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VLADIMIR KOSMA ZWORYKIN
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A Biographical Memoir by

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BY JAN RAJCHMAN

TELEVISION AND ELECTRONICS PIONEER Vladimir K. Zworykin died at the Princeton Medical Center on July 29, 1982, one day short of his ninety-third birthday. His inventions of the tubes for image pickup and display provided the keys to television. He was a prolific inventor, an inspired leader of research, and one of the most illustrious innovators of the twentieth century.

Vladimir Zworykin was born in the town of Mourom in Russia, where his father owned and operated a fleet of steamships on the Oka River. Vladimir studied electrical engineering at the Petrograd Institute of Technology, the elite technical center in tsarist Russia, and graduated in 1912. There he worked with Professor Boris Rosing, who already in 1906 was interested in television and believed it would become practical through the use of cathode-ray tubes, rather than the mechanical systems that were being proposed at the time. Zworykin credits Professor Rosing for his decision to become a scientist and innovator and in particular for his interest in developing television by the new techniques that came to be known years later as electronics.

In 1912 Vladimir Zworykin entered the prestigious College de France in Paris, where he engaged in X-ray diffraction research under Professor Paul Langevin. His studies were interrupted in 1914 by the outbreak of World War I. He returned to Russia and served as an officer in the Russian Army Signal Corps, mostly in radio communications. The Bolshevik Revolution forced him to flee his native country. He made two trips around the world before settling in the United States in 1919. After some odd jobs, such as bookkeeping in the Russian Embassy, he finally joined the staff of Westinghouse Company in Pittsburgh in 1920. He became a U.S. citizen in 1924, the earliest date at which this was possible.

At Westinghouse he worked first on photocells, which at that time were not very sensitive and could not be made uniformly. He greatly improved the method of sensitization using alkali metals. In 1926 he obtained a Ph.D. from the University of Pittsburgh for his work in this field; he also coauthored a book on the subject. But his main interest was television. For years television systems had operated by scanning successive picture elements by means of rotating discs or drums that exposed one element at a time to a photosensitive cell. These systems were very cumbersome, but worse, they worked only for extremely bright scenes, as only the light from the element being scanned was used, while the enormously greater light from all other elements was wasted.

This last question intrigued Zworykin for some years and he finally invented a way to capture all the light from all elements of the frame, rather than just that from the element being scanned, and thereby provided for the first time a means for a viable television system. His idea was to have a vast number of tiny photocells, a “mosaic” of photoemitting spots, on an insulating sheet such as mica. Actually the spots were tiny islands of silver sensitized by the method he had developed for macroscopic photocells. When the scene to be transmitted is focused on the mosaic, each element loses electrons and thereby acquires a positive potential. An electron beam scans the mosaic, and each element when bombarded by electrons, is successively discharged. The amount of discharge, equal to the charge accumulated, is therefore proportional to the light intensity on the element. The discharge produces the video signal through capacitive coupling to a plate backing the mosaic of elements. Each element stores the charge being produced in accordance with its illumination during the frame time (i.e., between one scan and the next). Hence all light on all elements is used. The video signal in this storing system is what would be obtained in a nonstoring system multiplied by an enormous factor, in practice a large fraction of the number of picture elements. This is the principle of the justifiably famous “television eye” or pickup tube that Zworykin named the “iconoscope,” from the Greek *eikon* (image) and *skopon* (to watch).

Zworykin demonstrated the iconoscope in 1924 at Westinghouse, but the executives were not impressed. In 1929 he demonstrated an electronic television system that used an improved iconoscope and a refined all-vacuum cathode-ray tube as a viewing device. Still he could not convince Westinghouse to pursue television. As it happens, at that time a number of engineers, including Zworykin, were transferred from Westinghouse to RCA. In a first meeting with David Sarnoff, a fellow Russian immigrant who headed RCA, Zworykin was asked how much it would cost to perfect his television system, and he replied, “About $100,000.” This meeting became a legend. David Sarnoff was never tired of relating that RCA spent $50 million before ever earning a penny from television.

At RCA, Zworykin had at last the means to develop a practical television system. Sarnoff, who presided over the creation of radio broadcasting, was convinced that television would be even more beneficial to humanity than radio and, of course, more profitable. He had the vision and the power to insure ample support for a research group, headed by Zworykin, to develop the basic electronics for picking up the image and for a receiver to display it, as well as for other groups to develop the other parts needed to create an entire television system, such as transmitters, antennas, system standards, and studios. Sarnoff never wavered in his determination to bring television into being. Television owes much to the fortunate team of Zworykin, with his technical vision, and Sarnoff, with his business acumen.

Soon after arriving at RCA, Zworykin was able to assemble a remarkable group of collaborators. Under his leadership this group developed the basics of the all-electronic television as we know it today. The iconoscope for image pickup and the kinescope, as Zworykin termed the cathode-ray tube, for display were developed into practical devices. Both depended on the precise control of electron trajectories so that electron optics became a main preoccupation of the group. Electron guns were developed for producing intense beams focused to very small spots. The complex details of electron trajectories in the iconoscope were unraveled and improved tubes were made. Cathodoluminescent materials producing a much brighter white image replaced the willemite that produced relatively dim green images on the face of the original kinescopes. The group also developed the electronic circuits for the whole television system, for amplifying weak signals at frequencies higher than possible hitherto, for producing the desired number of scanning lines for synchronizing deflection of the beams at the transmitting and receiving ends, and so forth. Many ingenious circuits were invented that involved basic new principles. By 1936 RCA was able to field test the whole system.

In April 1939 Sarnoff announced at the New York World's Fair that RCA was establishing a regular TV broadcast service. In 1940 the present television standards were adopted,

By the mid-1930s Zworykin's laboratory with its mastery of electron optics and clever pulse circuitry had in effect created a new technology, that of electronics. Zworykin was already dreaming of new applications of this new tool. When I had the good fortune of joining his laboratory in January 1936, he asked me, "What do you want to work on?" and to my reply, "television," he said, "You are too late!" Of course he knew this was an exaggeration, as many problems remained in television, and his laboratory made many new fundamental contributions to that art. He asked me to work on photomultipliers and eventually together with a colleague I developed a type still made today. Zworykin's real interest, however, was the electron microscope.

Early models of electron microscopes had already shown a much higher resolution than is fundamentally possible with light microscopes. Unfortunately, these laboratory instruments were totally unsuited for practical use. Zworykin, intrigued by the idea of the electron microscope for years, realized the enormous impact on mankind's world that would result from the real capability to see objects orders of magnitude smaller than was possible hitherto. He set his laboratory to the task of developing a practical instrument, and he engaged a young Canadian, James Hillier, who had already participated in the building of an electron microscope in Toronto. Hillier succeeded in demonstrating a working model in a very short time, and eventually, with the collaboration of several members of Zworykin's laboratory, he developed a very practical instrument that RCA developed into a product. This achievement involved the design of highly symmetric magnetic lenses; extremely stable high-voltage supplies; foolproof means for inserting the specimen in high vacuum; and the solving of many other difficult problems. Eventually, the laboratory became a center for biologists eager to use the new instrument and to learn the new techniques it demanded, such as making very thin specimens. Shortly thereafter the scanning microscope was developed, which enabled the viewing of surfaces of solids, and it became of great interest to materials scientists such as metallurgists. The pioneer work of Zworykin's laboratory was taken up by many groups the world over and, indeed, had the impact he foresaw; the ability to probe at angstrom scale literally transformed biology and materials science. Such developments as modern semiconductor integrated circuits would have been impossible without electron microscopy.

During World War II, much of the electron optics expertise was devoted to infrared image tubes—the snooperscope and the sniperscope—that enabled one to see in the dark. Zworykin's invention of an airborne television system to guide radio-controlled torpedoes was brought to fruition and was used before V-J Day. On a more humanitarian side, which always appealed to Zworykin, a device to help the blind to read was developed, though fortunately there were fewer blind victims of the war than anticipated. The war days also brought the laboratory to pioneer in computers.

As early as 1939 the U.S. Army was concerned about the slowness in the control of antiaircraft guns, as the Nazis then had superiority in the air, and asked RCA whether electronics could remedy this inadequacy. Zworykin thought this quite possible and assigned me to the job. In a few months I was joined by others, including Arthur W. Vance. We developed analog-type computers that saw action in the war. More significantly for the future, we pioneered in digital techniques with such devices as registers, counters, arithmetic units, read-only memories, and input and output devices. It soon became apparent that digital techniques could be applied to a more critical problem: that of speeding up the computation of ballistic tables that were then laboriously obtained by many human operators aided only by slow mechanical calculators. The task was eventually undertaken by a group at the University of Pennsylvania and resulted in the first modern electronic computer, the ENIAC. Many of RCA's pioneer techniques were used in that project, in which we collaborated in its initial stages.

John von Neumann, who started the development of such a computer at the Institute for Advanced Studies in Princeton, New Jersey, championed the concept of the stored-program computer, which evolved in that project. He asked Zworykin's laboratory to undertake the development of the necessary memory, and the task fell on me. I developed the first truly digital random-access memory, the selectron tube, which was an integrated vacuum tube as it would be called today, and also independently conceived and developed the core memory. Novel magnetic devices and magnetic logic were also developed. Zworykin's early foresight in 1939 of the potential of electronic computers was a driving force behind the basic contributions that his laboratory was able to pioneer. In the mid-1940s, when there was a struggle to achieve any working models aimed at solving strictly mathematical problems, Zworykin had the vision of the universality of the computer and in particular its use for weather prediction, now a daily routine, and for medical diagnosis, now reaching a clinical stage.

Fundamental advances in television continued to be made in Zworykin's laboratory while the new fields of electron microscopy and computers were being pioneered. The shading due to uncontrollable redistribution of secondary electrons was a basic difficulty in the iconoscope. The orthicon conceived by Albert Rose in 1937 avoided that problem altogether by using low-velocity scanning. The image orthicon was developed shortly thereafter and provided a tube of great sensitivity. Another pickup tube, the vidicon, developed in 1950 by Paul Weimer, uses photoconductivity rather than photoemission. This tube has great sensitivity and can be made in a small size suitable for portable TV cameras. Storage tubes capable of retaining one frame of television opened a variety of other new applications. Many improvements in television circuits were made as well.

The kinescope was improved radically by covering the screen with a thin aluminum coating that permitted the use of very high voltages and also reflects the backlight otherwise wasted. This technique, with improved cathodoluminescent materials, provided tubes that could be viewed comfortably in ordinary ambient light and permitted the making of high-intensity tubes for projection.

The most spectacular advance, however, was the color cathode-ray tube. In the mid-1940s, mostly at Sarnoff's prompting, RCA embarked on the development of color television. Among the many very difficult problems was that of developing the color display itself, a problem that was assigned to a task force. Many viable solutions were proposed. Eventually, the shadow mask tube, developed in Zworykin's laboratory by Alfred Schroeder, proved to be the solution. Harold B. Law invented very clever methods for making the tube, whose principle had been proposed some years ago. Mass production of color cathode-ray tubes is one of the production marvels of our age. The perspective of years makes apparent the great significance of the cathode-ray tube, which owes so much to the early work of Zworykin at Westinghouse—with high-vacuum rather than gas-filled tubes and electrostatically rather than magnetically focused guns—and mostly due to his leadership at

RCA, leading to advances in guns, cathodoluminescent materials, and screen construction. Fast addressing and efficient light production are obtained with ease and elegance, and as it turned out, color is attained by a radical yet natural extension. Despite efforts of many over many years, no alternative display has challenged the cathode-ray tube, which remains the key to television and computer terminals—two hallmarks of our age.

In his constant quest for broader applications of electronics to serve people's needs, Zworykin saw medicine as a prime fertile field. Typically he was not content to generalize but brought to fruition a number of concrete devices, such as an ultraviolet translating microscope; a radio endosonde (a tiny radio transmitter that when swallowed, could signal any desired internal condition, such as temperature or acidity); a cane with an ultrasonic radar to help the blind avoid obstacles; a quick method for measuring white corpuscles in the blood; and an electronic personal card to keep medical records. He realized that regardless of the number of ingenious devices a brilliant electronic researcher like himself might propose, an intimate working relationship with biologists and medical practitioners was indispensable for finding and developing the many potential possibilities. He became a champion of interdisciplinary research. As its main mentor, he was the chairman of the Professional Group for Medical Electronics of the International Federation for Medical Electronics and Biological Engineering. Many young pioneers were inspired by these institutions and are responsible for the varied electronic instruments that help to give us healthier and longer lives.

Another Zworykin interest was the automatic driving of cars. Annoyed at the boredom of driving on turnpikes and its consequent dangers, he thought the traffic sufficiently orderly to be amenable to automation. In cooperation with

General Motors, several cars were equipped with sensing and control devices, and automatic driving was demonstrated on a test loop at RCA Laboratories in Princeton. While the idea turned out to be too difficult to apply broadly, it had a useful by-product: the sensing loops buried in highways at intersections to control traffic lights according to traffic needs.

Ever since Zworykin joined RCA he was able to assemble, nurture, and direct a group of remarkable collaborators, many of whom gained international reputations for their own contributions. This may well be due to Zworykin's uncanny intuition in discovering latent talent in young recruits and his leadership, which provided a unique and superb training unimaginable elsewhere. Overflowing with imaginative ideas, Zworykin radiated enthusiasm and utter confidence in the workability of his proposals even though they were often based on the latest scientific or technological advances and were still full of unknowns. Zworykin (or "the Doctor," as he was known in his group) had an intense personal interest in every project. In his frequent—almost daily—visits to every researcher, he invariably asked, "What's new?" and then grasped every detail, often embroidering on what he heard with realism and imagination. When difficulties were identified, he would often suggest a solution. In any case he urged one to continue, and I remember he used to say, "One cannot stumble on an idea unless one is running." As most great minds, in complex situations he was able to pinpoint the central issue and make it a clear and simple concept. There was also a great deal of healthy skepticism and plain common sense in the Doctor's reasoning. He used to say, "It stands to reason that . . . ," which turned out to be a sure guide in some of the esoteric terrain we were exploring. To most, particularly the young, he inspired great self-confidence. He took it for granted that everyone was as knowledgeable as he was in the latest advances of any matter he was discussing. As a result, most of us had no hesitation in plunging into new fields and often managed to make contributions in a short time. There is no doubt that the Doctor inspired us to do better than our best. One of his collaborators used to say that only the impossible is a little difficult. The Doctor was an inspiring leader who brought all his energies toward the accomplishment of his laboratory. He kept administrative matters to an absolute minimum—sometimes even below that level—and he was greatly impatient with bureaucracy.

Zworykin's visions for an innovation were not limited to a key invention however brilliant or elegant. They included all the elements necessary for bringing it to fruition. Above all, he envisaged the betterment for humanity that would result from his idea, and he expressed it in such a way that a businessperson could be convinced of its utility and profitability. The doubting technical person was soon convinced by a direct experiment proving the most critical point. Zworykin was not a gadgeteer but an innovator of great breadth who saw his ideas in the grand perspective of humankind's progress.

When Zworykin joined RCA in 1929, he became the director of the Electronic Research Laboratory in Camden, New Jersey, which later also included a group in Harrison, New Jersey. In 1942 both groups were united in Princeton when most RCA laboratories moved to the new facility at that location. In that year he also became an associate director of RCA Laboratories. In 1947 he was named vice-president and technical consultant to RCA and continued to direct his laboratory. On August 1, 1954, he retired and was named honorary vice-president of RCA. He was the only one ever to hold that distinction and continued as a consultant to RCA for many years.

After his formal retirement, he continued to be very active. He pursued his passionate interest in medical electronics. He directed a medical electronics center at the Rockefeller Institute in New York. As a visiting professor for the Center for Theoretical Studies and Molecular and Cellular Evolution at the University of Miami (Florida), he directed the work of doctoral candidates. In addition, he lectured in various countries on the merits of electronic medical research. He never ceased to have imaginative proposals in medical electronics and in such fields as nuclear power generation. At age 91 he still drove to his office at RCA Laboratories to read his large collection of scientific journals.

Zworykin was the author or coauthor of more than 100 technical papers as well as 5 technical books. Among these, the book on television (1940), in its second edition, and the book on electron optics and the electron microscope (1945) are classics still widely read today. Zworykin was granted, as inventor or coinventor, more than 120 U.S. patents.

Dr. Vladimir K. Zworykin was the recipient of 29 major awards:

1934 Morris Liebmann Memorial Prize of the Institute of Radio Engineers

1938 Honorary degree of doctor of science, Polytechnic Institute of Brooklyn

1939 Overseas Award from the British Institution of Electrical Engineers

Modern Pioneer Award from the National Association of Manufacturers

1941 Rumford Medal of the American Academy of Arts and Sciences

1945 War Department Certificate of Appreciation

1947 Navy Certificate of Commendation
The Howard N. Potts Medal of the Franklin Institute
1948 Presidential Certificate of Merit
Chevalier of the French Legion of Honor
1949 Lamme Medal of the American Institute of Electrical Engineers
Gold Medal of Achievement, Poor Richard Club
1951 Progress Medal Award of the Society of Motion Picture and Television Engineers
Medal of Honor, Institute of Radio Engineers
1952 Edison Medal, American Institute of Electrical Engineers
1954 Medaille d'Or, L'Union Française des Inventeurs
1959 Trasenster Medal, University of Liege
Christoforo Colombo Award
Order of Merit, Italian government
1960 Broadcast Pioneers Award
1963 Medical Electronics Medal, University of Liege
Albert Sauveur Award, American Society of Metals
1965 Faraday Medal of the British Institution of Electrical Engineers
1966 De Forest Audion Award
National Medal of Science
1967 Golden Plate Award of the American Academy of Achievement
1968 Founders Medal of the National Academy of Engineering
1977 Installation in National Inventors Hall of Fame
1980 Ring from Eduard Rhein Foundation

Among these awards the most prestigious is the National Medal of Science—the highest scientific honor in the United States—which President Lyndon Johnson presented to Zworykin in 1966 "for major contributions to the instruments of science, engineering, and television, and for his stimulation of the applications of engineering to medicine." Zworykin was proud and very appreciative of all the awards and honors that were bestowed on him. However, as he once told me, he valued most his first award, which he received while still relatively young and unknown: the Morris Liebmann Memorial Prize "for important technologies recognized within recent years" and given traditionally to young contributors. When the Institute of Electrical and Electronics Engineers established a Vladimir K. Zworykin Prize Award in 1950 "for the most important contributions to electronic television," Zworykin insisted on the stipulation that it be given to the young.

Vladimir K. Zworykin was a member of 21 scientific and technical societies, including The National Academy of Sciences, to which he was elected in 1943. In most of them he had a senior or highly honorary status. These are:

American Academy of Arts and Sciences (member)
American Association for the Advancement of Science (fellow)
American Institute of Physics (fellow)
American Philosophical Society (member)
British Institution of Radio Engineers (honorary member)
Electron Microscope Society of America (charter member)
Eta Kappa Nu Association (eminent member)
French Ministry of Education (officer of the academy)
Institute of Electrical and Electronics Engineers (life fellow)
National Academy of Engineering (member)
National Academy of Sciences (member)
New York Academy of Sciences (member)
Sigma Xi (member)
Société Française des Electroniciens et Radioélectriciens (honorary member)
Society of Motion Picture and Television Engineers (honorary member)
Society of Television Engineers (charter member)
Society of Television Pioneers (charter member)
Television Engineers of Japan (honorary member)
Television Society (England) (honorary fellow)

Dr. Zworykin was elected a member of the American Philosophical Society in 1948. The nominating paper says of him: "His invention of the iconoscope has been a major factor in the development of television. He has made notable contributions to the development of the electron microscope and to war applications of electron optics." He read two papers to the society: "An Electronic Reading Aid to the Blind" with L. R. Flory in 1946 and "Medical Electronics: Promise and Challenge" in 1960.

Beyond his passion for electronics, Zworykin had a wide interest in other sciences, particularly in biology, meteorology, and nuclear physics. He had an insatiable curiosity for all natural phenomena. He was also interested in philosophy and current affairs. He had many friends and acquaintances in these various fields, and he liked to have lengthy discussions with them. This was greatly facilitated by his warm and generous hospitality. He had frequent social gatherings and dinners that included the most knowledgeable and brilliant personalities in practically every endeavor, which were hosted by his charming wife, Katyusha. Zworykin was unusually robust and healthy until his last years. Believing that *mens sana in corpore sano* (a healthy mind in a healthy body), he engaged in physical activities that included swimming, which he indulged in at his home in Taunton Lakes, New Jersey, and later on Hibiscus Island at Miami, Florida. He was also a regular walker. Zworykin loved to hunt, perhaps because in his childhood he participated in rather wild hunting expeditions that he relished in recounting. He always had a dog to which he was highly devoted.

Vladimir K. Zworykin is survived by his second wife, the former Katherine Polevitzky whom he married in 1951; Elaine Zworykin Knudsen from Pasadena, California, a daughter from his first marriage; and seven grandchildren.

Zworykin was an innovator who changed our lives as profoundly as did Edison, Bell, and Marconi.

NOTE

Dr. Alexander B. Magoun and Dr. George Cody provided editorial assistance in preparing this memoir for publication.

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