratory until 9:00 p.m. the previous night, gathering data with two undergraduate students on one of his best known, if controversial, experiments, the search for fractional charges (free quarks).

Born in Minneapolis, Minnesota, on February 24, 1917, Bill Fairbank, along with his future wife Jane Davenport and his younger brother Henry, graduated from Whitman College with A. B. degrees in chemistry (1939) and physics (1940). After 18 months as physics graduate students at the University of Washington, he and Jane became staff physicists at the MIT Radiation Laboratory in 1942, where they worked together on overwater tests of 10 cm and 3 cm radar, and Bill obtained his first patent, for a device for calibrating radar systems. In 1945 he reentered graduate school at Yale where Henry, who had already obtained his Ph.D., was now a member of the physics faculty working with C. T. Lane in one of the very few low temperature groups in the U.S. at that time. Bill did a highly original doctoral dissertation on the surface resistance of superconducting tin at microwave frequencies--research that was to bear fruit later in work at Stanford in the 1960's on a superconducting particle accelerator. He also collaborated with Lane and Henry on the-first U.S. experiments on "second sound" in superfluid He^4 mixtures, and on the properties of He^3-He^4 mixtures.

From 1947 to 1952 Bill was an assistant professor at Amherst College where he worked on an extremely ambitious project to separate out the pure He^3 isotope from solution in He^4 by means of a heat-flushing technique invented by Henry. He then moved to Duke University, where in seven years between the ages of 35 and 42 he established himself as arguably the best and certainly the boldest low temperature experimentalist in the world. With students and colleagues he performed in 1954 the first measurements demonstrating the Fermi-Dirac degeneracy of liquid He^3, making use of nuclear magnetic resonance (NMR) techniques at the then very low temperature of 0.25 K, a technically extraordinarily difficult experiment performed at breakneck speed. Two years later, also using NMR techniques, he and his group discovered an unexpected phase transition of He^3-He^4 solutions into dilute and concentrated phases at 0.8 K, a result that strongly influenced Heinz London's brilliant invention of the He^3-He^4 dilution refrigerator. During the same period he collaborated with Martin Block in developing a liquid helium bubble chamber for research in particle physics. Then in 1957 he performed, again, with great rapidity, another experimental *tour de force*. With M. J. Buckingham and F. Kellers he devised an apparatus to measure the specific heat of liquid He^4 near its super fluid transition temperature (2.16 K) with a temperature resolution of one microkelvin, three orders of more precise than had been previously deemed possible.

They established that the specific heat has extended logarithmic divergences on either side of the transition with a discontinuity at that temperature. This work drove future theoretical understanding of second order phase transitions, including the work on applying renormalization group theory to cooperative phenomena for which K. G. Wilson received the Nobel Prize in 1982.

In 1959 Bill came to Stanford and remained here almost without a break for the next thirty years, even during his sabbaticals. To appreciate his immense contributions to science and to Stanford one must understand something of both the changing nature of low temperature physics in the late 1950's and the opportunity Stanford presented to him to develop large-scale physics programs.

Seen in retrospect, the main thrust of low temperature physics up to 1960 was to uncover and interpret collective phenomena dominated by the laws of quantum mechanics. Bill's work on Fermi degeneracy in He^3 was a case in point. As theory progressed the field became less of an exploratory one, and when finally in 1957, Bardeen, Cooper and Schrieffer (BCS) provided a microscopic theory of superconductivity many people felt that low temperature physics was finished. Bill vigorously rejected that thought; yet with his acute nose for theory he did begin to seek techniques at his command. His bubble chamber work at Duke was the start, but Stanford provided the real turning point, even though his first triumph here was the discovery with Bascom Deaver of "quantized flux" --a major experiment done very quickly which demonstrated that in a ring of superconductor the roughly 10^{23} electron-pairs all move in concert governed by a single quantum mechanical wave function analogous to the one governing the motion of the single electron in a hydrogen atom.

Had Bill played safe, he might have won the Nobel Prize for the quantized flux experiment alone. Though afterwards seen as a proof of the BCS theory, its outcome was a considerable surprise, and it had wide implications. It was fundamental to Brian Josephson's discovery of quantum tunneling in superconductors, and therefore through J. Zimmerman and A. Silver's invention of the SQUID (Superconducting QUantum Interference Device) to a whole new technology of precision measurement. The role of SQUID magnetometers in Bill's later work will soon appear.

Since the 1930s experimental physics at Stanford has followed two complementary modes: (1) elegant "tabletop" research like Felix Bloch's measurement (1937) of the magnetic moment of the neutron and his joint invention with W.W. Hansen of nuclear magnetic resonance (1946), and (2) large-scale programs with an engineering dimension like David Webster's collaboration with the EE Department in 1935 on a high voltage x-ray machine and Hansen's other great post-war invention, the electron linear accelerator. Housed in a specially constructed laboratory (HEPL) on the Near West campus, Hansen's 180 ft (later-300 ft) long machine, completed in 1951 shortly after his death, yielded a flood of brilliant discoveries, including the first precise determinations of the shapes of atomic nuclei and protons. By 1959, however, when Bill arrived at Stanford, the laboratory was beginning to move in new directions. Plans for the two-mile long SLAC accelerator (the "Monster"), placed off-campus, were already far along; HEPL was in flux; and Bill found himself presented with a great--though only dimly visible--opportunity: the chance to participate in the next phase of development of a major research laboratory with the facilities and resources to execute large programs.

He began modestly. In a coffee room discussion, Burton Richter had remarked that an accelerator with superconducting resonant cavities--if it could be built--should have the important advantage of providing a continuous electron beam instead of the short pulses (0.1 % duty cycle) to which Hansen's accelerator had been limited. Bill's thesis research gave him mastery here, and in 1961 he encouraged a student (John Pierce) and a colleague in HEPL (Perry Wilson) to start work on the large, high Q (quality factor) superconducting cavities needed for such a machine. With Alan Schwettman's arrival at Stanford in 1962 the program took off; by 1969 the first 40 ft long superconducting accelerator (SCA) was operational, with a 400 ft 2 GeV machine in planning. All this was a huge research effort, requiring the development of cavities with Qs as high as 10^{11}, superfluid helium technology on an unprecedented scale, and a quiet revolution in generic accelerator design through far-reaching inventions in feedback stabilization, cavity loading and beam focusing. Throughout it Bill, while leaving details to others, maintained an impressive grasp of the technical issues at stake.

The SCA's later history was complex. For various reasons it proved impossible to establish at Stanford the national facility appropriate to the achievement; and after some confusion in the early 1980s, the NSF decided to set up a 4 GeV machine CEBAF (Continuous Electron Beam Accelerator Facility) in Virginia with J. D. Walecka of Stanford as its director. Meanwhile Bill's student John Madey had conceived of the idea of a continuously tunable Free Electron Laser (FEL) based on accelerator technology and in 1976 he, Todd Smith and Alan Schwettman successfully applied the 120 ft long Stanford SCA to make the first FEL. The Stanford SCA-FTL facility is now rapidly developing into a major center for chemical and medical research.

Most physicists would count one large-scale program as enough. Not Bill. In 1960, under stimulus from the then-chairman of the Physics department, Leonard Schiff, he entered the field of experimental relativity. General relativity--Einstein's theory of gravity--had long been recognized as at once the most profound and the least tested of all the theories of physics when Schiff in later 1959, two years after Sputnick and a few months after writing an article on the inadequacy of existing tests of Einstein's theory, rapidly conceived of two new ones based on observations with gyroscopes in Earth orbit. At first, the experiment seemed absurd. It required gyroscopes a million times better than the best inertial navigation instruments, but Schiff and Bill in consultation with Robert Cannon of the Aero-Astro department soon realized that a combination of a low temperature with the low acceleration environment of space might do it. A related idea due to George Pugh of the Pentagon, who independently proposed a similar experiment two months before Schiff, was to improve the gyro performance still further by compensating the residual drag on the spacecraft by means of translational thrusters referenced to an internal "drag-free proof mass."

After preliminary work by graduate students, Bill brought Francis Everitt to Stanford in 1962 and a year later NASA commenced funding a joint program between Physics and Aero-Astro, later transferred into HEPL. The development of Gravity Probe

B, as it is now called, has called for many new techniques in precision machining and metrology, ultrahigh vacuum, low magnetic fields, space cryogenics, telescope design, attitude and translational control and, above all, in gyroscope technology. The gyroscopes are quartz spheres, coated with superconductor, electrically suspended and spun up initially by gas jets. Deepest is the problem of reading out the direction of spin, which Schiff and Bill had worried about from the beginning and tried at least three approaches to. In 1963 a solution was conceived based on a phenomenon, the "London moment," that Bill's student Morris Bol had been studying for other reasons. As Fritz London, the father of quantized flux and Bill's theoretical mentor at Duke, had shown, a spinning superconductor will develop a magnetic moment aligned with its instantaneous spin axis--in effect a magnetic pointer. By observing this with a SQUID connected to a superconducting loop around the spinning sphere one obtains exquisitely precise gyro readout.

Reducing Gravity Probe B's new technologies to practice has taken the sustained effort of a dedicated research staff, with no fewer than 29 graduate students obtaining doctorates for research on a wide variety of physics and engineering topics. Currently there are 20 graduate and 9 undergraduate students from five Stanford departments, and altogether 15 students at six other universities. In 1985 NASA initiated development of the flight instrument through Stanford with Lockheed as aerospace subcontractor. Nothing points to the unusual scientific status of general relativity--or to the insight of Schiff and Bill--better than the fact that today thirty years after it was proposed, Gravity Probe B remains unique, providing both the deepest and the most precise tests of Einstein's theory so far suggested.

And Bill went further. In 1969 with Bill Hamilton, then an assistant professor at Stanford now a professor at Louisiana State University, he initiated a third large-scale project, the search for gravitational radiation by means of a low temperature "Weber bar" Ten years earlier Joseph Weber of the University of Maryland had developed an apparatus consisting of a 5 ton aluminum bar at room temperature, carefully isolated from external sources of vibration and instrumented to detect any "ringing " of the bar excited by gravitational radiation from cosmic sources. He obtained evidence for violent events at the center of our galaxy, but his results were not confirmed by other investigators. The two Bills set up a 2-ton bar at low temperature (2 K) in a spare 20-ft long dewar from the SCA, thus reducing thermal noise in the bar and allowing the use of a vibration detector based on SQUID-technology. Later Stanford and LSU set up a collaborative program with two 10-ton bars, each with an energy sensitivity approximately 5000 times higher than Weber's original bar. In a further development due to Peter Michelson, the bar will be cooled to a temperature of 10 mK to provide a further increase in sensitivity of about 10,000, allowing detection of the collapse of a star into a supernova anywhere in the Milky Way or other nearby galaxies.

One other larger program that Bill helped establish was John Lipa's orbital Lambda point experiment designed to probe the logarithmic discontinuity in the billionth of a degree, i.e. with a temperature resolution 10,000 times finer than in the Buckingham-Fairbank-Kellers experiment.

Each of the four programs just described has required, in contrast to Bill's earlier experiments, a massive technology investment taking many years. This slowing of the apparent productivity brought Bill heavy criticism, which was not lessened by the difficulties he encountered in two smaller programs, the quark search and an experiment to measure the force of gravity on positrons and electrons. The criticisms were ill judged. Behind the eventual spectacular success of Hansen's accelerator lay 17 arduous years in which Stanford was struggling to enter the world of high energy physics. That it did so in an original way instead of by carbon-copying what was being done elsewhere was a consequence of Hansen's technological flair, beginning with his invention of the rhumbatron (microwave cavity resonator) in 1933. Though Bill's scientific persona was very different from Hansen's, his inventive drive has helped make HEPL in the words of a recent Visiting Committee "a unique capability for technology development enabling new science which will not easily be done by other universities."

This is the place to say something about Bill as teacher. In the formal classroom setting he was, frankly, inept. When giving a colloquium, however, and still more in personal discussion he was magnificently inspiring--imaginative, resourceful and laden of with intuitive insights into physics. He was a master of the relevant order-of-magnitude calculation. If the best measure of him is the wide success of his graduate students, his gift with undergraduates should also be remembered. Among the many honors that came Bill's way the one that may have given him greatest pleasure was the last. At the 1989 Stanford commencement ceremonies, three months before his death, he was, much to his own surprise, made the first recipient of the Allan Cox award for achievement in inspiring undergraduate student research, largely for work done in his "retirement."

Scientists are sometimes regarded as bloodless, unemotional creatures. Bill was anything but that. His excitability was a by-word as, more importantly, was his optimism. He was fortunate in his family life. Jane, his wife, had the intelligence and strength of character to be an essential counterpoise as well as a definite person in her own right. She survives him together with three sons, Bill Jr., Bob and Richard, all well along in diverse careers. There are seven grandchildren. Both Bill and Jane came from religious backgrounds with missionary connections. Bill himself, encouraged by a prominent member of Ladera community church of which at the time of his death was Moderator. Though not a philosopher in any formal sense, Bill brought something of the same inquiring spirit to his faith as he did to his physics; one of his favorite quotations was the famous passage at the end of Albert Schweitzer's *Quest for the Historical Jesus* where Schweitzer moves beyond relentless intellectual inquiry into personal mystical experience. It is pleasant to record that Bill, who in his middle years was not infrequently blind to other people's reactions, became increasingly alert and aware as he grew older.

For Bill's 65th birthday, his students and colleagues organized a three-day conference in his honor attended by some 200 people. Flowing from this came a book *Near Zero: New Frontiers of Physics* (W. H. Freeman 1988: editors J. D. Fairbank, B. S. Deaver, C. W. F. Everitt, P. F. Michelson) containing 56 papers which reveal, in the words of the reviewer for *Nature*, the "astonishing scope and breadth" of Bill's interests. The title is a variant on the title of the Richtmeyer lecture that Bill had delivered to the American Physical Society in 1985; it expresses the theme that one important way of doing physics is by reducing the variables to zero. Exciting things happen near the absolute zero of temperature, but there are other "near zeros" also: very low pressure, very low magnetic field, very low gravity and so on. The idea of isolating systems from disturbance in order to perform ultra precise experiments is not Bill's alone, but the insight and enthusiasm he brought to it and the ways in which he combined it with large-scale physics made him a unique figure, on whose influence on physics and on Stanford University will be felt for many years to come.

Francis Everitt, Chairman
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