8 From Pal'chinskii to Zworykin

Peter Akimovich Pal'chinskii (1875–1929)

Russia has produced some great engineers, who had to contend with political as well as technical difficulties. The first to be profiled here, Peter Akimovich Pal'chinskii, became one of the victims of Stalin's paranoia. His father, Akim Fedorovich Pal'chinskii, a land surveyor and estate appraiser, married twice and had five children by his first wife, Aleksandra, seven by his second, Olga. Born on 3 October 1875, Peter was the oldest son by Aleksandra. As a child, he lived with his mother in Kazan, along with his brother Fedor and his three sisters Anna, Sophia and Elena, while the children of the second marriage lived with their parents in Saratov, further down the Volga.

Peter was an energetic youth and a bright student. After the age of eight, when his parents were divorced, he saw his father rarely. He confided primarily in his mother, a member of a socially prominent but impecunious family. She greatly influenced his early education. Under her tutelage, he became a good pianist, despite his lack of natural talent for the instrument. She also encouraged him to use the extensive family library, where, as well as works of literature, Peter read books on popular science and history. He also learned French and German; later he added English and Italian.

In the autumn of 1893, Pal'chinskii entered the Mining Institute of St Petersburg, one of the elite engineering institutions of tsarist Russia. He took special pride in the fact that he had been admitted on his own merits, without any help from influential friends or high officials. During his student years, Pal'chinskii was seriously short of money; the government grant he received was quite inadequate to meet his living expenses. To supplement this, he worked as a labourer on railways, in factories and mines during summer vacations. In these occupations, he developed a sympathy for manual workers and for the need to improve their pay and working conditions.

Like many young educated Russians around the turn of the century, Pal'chinskii was attracted to radical political doctrines that promised a better society than the authoritarian and poverty-stricken tsarist economy. As a result he attracted the attention of the secret police, who kept him

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under almost constant surveillance from then on. Later he would be imprisoned five or six times, for political reasons. Compared with his siblings he was a monument of stability and prosperity; they often turned to him for help, psychological and financial. By his mid-20s he was supporting some of them.

On 23 November 1899, Pal′chinskii married Nina Aleksandrovna Bobrishcheva Pushkina, a member of a prominent liberal family of St Petersburg. They lived in the capital until he graduated from the Mining Institute the following year. As a student who had received a state stipend, however inadequate, he had to accept government assignments. In his case, he was directed to report on the reasons for the decline in coal production in the Ukrainian Don basin. The basin supplied over two-thirds of Russia′s coal in 1900, so that inadequate supplies of coal threatened the continued growth of industry. Pal′chinskii was struck by the fact that the mine owners knew and cared very little about the mine workers living or working conditions, which were appalling. He sent back a report to St Petersburg, being careful to avoid political comment. Its impact was slow to take effect but when its implications were realized, he was sent to Siberia in what amounted to administrative exile, although permitted to continue to work as a consultant to the mining industry.

After the revolution of 1905, which he supported, Pal′chinskii was arrested and, although not sent for trial, exiled under police supervision to Irkutsk, in Siberia, under emergency powers granted to the police during revolutionary turmoil. While he was there, Pal′chinskii continued to work as an engineer and became an expert consultant on mining operations. He was valued by mine owners for his ability to improve productivity and reconcile differences between management and labour. However, he objected to police supervision and, in August 1907, he escaped Siberia and returned to the Ukraine, where he roamed from city to city to elude the authorities. Early the next year, he managed to slip across the border and begin a new life in Western Europe.

Meanwhile, his wife moved back and forth between Irkutsk and St Petersburg, unsuccessfully trying to persuade the authorities to drop the criminal charges against her husband. She was active in workers′ education: she taught in special schools for workers, where she not only helped her pupils achieve literacy but taught them the political doctrines of reform and change. She was also concerned about the status of women and when, in 1909, she moved, with her mother, to join Pal′chinskii in Western Europe, she became active in the struggle for the emancipation of women and wrote articles about the women′s movement for a feminist journal in St Petersburg. She led an increasingly independent life, once she discovered that her husband was unfaithful to her.

By this time, Pal′chinskii had become a successful industrial consultant, insisting on viewing engineering projects within their political, social and economic contexts. For example, when he was asked to improve the productivity and efficiency of major seaports he reported that it was not simply a matter of providing cranes, rail spurs, deep sea channels, wharves and warehouses; it was also a matter of workers′ housing, schools, public transportation, medical care, recreational facilities, adequate pay and social insurance.

While Pal′chinskii seems to have adjusted well to life in Western Europe, he maintained his contacts in Russia. He wrote articles advising the tsarist government on how to improve the country′s industry. The country, he maintained, needed hard-headed engineers who evaluated problems in all their aspects. The obstacles to Russia′s industrial advancement, he believed, were not technological but political, social, legal and educational. For example, the legal system needed to be overhauled to bring order to land titles which, he wrote, were currently so disorganized that railways and mines were impossible to build because no-one knew who owned the land. He was particularly critical of engineering education, which he rightly believed was too academic. Pal'chinskii was convinced that Russia could sell coal and ores on the world market if it would only take the necessary political and economic steps.

In 1913, when his eight-year Siberian exile would have ended had he remained in Russia, he received a pardon from the tsarist government, and he and Nina returned to their native land. Three years later, he established an institute devoted to the rational use of the natural resources of Russia, which began publishing a journal about mining and industry. He served on the board of a mining company and established close connections with the business community. During the First World War, he was an advisor to the defence industry and served as deputy chairman of the government's War Industry Committee.

Pal'chinskii was a strong supporter of the provisional government that was established in Russia in February 1917 after the downfall of the monarchy. He held several official positions and supported the war effort against Germany. When the Bolsheviks took over the Winter Palace they imprisoned the top officials of the provisional government who had taken refuge there, including Pal'chinskii. Early the next year, he was released, then imprisoned again three months later, this time for nine months. At first Pal'chinskii, like the great majority of technical specialists in Russia immediately after the Revolution, had little sympathy with the Bolsheviks, whom they considered to be usurpers of power.

The Bolsheviks were committed to creating a command economy, to industrialization, and to science and technology. They seemed eager to benefit from the services of engineers and scientists. Pal'chinskii volunteered to help the new planning agencies that proliferated immediately after the Bolshevik victory and although dodging the police by staying away from Petrograd, as St Petersburg was now called, he consulted for a variety of Soviet offices and projects, including the building of the giant dam on the Dnieper river, the drafting of maps of population density and mineral deposits, and the construction of sea and river ports. He quickly became one of the best known engineers in Soviet Russia, serving as chairman of the Russian technical society and a member of the governing presidium of the all-Russian association of engineers. This did not prevent him being jailed for two months when he attempted to renew his youthful anarchist connections.

Pal'chinskii was eager to work with the Soviet authorities and the communist party in planning industry and increasing the strength of Russia but stoutly resisted the takeover by the party of any organization of which he was a member. His outspoken ways often got him into trouble. He was an independent, even stubborn, man who refused to give an evaluation of a project until he had studied all the relevant data. In 1926, he made a long tour of Soviet Central Asia, evaluating the potential of the oil and gas industry. With similar-minded colleagues, Pal'chinskii developed a programme for the industrialization of the Soviet Union, based on the exploitation of its enormous mineral riches. He thought that Soviet engineers, freed from capitalist employers, could have a greater influence on their nation than engineers anywhere else.

Although he favoured the general idea of central planning, Pal'chinskii considered that it should be combined with regional planning based on careful studies of local characteristics. He strongly criticized the belief of party leaders that the best facilities would always be the largest. He advocated foreign investment. Above all, he advocated humane engineering; concern for the needs of workers was not just an ethical principle but a requirement of efficient production. The Bolshevik leaders admired American methods of production: he did not.

When Stalin gained absolute control at the end of the 1920s, Pal'chinskii found that his ideas were considered dangerous. Stalin particularly mistrusted specialists, like himself, who were educated before the revolution and prepared to eliminate such people. In April 1928, a group of engineers was charged with sabotaging coal mines in the north Caucasus, some were acquitted, others sentenced to long terms of imprisonment or death. This was the start of a reign of terror among Soviet engineers. Early in 1929, Pal'chinskii was charged with treason and executed in secrecy without trial. His wife, Nina Aleksdrovna, was also arrested and disappeared into the camps.

Edith Clarke (1883–1959)

Until the end of the nineteenth century, and even beyond, there were all kinds of obstacles that made it difficult for a woman to become an engineer. Although women inventors were not uncommon, the doors of the profession were closed to women. The ability of Edith Clarke to survive in a male-dominated profession served as an inspiration to other women who aspired to a career in science and technology and helped to break down the barriers that had precluded women from pursuing such careers.

Born on 10 February 1883, she was one of nine children of John Ridgely Clarke, lawyer and farmer, and his wife Susan Dorsey Owings. Since her father died when she was seven and her mother five years later, an uncle

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became her guardian while her sister looked after her and the other children. The family farm, where she spent her childhood, was in Maryland. She began her school education there, and then was sent to a boarding school up to the age of 16, where she received a conventional education; mathematics was her strongest subject. When she left school, she had no thought of a career but enjoyed the old-fashioned social life that still existed in the farming community of rural Maryland, relatively untouched by the American Civil War.

At the age of 18, she came into her inheritance and decided to use it to resume her education, against the advice of family and friends. After some preparatory lessons from a tutor in classics, she passed the entrance examination for Vassar college, where she majored in mathematics and astronomy. After graduating with honours she spent three years as a schoolteacher before deciding not to make a career of it. In 1911, having recovered from a serious illness, she enrolled at the school of civil engineering of the University of Wisconsin, where she lived in a sorority house and enjoyed the social life that it provided. At the end of her first year, she took a vacation job with the American Telegraph and Telephone Company (AT&T) in New York City.

At this time, the only openings for women in engineering in America were as numerical analysts, then known as computers, assisting male

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research staff with the tedious and time-consuming calculations that their work entailed. In Clarke's case, this was related to the transmission and distribution of electrical power. She became so interested in this that, instead of returning to Madison as she had intended, she took a permanent position at AT&T, where she trained and supervised a workforce of numerical analysts. To improve her qualifications, she took a course in radio at Hunter College and several at Columbia University, in the night school.

Clarke then left AT&T to study full-time at MIT, first as a senior undergraduate and then as a graduate student. In 1918, she received a Master's degree in electrical engineering, the first woman to receive such a degree from this prestigious school. However she found that this did not lead to the engineering position she was determined to get. She fell back on work similar to what she had been doing before, but this time in the turbine division of General Electric at Schenectady, New York State. After two years more of human computing she decided to satisfy a yearning for travel by becoming professor of physics at the Constantinople Women's College, in Istanbul. On the way there, she travelled through France, Switzerland and Italy, and on the way back, Austria, Germany, the Netherlands and England. During college vacations, she explored Egypt and the interior of Turkey, which she found fascinating. The urge to travel never left her; on leave in 1928 she went to the Arctic.

In her absence, General Electric reassessed her worth and on her return she was appointed a fully fledged engineer, at last, in the central station engineering department. Her work mainly consisted in solving the special problems encountered in large electrical power systems. Using her mathematical knowledge, she developed devices and charts by which many laborious calculations were rendered unnecessary. She wrote up her work in 18 technical papers published by the professional societies; these papers greatly simplified the analysis of transmission line and power systems by the use of applied mathematics. She also published a book on the subject. She invented a voltage regulator for long-distance power lines, which prevented an excessive drop in the terminal voltage, thereby making it possible for such lines to transmit more current by maximizing voltage.

When she retired from General Electric in 1945, she returned first of all to her native Maryland but, after two years, took up a position at the University of Texas teaching electrical engineering, which she held until 1956. The last years of her life were spent in Maryland, where she grew up; she died on 29 October 1959. Five years earlier, she had received the Achievement Award of the Society of Women Engineers. She was the first professionally employed female electrical engineer in the United States as well as one of the first women engineers of any kind. She was one of the earliest women elected to the American Institute of Electrical Engineering.

Andrei Tupolev (1888–1972)

Pal'chinskii was perhaps the most prominent of the Soviet engineers who were victims of the Stalinist purge. Most were thrown into labour camps with little chance of survival. The luckier ones, such as the subject of this profile, were placed in special research and development prisons and assigned tasks by the government. In the special science and technology facilities, often located within large cities, living conditions were comparatively good and they had relative autonomy, yet they had no doubt that they were in prison and were forbidden any contact with the outside world. The system was hopelessly inefficient; for example, the engineers who designed the White Sea Canal were not allowed to inspect the terrain through which it passed. Arbitrary acts of terror, such as the sudden removal of a prisoner from the workshop, might happen at any moment. The obsessive secrecy that operated in Soviet society slowed the flow of information, halting

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projects at critical junctures. Stupid political operatives and secret police officers interfered with the engineers' work.

Despite this, remarkably good work was done, particularly in the most famous of these facilities, known as the Aviation Gulag, under the leadership of Andrei Tupolev. The aircraft designer was born on 10 November 1888 in Pustomazovo, a small town north of Moscow. His father, Nikolai Ivanovitch Tupolev, was a notary and subsistence farmer who had been an active radical during his student days at Moscow University. His mother, Anna Vasilyevna, née Lisitsina, had a facility for languages. An educated, middle-class family, they lived on a small farm near Tver (now Kalinin), the provincial capital, where their seven children were sent for their formal education. At the provincial gymnasium Andrei shone at mathematics and physics but not at other subjects. His handwriting was very bad but he read a great deal. He greatly valued his independence and personal freedom.

Against the advice of his father, his family and his school-friends, Tupolev decided to dedicate himself to the natural sciences. The first step was to pass the entrance examination for the Imperial Moscow Technical Institute, which offered the best technical training in Russia. There he came under the influence of Nikolai Zhukovsky, regarded as the father of Russian aviation, who was the first to provide a scientific explanation of the lifting force of an aerofoil, and to calculate its magnitude. He was inspired to pursue aeronautics, and gradually became Zhulovsky's assistant.

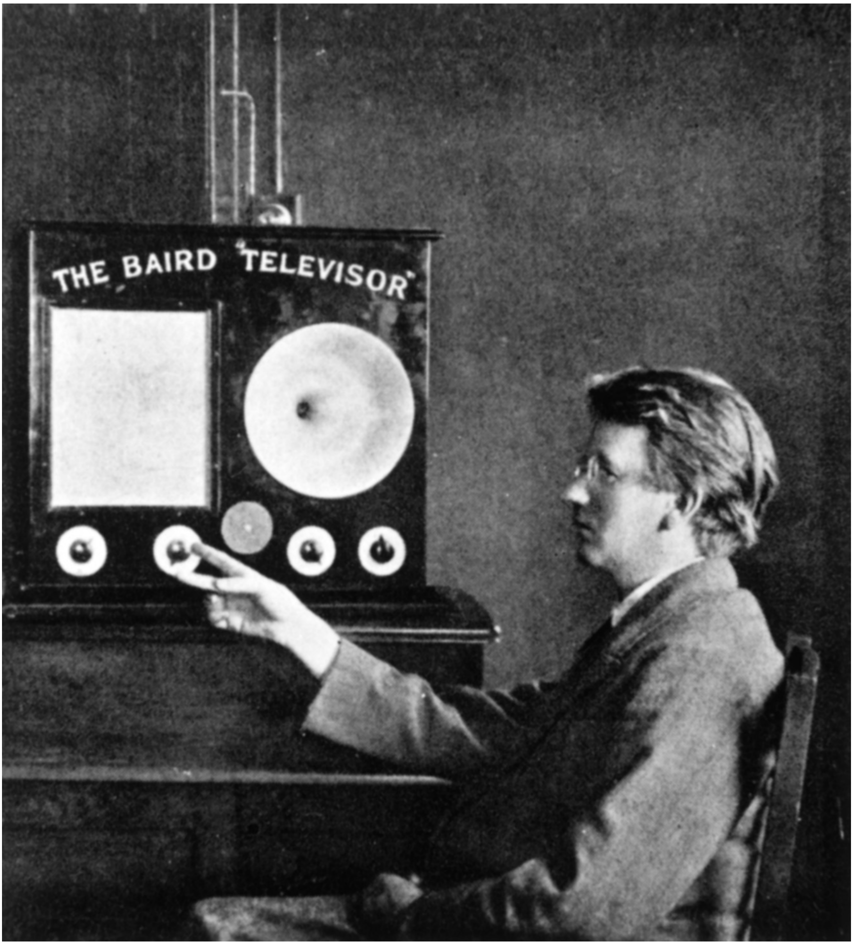
In 1911, there were student uprisings in Moscow, in which Tupolev was involved. He was arrested and imprisoned. While he was in prison, Tupolev's father died and he was released to return home and look after the family farm. In 1912, he was allowed to return to Moscow and resume his studies. Three years later, he was invited to be supervisor at a factory making flying boats, but Zhukovsky lured him back to join him in training the pilots of military aircraft. When the October Revolution was over, Zhukovsky was one of the older scientists who immediately pledged loyalty to the new Soviet government, and the rest of his team followed his example. Meanwhile, Tupolev gained his diploma with a thesis on the theory of the seaplane, which Zhukovsky praised highly. Encouraged by Zhukovsky, Tupolev then proposed the creation of a world-class Central Aerohydrodynamics Institute in Moscow, incorporating some of the existing facilities. The proposal was put before Lenin, who gave his approval, and the centre was established without delay. Tupolev was chosen to lead it, although his authoritative manner alarmed some of his colleagues. He was suffering from pulmonary tuberculosis, which obliged him to spend a year being treated in a good sanatorium. He returned much refreshed, determined to design his first real aeroplane.

In the purge of the engineers, Tupolev was not one of the first to be arrested and he was one of the lucky ones who were confined to the Aviation Gulag rather than sent to a labour camp. Living conditions in these prisons were tolerable but, even in this priority industry, engineers and scientists laboured under constraints that Western professionals rarely encountered. Tupolev was subject to interference by people who knew nothing about aircraft design. On one occasion he was summoned by Beria, the all-powerful head of the secret police. Beria wanted to know the specification of the dive-bomber he was working on. He then ordered Tupolev to increase the speed, the range and the load it could carry, and then dismissed him.

Under Tupolev's leadership more than 100 types of aircraft were designed, from light fighter planes to huge long-range passenger aircraft. To support the legitimacy of the régime, the Soviet government were promoting grandiose engineering projects of various kinds. As part of a campaign for technological display, one-of-a-kind aeroplanes were produced. The most remarkable of these was the huge *Maxim Gorky*, perhaps the largest plane in the world at the time, which was designed to break long-distance records. This appeared at international air shows until it crashed in 18 May 1935.

Tupolev was the first designer in the Soviet Union to use all-metal construction in both civil and military aircraft. In 1955, he built the first Russian jet passenger aeroplane, powered by engines imported from Britain. Yet his team of designers were forbidden the use of computers, which would have been invaluable to them. He was appointed a corresponding member and then, in 1953, a full member of the Soviet Academy of Sciences. He also received honours from other countries.

There were other remarkable aircraft designers in the Soviet Union, for example Ilyushin and Sikorsky. The latter, who designed flying boats and helicopters, was more original than Tupolev, whose team often copied designs that were developed in the West. American warplanes that crashed in Siberia were always carefully examined and their features copied. Tupolev spent the last years of his life working on the Tu-144, the Soviet Union's supersonic transport built to challenge the Anglo-French Concorde. When he died, on 23 December 1972, the Soviet press chronicled his many successes but did not mention that some of his aircraft were designed in the special prison workshop, whose existence was still a state secret.



John Logie Baird (1888–1946)

Scotland has given us Watt, Rennie and Bell; I now profile another Scot, one of the last of the private inventors. The youngest of the four children of the clever and fiercely independent Presbyterian minister John Baird, John Logie Baird was born at Helensburgh, then a small fashionable resort on the Firth of Clyde, on 13 August 1888. His capable mother, Jessie Morrison Inglis, came of a shipbuilding family in Glasgow; she gave birth to two sons and two daughters. In his boyhood, Baird, who was shy and short-sighted, had spent most of his leisure time either reading or constructing electrical gadgets. After a conventional school education, John took an engineering course at the Royal Technical College, now the University of Strathclyde,

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during which he gained some experience of monotonous hard factory work, and then went on to start a year at Glasgow University, which came to a premature end when the First World War broke out. Persistent ill health caused him to be rejected when he volunteered for military service and to resign from a post as a superintendent engineer of the Clyde Valley Electrical Power Company, which he held during the war years. Then he tried three small-scale commercial ventures in succession, with mixed success. The first involved selling under-socks in Glasgow, then preserves in Trinidad, to which he had gone for health reasons, and then assorted groceries in London. After a complete mental and physical breakdown in 1922, he retired to live in Hastings, a seaside resort in East Sussex. His mother died in 1924, providing him with a small legacy, which helped him embark on the work that was to make him famous.

Although handicapped by ill health and short of money Baird began trying to put his knowledge of electrical engineering to use. He was particularly interested in television, which after an experimental phase was awaiting someone to develop it into a commercial operating system. Efforts were under way in France and the United States but had not progressed very far since 1911, when the Scottish scientist Campbell-Swinton, in a public lecture given in London, had described the ways in which television might be achieved. There were two possible methods, Campbell-Swinton explained; one used mechanical scanning, the other electronic. He concluded that only a large American firm, such as Westinghouse Electric, would have the resources to make a viable system. Baird chose the mechanical method and after two years had contrived a primitive apparatus, capable of transmitting a flickering image over a distance of a few feet. Having conveyed his equipment to two attic rooms in London, he gave the first official demonstration of true television in January 1926. Fear of industrial espionage meant that he was extremely secretive about his process.

In December the same year, Baird showed his 'noctovisor', enabling images to be transmitted from a dark room by means of infrared rays. He also patented a form of fibre optics. In 1927, Baird demonstrated television by telephone line between London and Glasgow and the next year between London and New York, and also to a ship in the mid-Atlantic. He also pioneered television in natural colour, and stereoscopic and big screen television; and, in 1929, ultrashortwave transmission. He formed the Baird Television Development Company, which was allocated wavelengths allowing it to experiment with the first true television programmes. Synchronization of sound and vision was achieved a few months later, and half-hour

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programmes were transmitted regularly on five mornings a week. Because the receivers were very expensive, the programmes were generally shown in public places. The showing of the Derby horse race at Epsom in 1931 attracted a great deal of publicity. Foreign visitors were amazed at the uniformly high quality of the pictures, the regularly scheduled programmes, and the coverage of outside broadcasts, but the British Broadcasting Corporation, which enjoyed a national monopoly of radio transmissions in Britain, displayed a generally unhelpful attitude. Baird's company was also fiercely opposed by Marconi's firm, which was allied to powerful American interests, notably the Radio Corporation of American and its affiliates. As we shall see in the next profile, they had developed a competing system of television, known in Britain as the Marconi-EMI system.

Baird was now 40, and his affairs were beginning to prosper. He moved to a comfortable villa on Box Hill, in the country south of London. He had always received favourable press coverage in the United States and so he went there in 1931 to negotiate for a wavelength with the authorities and launch his system. He had already established links with France, Germany and other European countries. Although his visit was not a success in business terms, while in America he married Margaret, gifted daughter of the late Henry Albu, a manager at the De Beers diamond mine at Kimberley, who had come to London to study music and aspired to become a concert pianist. After their return to England he installed her first in his villa on top of Box Hill, then more suitably in another house in Primrose Hill, close to the centre of London. Then, without consulting her, in 1933 they moved again, to a very large Georgian house in Sydenham, convenient for his research activities at the nearby Crystal Palace, the huge cast-iron and glass edifice originally built in Hyde Park but subsequently moved to this part of south London. In 1935, a major fire at the Crystal Palace destroyed valuable equipment and records of his research.

Baird was waiting for the report of a departmental committee on which of the rival television systems were to be adopted as standard in the United Kingdom. Eventually, the committee came out in favour of the Marconi-EMI system. For two years, Baird's company operated side by side with its rival, which had the resources of the Marconi organization behind it. In September 1937, Baird's system, working on 240 lines, mechanically scanned, gave place finally to the electrically scanned 405 line system promoted by Marconi-EMI. Baird struggled on, but he had no income and had to live on his limited capital; his shares in the company were worthless. He had two children; a daughter Diana, born in 1932, and a son, Malcolm, born in 1935. When the Second World War began, the family moved to the small seaside resort of Bude, on the north coast of Cornwall, although most of the time Baird himself continued to live and work at Sydenham.

Baird continued to work on television, but using the technology based on the cathode ray tube rather than the scanning disc. He was also interested in the technology we know as radar, which was to play a vital rôle in the war and afterwards. Although the applications were very different, the two technologies were virtually identical. While Britain pioneered the development of radar, the United States, France, Germany and the Netherlands were not far behind. Although Baird offered his services to the War Office, he was not called upon in any significant way. As the war drew to a close, his health was failing, and his wife had moved the family to Bexhill, close to Hastings. In February 1946, he suffered a stroke and he died in the early hours of 14 June. He was survived by his wife and their two children: Malcolm, who became professor of chemical engineering at McMaster University, in Canada, and Diana, who was a schoolteacher before marriage.

It cannot be denied that Baird had defects of character. He could be charming in company but he made enemies, one of whom was Reith of the BBC. He did not have much business sense and did not realize the need to improve on his most promising inventions, rather than keep making new ones. His wife, in her memoir of him, recalled that his sense of humour could be cruel and wounding. What she found depressing was his lack of enthusiasm for anything except television. He had plenty of acquaintances, plenty of business contacts, but no real friends. One of his associates commented:

> My most vivid impression was his enormous toughness, underneath the quiet, dreamlike quality of his external personality. He would stop at nothing to achieve his end, which was always the furtherance of television. He had an unmatchable sense of humour and great courage but I shall remember his resilience till I die.

Another described him as having the vision of a prophet, the happy confidence of a child and the business sagacity of a sheepdog. Yet another described him as an eccentric visionary with a passion for gadgetry, a modest man of inflexible resolve, ready to try anything but constantly in financial trouble. Quiet, humorous, always approachable, he never made extravagant claims.

Vladimir Kosma Zworykin (1889–1982)

After the October Revolution, some of the leading Russian engineers emigrated to the United States. One of them was Vladimir Kosma Zworykin, Baird's rival in the development of television. He was born on 30 July 1889 in the ancient Russian town of Murom, the youngest of seven surviving children, five daughters and two sons, of Kosma and Elena Zworykin. His father was a local businessman, whose mansion at the centre of the prosperous town, only 240 kilometres from Moscow, was where the children grew up. After graduating with honours at the local Realschule, he enrolled at the St Petersburg Institute of Technology to study physics. In the summer vacations, he was sent to gain some practical experience of working in industry, at first on the railway, then at a steel plant and finally at a power station. During his third year, he was one of a group of students who were sent to Germany, Belgium, France and England to familiarize themselves with European industry.

The professor in charge of the physics laboratory, Boris Rozing, was working on electrical telescopy and 'seeing at a distance', an early form of television. Zworykin became his assistant. There were also French and German scientists working in this area. To remedy his lack of knowledge of theoretical physics, which was undergoing a revolution at that time, Rozing arranged for Zworykin to study first with the leading French physicist, Paul Langevin, in Paris and then at the Charlottenburg Institute of Technology in Berlin. Unfortunately, Germany declared war on Russia soon after Zworykin arrived there and it was only with difficulty that he succeeded in returning to St Petersburg. He was promptly drafted into the army, where he set up a radio station and spent most of his time coding and decoding radiograms.

In April 1816, Zworykin married a student of dentistry named Tatiana Vasilieff after a brief courtship, but the marriage was not a success. At this stage, he had risen to the rank of lieutenant and was based in St Petersburg, until he was sent to a small desert town named Turgai on the border with Chinese Turkestan, where the army was trying to suppress a rebellion. When this was over, he was moved to Moscow, where revolution was in the air, and then back to St Petersburg, just renamed Petrograd, which was in a state of turmoil. Eventually, his unit was sent to a place on the Dnieper river opposite Kiev, which was in German hands, and Tatiana joined him there.

After Zworykin was demobilized they went to Moscow but conditions were so chaotic that he decided to leave the country. There was no time to lose, as he was liable to be arrested as a former tsarist army officer. He travelled first to Archangel, where he arrived in August 1918 and managed to get an American visa. Onward travel was still difficult but in November, when the armistice had been signed, he was able to secure a passage to the United States via London. After a few months in New York, he decided to return to Russia, this time across the Pacific, but conditions in Russia were still so unsettled that he only stayed long enough to collect his belongings before going back to the United States, where he was to settle permanently. All this time, he had been trying to locate his wife. Eventually, he found that she was living with friends in Berlin and a few months later they were reunited. Before long she was expecting their first child.

Although Zworykin had difficulty in communicating verbally in English he could read and write the language well enough. The Westinghouse Electric Company had a policy of hiring recent Russian émigré scientists who had come to the United States after the October revolution. A team of their engineers was working on the development of a new amplifying tube to be used in receivers of broadcasts from the Westinghouse radio station in east Pittsburgh. Zworykin joined the team, but after a successful first year he was shocked to find that his pay was being reduced. He resigned and went to work for a small company in Kansas City at twice his previous salary. He liked it there, but soon the laboratory was shut down after he convinced the owners the process they were trying to develop would never work. Then Westinghouse came back with the offer of a job under much better conditions than before. This gave Zworykin the opportunity to work on what he most wanted, an all-electric cathode ray television. The difficulty was with the camera tube, not with the receiver.

When Zworykin had found a way of dealing with this, sometime in 1925, he demonstrated a working model of his design to the senior management of Westinghouse, who were not impressed. As a result, the television project was taken away from him and given to a believer in mechanical scanning. By 1928, Zworykin was working on three different projects for Westinghouse, a new, highly sensitive, photoelectric cell, a new method for recording sound on cinema film, and a new telefax transmitter and receiver. In 1928, he was sent to Europe, where he saw that in television the Europeans were ahead of the Americans. When he reported this to Westinghouse, he was given what he most wanted, carte blanche to produce a viable commercial system of television.

In 1933, Zworykin was back in Europe and this time he made an official visit to Moscow, the first time he had returned to his homeland since 1919. The next year he went again for six weeks to give a series of lectures on television. After several more visits, the Soviet trading corporation placed a large order with Westinghouse for radio and television equipment. In England, he heard that a public television station at Alexandra Palace would soon be functioning, although the receivers were costly. A comparable service was not started in the United States until 1939. A few months later, on the outbreak of war, the British transmission was shut down, and the American followed suit after the United States came into the war.

Zworykin had already taken out American citizenship at the first opportunity. In 1943, he had been elected to the National Academy of Sciences, shortly after moving to Princeton. In 1944, the Federal Bureau of Investigation became interested in his activities, and he was placed under surveillance. He was denied permission to leave the country, but in 1946 his file was closed and Zworykin was free to travel again. Doubts about his loyalties resurfaced in 1954, towards the end of the McCarthy red-baiting era, but an investigation failed to disclose any espionage activities or membership of the Communist party. In 1967, Zworykin was presented with the National Medal of Honour by President Nixon, 'for major contributions to the instruments of science, engineering and television, and for his stimulation of the application of engineering to medicine.'

Zworykin still spoke English with a heavy Russian accent. He had a wide range of non-technical interests and displayed the social graces typical of the well-to-do in tsarist Russia. Among his many friends were writers, artists, musicians and philosophers, especially Russian émigrés. In 1951, he divorced his first wife, after 20 years of separation, and married Katherine Polevitsky, a widow who was a neighbour at his summer home at Taunton Lakes, New Jersey. He died in Princeton on 29 July 1982, just one day short of his 93rd birthday.