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The Invention of Television

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Television is the electrical transmission and reception of transient visual images, and is probably the first invention by committee, in the sense of resulting from the effort of hundreds of individuals widely separated in time and space, all prompted by the urge to produce a system of 'seeing over the horizon'.

Whether with tom-toms, smoke signals, or semaphore, human beings have always tried to communicate with neighbours beyond the horizon. The desire has been a matter of commerce, curiosity, or most importantly, warfare. Written messages were sent by ships, horses, birds, and shank's mare. But these were slow, cumbersome, and subject to the whims of weather, terrain, or the endurance of animals. The first steps towards *instant* communications were really taken by seventeenth- and eighteenth-century scientists such as Luigi Galvani, Allesandro Volta, Hans C. Oersted, André Ampère, George S. Ohm, Michael Faraday, and James Clerk Maxwell, who found that electrical currents could flow through certain materials as well as interact with magnetic forces. The first practical solution came in 1843 when Samuel F. B. Morse developed his 'telegraph' (distant-record) machine. This was a means of communication by which the letters of the alphabet were converted into electrical equivalents (the Morse code) that could be either recorded on paper tape or transcribed by trained operators. Since the code was transmitted over wires at almost the speed of light, it soon became the quickest means of point-to-point communication. Before long, electric wires were strung on poles connecting most of the major cities. These same wires were also run under the lakes and oceans of the world.

About the same time, other inventors were seeking means to transmit more than dots and dashes over these same wires. One of the earliest was Alexander Bain in 1843. In Bain's device, alphabetical letters were formed by a number of lines, each being connected by a separate wire. A comb-like probe containing insulated metal points scanned the type to be transmitted. At the receiver, a similar metallic comb reproduced the letters on chemically treated paper.

The Transmission of Symbols

A more advanced device was that of Frederick C. Bakewell in 1847 for transmitting handwriting, which used a metal foil inscribed with insulating ink wrapped around a cylinder. As the cylinder was rotated by clockwork, a metal stylus was used to glide over the foil. A similar device at the receiver provided means to shift the pens and to keep the devices in synchronism.

Another interesting device by Giovanni Caselli in 1855 used the actions of pendulums. At the transmitter a stylus connected by a lever to a pendulum would physically trace the object to be transmitted and would be electrically turned 'on' or 'off' as it scanned parts of the message. At the receiver, another stylus moved by a pendulum would be turned 'on' or 'off' in sequence and would create a replica (on some form of recording medium) of the image being transmitted.

The scanning of simple figures was quite important as it involved two of the foundations of the later system of instant visual transmission. The first was sequential scanning (dissecting) of the picture. The second was a means to synchronize (keep in step) the transmitter with the receiver. These primitive machines, while quite cumbersome, did work, and though of limited value at the time led to more important devices in the future. These systems were then called 'copy-telegraphs'. Today they are known as photo-telegraphy or facsimile (fax).

The next step was the transmission of audio over these same wires. In 1876 the telephone pioneer Alexander Graham Bell transmitted the sound of a voice by means of an electric wire and thus three means of instant communications came into existence, the telegraph, the copy-telegraph, and the telephone, and the time was ripe for the introduction of a visual transmission system.

In 1873, Willoughby Smith with Joseph May, an electrician working on the Atlantic Telegraph cable, reported that selenium rods used for continuity checks changed their resistance (conductivity) when exposed to varying light. This ability of certain metals to react to changes of light intensity was widely reported and manifested itself in plans for devices that would transmit pictures.

By the end of 1878, the combination of Bell's telephone and Edison's invention of the phonograph (1877) combined with progress being made in photography led the magazine *Punch* to print a cartoon of a new Edison invention the 'telephonoscope'. Here was depicted a two-way visual system on a wide screen depicting parents in London speaking with their daughter in Ceylon by means of an 'electric camera obscura' and telephone. Edison did not apply for a patent on a motion picture system until 1889. It is ironic that *Punch* should have Edison invent an 'electric camera' before he invented the motion picture camera. But there were many schemes for visual communication gadgets at the time.

In 1880 Maurice LeBlanc detailed an ingenious method of transmitting moving images over an electrical wire. He described a scanning device (at both sender and receiver) consisting of two vibrating mirrors working together at two different rates of speed. The light from the image would be sent to a transducer (such as a selenium or Becquerel thermo-electric cell) to be converted into electricity. At the receiver, he proposed that two pieces of mica (as a shutter) would be moved according to the signal to control the light from a lamp. He suggested that because of persistence of vision, it would be possible to build up a likeness of the transmitted image. LeBlanc's 1880 fundamental paper contained in fact all the elements for a practical visual transmission system.

It was not long before the first practical solution appeared. In 1884, Paul Nipkow applied for a German patent for an *Elektrisches Teleskop*. The heart of Nipkow's patent was a revolving apertured disc. The disc had twenty-four holes in a spiral near the outer rim. Nipkow proposed that light from the subject would pass through the perforated disc on to a selenium cell. At the receiver, a similar perforated disc would be illuminated by a polarized light source. With both discs rotating at a constant speed, it was intended that an image would be built up and viewed through an eyepiece. This patent had all the elements (synchronization was presumed by a constant rotating speed) for a successful visual transmission system, and was soon followed by other ideas based on a rotating disc, including revolving mirror drums (Lazare Weiller), lensed discs (Louis Brillouin), and perforated bands and strips (Paul Ribbe).

Experiments with electrical discharges inside evacuated glass tubes started with the work of Heinrich Geissler and Julius Plücker in 1858. Plücker designed a sealed glass tube filled with gas, with an electrode inserted at each end. When a certain voltage was applied to the electrodes, the gas in the tube ionized (incandesced), current flowed, and the tube glowed with a characteristic colour. This became known as a 'Geissler' tube.

Other scientists soon started to experiment with these tubes. Wilhelm Hittorf discovered in 1869 that a solid body would cast a shadow on the walls of the tube. In 1876 Eugen Goldstein concluded that the radiation came from the cathode and called them 'cathode rays'. William Crooks showed that the rays were projected at high velocities by electric forces near the surface of the cathode. Jean Perrin showed that the charge was negative in 1895. In 1897, J. J. Thompson proved that they could be deflected by an electrostatic field, and finally in 1897 Karl Ferdinand Braun developed the cold cathode ray tube that bears his name.

The Cathode Ray Tube

An International Electricity Congress was held in conjunction with the 1900 Paris Exhibition. On 25 August 1900 a paper was read by one Constantin Perskyi entitled 'Television', in which he described an apparatus based on the magnetic properties of selenium. This new term slowly supplanted the older names such as the 'telephot' or 'telectroscope' to describe the newly born art and science of 'seeing at a distance'.

The various theories of transmitting pictures by wire had created much controversy in the scientific community. A letter to *Nature* by Shelford Bidwell in June 1908, reviewing the various methods being proposed, concluded that, 'It was improbable for any system of television to view images hundreds of miles apart.'

This letter was answered by Alan Archibald Campbell Swinton who wrote that 'distant electric vision' was possible with tubes using cathode rays (at both the transmitter and receiver) properly synchronized and with the necessary means for converting light to electricity and back to light. This was the first mention in the literature of an all-electric television system.

Unknown to Campbell Swinton, both Professor Boris Rozing in Russia and Dr Max Dieckmann in Germany were also experimenting with cathode ray tubes as receivers. However, no one before had suggested the use of a cathode ray tube as an image transmitter.

Just one year later, in 1909, three different television systems were actually built and operated. The first (in order of publication) was that of Dr Max Dieckmann. His equipment consisted of a unique device at the transmitter with a cold cathode Braun tube for a receiver. The transmitter consisted of a rotating wheel that was fitted with twenty wire brushes. (It had no photo-cells or other light-transducing means.) The brushes actually touched the image to be transmitted, very much like the early devices of Bain and Caselli. At the receiver, the Braun tube with four deflecting magnets scanned a picture approximately 1.25 inches square. The electron beam was turned 'on' or 'off' as the rotating brushes touched the object, thus creating a picture on the screen. This was not a *true* television system as the transmitter was actually a form of telegraph sender rather than a transducer of light to electricity.

The second system was that of Ernst Ruhmer. It consisted of a mosaic of twenty-five selenium cells in rows of five each. Each cell when exposed to light was connected to a relay, which sent an alternating current over a line to a receiver. Here, there was a similar mosaic consisting of twenty-five incandescent lamps. At the receiver, there was one relay for each cell that would operate its own incandescent lamp. Only simple geometric figures could be shown. As it was a multi-wire (simultaneous) device, it was not a true television system.

The third was a quite different television device built and demonstrated by Georges Rignoux and Professor A. Fournier in 1909. The transmitting screen consisted of a bank of selenium cells, each connected to a separate relay. The relays were connected in sequence by a rotating commutator. As each relay was connected in turn to the commutator, it sent its signal through a single wire to a receiver. Here the signals were sent to a light valve (modulator) based on the Faraday effect of polarized light. (The light beam was aligned by a Nicol prism and then sent through a tube filled with bisulphate of carbon around which was wrapped a coil of wire.) As the current varied in the coil (due to scanning) the polarized light was 'rotated' in such a manner as to vary the amount of light passing through the tube. This modulated light was then sent through a set of rotating mirrors where the image was reconstituted on a screen. There were means provided to synchronize the receiver with the transmitter. This was a 'real' television system, the first on record as having been built and operated.

Rozing, Zworykin, and Swinton

Important work on a cathode ray system was also being conducted by Professor Boris Rozing of the Technological Institute of St Petersburg. In 1907, Rozing applied for a Russian patent proposing a television system using a cathode ray tube as a receiver. The transmitter used two mirror drums for scanning and dissecting the image. The mirror drums moved magnetic coils as they rotated, thus creating scanning currents for deflecting the electron beam at the receiving tube.

At the receiver, the currents were sent to a cold cathode ray (Braun) tube which had its beam deflected by either moving coils or plates. The beam itself was modulated (varied) in brightness by physically moving up or down between two small metal plates in the neck of the tube in accordance with the incoming signal. (At the time, there was no known method for modulating an electron beam, so this was quite ingenious.) The electron beam itself was deflected by coils using currents generated at the transmitter. This patent was second only in importance to that of Nipkow's of 1884.

It is claimed that Rozing had started working on such a device as early as 1904, and was actually building working apparatus. In 1908, he had carried out experiments with actual models and attempted to transmit simple images (slides, drawings, hands, etc.). In May 1911, he successfully demonstrated a distinct image consisting of four luminous bands to his colleagues at the Technological Institute of St Petersburg. For this he received a gold medal from the Russian Technological Society.

Professor Rozing built all of his apparatus (except for the cold cathode Braun tube that he purchased from a scientific laboratory in Berlin), including his own photoelectric cells. For this he had the assistance of a young engineering student by name of Vladimir Kosma Zworykin. Zworykin had been chosen by Rozing in 1911 to help him with his laboratory experiments as a result of his great interest in physics. Rozing introduced him to the new art of 'electrical telescopy', something Zworykin had never heard of before. Zworykin worked part time in Rozing's laboratory until his graduation in 1912. This was the beginning of young Zworykin's interest in cathode ray television.

In November 1911, A. A. Campbell Swinton became president of the Röntgen Society of London. He gave an inaugural speech entitled 'Distant Electric Vision'. He elaborated on his article of 1908 in *Nature* magazine and described a complete electric television system using cathode ray tubes for both transmitter and receiver. He admitted that his plan was an idea only, had never been constructed, and that it would take a great deal of experimentation and modification to be practical. However, the Röntgen Society was quite small and its journal's circulation quite limited, so his ideas were not widespread at the time.

With the start of the World War in Europe in 1914 interest in the new art of television diminished. But the war brought great advances in communications both by wire and radio. The end of the war found the (British) Marconi Wireless Telegraph Company in virtual control of long-distance communications between the United States and Europe. The Marconi Wireless Telegraph Company then tried to buy from the General Electric Company the Alexanderson radio alternator, which made these long-distance communications possible. This was brought to the attention of the US Navy Department, which objected strenuously. General Electric was told to reject the order. It was decided to buy out the American Marconi Company and replace it with a new American company to be formed by General Electric. This new company was to be called the Radio Corporation of America (RCA). A patent pool was formed and on 17 October 1919, RCA was incorporated. On 1 July 1920, an agreement was also reached with the American Telephone and Telegraph Company and its subsidiary the Western Electric Company, which were together known as the Telephone Group. This alliance did not last: two years later AT&T sold its RCA stock but remained in the patent pool.

Commercial radio broadcasting began in the United States in 1920 when Westinghouse Electric started operating radio station KDKA. This was so successful that on 30 June 1921, Westinghouse Electric was allowed to join the GE/RCA/AT&T consortium. KDKA was soon joined by hundreds of radio stations all over the United States.

Interest in television was also revived after the war. In August of 1921, the first patent for an electric camera tube was applied for by one Edvard Gustav-Schoultz of Paris. There is no record of this tube being built and no more was heard of the inventor.

In the United States, Charles Francis Jenkins had turned his attention from the motion picture (he had invented the first motion picture projector with Thomas Armat in 1895) to that of telephotography and television. In 1922 Jenkins applied for his first patent for transmitting pictures by wireless. It used a unique scanning device, 'prismatic rings'. These were glass prisms with varying surfaces that would bend the light from an object as they rotated. At the transmitter, the two prisms operating together would scan the scene (at two rates of speed) to analyse it and send the light to a photoelectric cell. At the receiver, two similar prisms reconstructed the image using a light valve of the Faraday type proposed by Rignoux. This light was projected on a type of fluorescent or phosphorescent screen.

Jenkins was assisted by both the General Electric Company and Westinghouse. He was the first experimenter to use the special neon light valve developed by D. McFarlan Moore of the General Electric Company in his receiver.

In December 1923, Jenkins demonstrated his television apparatus separately to Hugo Gernsback, editor of *Radio News*, and Watson Davis, editor of *Popular Radio*. They claimed that the apparatus was crude and cumbersome. Gone were the prismatic rings, prismed, mirrored discs being substituted. Jenkins was using the sensitive Theodore Case Thalofide photoelectric cell at the transmitter and the General Electric Moore glow-lamp at the receiver. Both editors claimed that they could put small objects in the path of the transmitter and see them at the receiver. The signals were sent by a small radio transmitter across the laboratory. As far as can be determined, these were the first witnessed demonstrations of radio-television ever reported.

The Struggles of John Logie Baird

About this time in 1923, a young experimenter, John Logie Baird, started what was to be his life's work on television in London. With the financial assistance of Wilfred E. L. Day he was set up in a laboratory at 22 Frith Street, Soho. He filed for his first television patent in July 1923. It included a Nipkow disc at the transmitter with a bank of lights arranged to form an image on a screen at the receiver. This was the first of a multitude of patents taken out by Baird in his quest for a practical television system.

Another application for a camera tube was made on 29 December 1923, by Vladimir K. Zworykin of the Westinghouse Electric Company. It was part of a patent for an all electric television system. The camera tube had an aluminium foil plate covered with a thin layer of potassium hydride. At the receiver, a Braun tube would reconstruct the image on a fluorescent screen. While this patent had many similarities to the original Campbell Swinton plan of 1911, it differed in one major aspect. Campbell Swinton's camera tube disclosed a mosaic of rubidium cubes, Zworykin's showed a plate covered with a layer of photoelectric material. This was to cause Zworykin much grief during the patent process and it took fifteen years before it was granted by the US Patent Office.

In April 1924, Campbell Swinton again described his all-electric television scheme in *Wireless World* and *Radio Review*. He had updated his ideas with the use of a hot cathode to create an electron beam resulting in better focus at the viewing screen. He lamented the hopelessness of his task unless one of the big electric companies with money and resources decided to get involved. This paper stimulated many researchers to start work on television projects, including the General Electric Company in Schenectady, the American Telephone & Telegraph Company, as well as many independent researchers, among them Dr August Karolus and Manfred von Ardenne in Germany and Kenjiro Takayanagi in Japan.

In January 1925 the Bell Telephone Laboratories (the research arm of the American Telephone & Telegraph Co.) started a research programme dealing with the problem of television, under the guidance of Dr Herbert E. Ives. He had been working on photoelectric cells for photo-telegraphy and invited Dr Frank Gray and John Hofele to head the programme. With the enormous technical resources of the new Bell Telephone Laboratories in New York City, the group made excellent progress and by July 1925 were sending half-tone pictures from slides across the laboratory.

Their mechanical system was based on the Nipkow disc for both transmission and reception. Their success came from the invention by Dr Frank Gray of the 'flying spot' scanner, developed around May–June 1925. In this device, the subject was bathed in a flying spot of light from an arc lamp behind the Nipkow disc. The reflected light went to four huge photo-cells that picked up the picture signal. This made half-tone television possible.

In April 1925, John L. Baird set up his apparatus in Selfridge's Department Store in London for three weeks and gave the English public their first crude demonstration of mechanical television. Then on 2 October 1925 Baird also independently discovered the principle of the flying spot scanner. He applied for a patent on this idea on 20 January 1926, and gave a demonstration of his new system to some forty members of the Royal Institution at his laboratory in Frith Street on 26 January 1926. This was the first public demonstration of television with half-tones ever given.

While it was reported that the pictures were 'faint and often blurred', the demonstration was considered a success. Baird and his associates were careful not to reveal how it had been done at the time. (The flying spot principle had been patented by G. Rignoux in France in 1908, by A. Ekstrom in Sweden in 1912, and filed for in August 1923 by John H. Hammond Jr. in the USA; issued in 1929.)

In June 1925, Charles F. Jenkins made headlines in newspapers all across the United States. He again demonstrated his television system by transmitting the image of a revolving windmill five miles by radio from the US Navy radio station NOF in Anacostia, Maryland, to his laboratories in Washington, DC, an event witnessed by many United States officials.

Meanwhile in the autumn of 1925 (the exact date is unknown) Vladimir K. Zworykin assembled a complete, working electric television system for a demonstration to management at the Westinghouse Electric Company. With the help of his tube blower he built the first electric camera tube in the world and used a converted Western Electric oscilloscope tube for a receiver. He also constructed the rest of the system, which operated quite erratically.

Unfortunately the demonstration, which consisted only of an *X* painted on the face of the camera tube, was not considered a success by management. They recommended that he be put to work on something more useful. Zworykin was then forbidden by Westinghouse to do any more actual work on television (filing patents was permitted) and he concentrated on photoelectric cells and other devices that had immediate commercial value. However, this demonstration was the first of an electric camera tube to be displayed on a cathode ray tube.

On 26 July 1926 Édouard Belin gave a demonstration in Paris of his new cathode ray television system to three important French officials. He revealed that he had been joined by Dr Fernand Holweck, Chief of Staff of the Madame Curie Radium Institute. The system was now called the 'Belin and Holweck' system after its inventors. It had been built and operated by Belin's chief engineer Gregory N. Ogloblinsky. The images were picked up by two small vibrating mirrors that were synchronized together. The receiver featured a metal cathode ray tube that had been designed by Holweck. The face of the tube could only show outlines of faces or figures. These pictures were 33 lines at about 10 frames per second. They gave the first demonstration of moving images on a cathode ray tube.

About two weeks later (2 August 1926) the cathode ray television system of Dr Alexandre Dauvillier of the Physical Research Laboratory of the Louis de Broglie Laboratories in Paris was revealed. He also used two small vibrating mirrors to dissect his image. However, his cathode ray receiving tube was quite modern. It was made of Pyrex glass, had a high vacuum, and used magnetic focus. His screen was made of willemite. He claimed to be producing 40-line pictures at 10 frames per second.

In October 1926, Kenjiro Takayanagi in Japan started his first actual experiments with cathode ray

television. He claimed that he was able to transmit the Japanese character katakana (i) inscribed on a mica plate on 25 December 1926.

On 7 April 1927, the American Telephone & Telegraph Company gave their first public demonstration of television. This was a joint effort of the Bell Telephone Laboratories and Western Electric that was part of the Telephone Group. It consisted of a television programme transmitted by land-line (wire) from Washington, DC, to New York City. There was also a wireless (radio) transmission from Whippany, New Jersey, to New York City. It was claimed that there was no difference in the quality of the images transmitted.

Using a 50-hole Nipkow disc running at 18 frames per second, the pictures were of excellent quality. It was in fact the finest demonstration of television ever made up to that time. The Bell Laboratories admitted that they had been working on the project since 1925 and the demonstration required the services of almost 1,000 men.

This successful demonstration by the Telephone Group dismayed David Sarnoff, now Vice-President of RCA. Relations between the two giants of communications, the Radio Group (GE/Westinghouse/RCA) and the Telephone Group, were strained. Earlier (July 1926) Sarnoff had successfully removed the American Telephone & Telegraph Company from radio broadcasting and he certainly did not want them to have the lead in television research. Sarnoff immediately ordered both General Electric and Westinghouse Electric to double their research efforts to match those of the Telephone Group.

In San Francisco, California, a newcomer to the field of television, Philo T. Farnsworth, applied for a patent (7 January 1927) on a completely different electric television system. His camera tube was an 'image dissector' that had a photoelectric plate upon which the light from the scene was converted into electricity. This created an *electron image* that was passed *en masse* by scanning coils sequentially to an electrode where it became the television signal.

Farnsworth had started work on his system in May 1926. He had obtained financing and was constructing all of his equipment in a small laboratory in Los Angeles. He soon moved to San Francisco, where he continued his experiments. It was claimed that by 7 September 1927, he was able to transmit lines of various widths in one direction, on a cathode r tube, so that any movement at right angles was easi recognizable.

Farnsworth continued to improve his system. January 1929, he hired a young engineer, Har Lubcke, to work in his laboratory and by July 192 Lubcke and Farnsworth had devised and built an a electric scanning and synchronizing pulse generat With it installed, Philo Farnsworth was now oper ing the first all-electric television system in the worl It consisted of his camera tube (the 'image dissecto and his magnetically focused picture tube (the 'osc lite'). There were absolutely no mechanical parts the entire system.

On 13 January 1928, General Electric gave a tele sion demonstration from its labs in Schenectac New York. This was under the direction of Dr Ern F. W. Alexanderson. It was a demonstration of a 4 line picture at 16 frames per second of 'live' imag using the flying spot system of Dr Frank Gray. Th images were received on three receivers located i the Schenectady area.

In April 1928, RCA applied for a permit for a telev sion station to be constructed in New York City. was to be operated by the Research and Test De of RCA at Van Cortlandt Park under the direction Dr Alfred N. Goldsmith. This station W2XBS w part of a plan by David Sarnoff to have a televisio station operating by the end of the year.

On 8 August 1928, Westinghouse Electric gav a television demonstration of 'radio-movies' fro their radio station KDKA in East Pittsburgh. It was transmission of 35 mm motion picture film of 60-lin pictures at 16 frames per second. The pictures wer transmitted by land-line (wire) to the transmitte and back by radio (wireless) to special receivers at th laboratory. Westinghouse gave radio engineer Fran Conrad credit for this demonstration.

Conspicuously missing from this demonstratio was Dr V. K. Zworykin. True to its word, Westing house had not allowed him to participate in it Sometime late in November 1928, on David Sarnoff' orders, he was sent to Europe to inspect the variou laboratories that had commercial agreements wit the Radio Group (GE/Westinghouse/RCA), takin in Germany, Hungary, and France. In Paris he visite the laboratories of Établissements Belin and wa shown all of their work in progress. Here he me

Édouard Belin, founder; Fernand Holweck, chief scientist; Gregory N. Ogloblinsky, chief engineer; and one Pierre E. L. Chevallier, consulting engineer.

He was shown an advanced version of the 'Belin and Holweck' television system. It had a new picture tube that featured 'electrostatic focus'. This was accomplished by carefully controlling the voltages in two diaphragms that were in the path of the beam. The two-piece tube was metallic, continuously pumped (a Holweck speciality) with a glowing cathode that displayed 33-line pictures at 10 frames per second. It was rather crude, and, while quite sharp, could not display pictures with any more brightness than the usual Braun tubes using either magnetic or gas focus.

A Practical Television System

Dr Zworykin was elated by this disclosure. He knew that by making several important changes to this tube he had the answer to the problem of a practical television system. He made arrangements with Belin to purchase a Holweck cathode ray tube and a Holweck vacuum pump and bring them back with him. He also made plans to hire Ogloblinsky at an early date.

Zworykin arrived back in Westinghouse late in December 1928 and related his finding to Samuel Kintner, his superior at Westinghouse. Kintner showed very little interest in it and suggested that Zworykin go to New York and see David Sarnoff personally as he had gone to Europe on RCA's (not Westinghouse's) behalf.

This resulted in the famous meeting between Dr Zworkyin and David Sarnoff and their oft-quoted conversation. Zworykin convinced Sarnoff that he had the solution to a practical television receiver—to wit, one that needed no maintenance, had no moving parts, could be viewed in a semi-dark room, and operated by the average man in his home. He told him that he had the basic device working in his laboratory. This was true: he had converted the Holweck cathode ray tube to conform to his new ideas. When asked how much it would cost, Zworykin stated, 'some $100,000', a considerable understatement. But Sarnoff, who was quite eager to give RCA the lead in television research, gladly gave his consent and Zworykin was set up in his own laboratory at East Pittsburgh and provided financing and manpower to build a practical television system based on his revolutionary picture tube.

In February 1929, Zworykin ordered thirteen glass bulbs from the Corning Glass Company and began work on his new system. The first usable tube was assembled in April. A modified 35 mm film projector (Zworykin had no camera tube at the time) was to be used as a source of picture signals. Several top engineers from Westinghouse were assigned to the project. They included Harley Iams, John Batchelor, Arthur Vance, Randall Ballard, and W. D. Wright, an optical engineer.

The project went very well. On 9 May 1929, a demonstration was given of motion picture film using three sets of electrical circuits. Finally, on 17 August 1929, a demonstration was given by radio to a group of RCA and General Electric engineers.

The receivers were all-electric, with no moving parts. The seven-inch picture tubes, now called 'kinescopes' ('kineo' to move, 'scope' to see) could easily be viewed in a dimly lit room. Seven receivers were installed at various locations in East Pittsburgh (including one in Zworykin's home). Zworykin was allowed to use the KDKA Conrad short-wave radio transmitter late at night for his experiments.

Zworykin filed for a patent on the kinescope on 16 November 1929, and revealed it in a speech before the Institute of Radio Engineers on 19 November 1929. His paper was an oral presentation only, no demonstration was given. The speech was featured in papers, magazines, and journals all over the world. His development of the kinescope was the single most important event in the history of television. It made television as we know it today possible.

At Westinghouse, Zworykin was not content to rest on his laurels with the kinescope. With the arrival of Ogloblinsky from Paris in July 1929, he went to work to perfect a television camera tube. They used the same demountable Holweck cathode ray tube as the basis of their experiments. While only producing 12-line pictures, it proved that a camera tube with 'charge storage' was possible.

'Charge storage' was a long-sought-after goal. It meant that a camera tube would accumulate an electrical charge on each element that would continue to build up until scanned by the electron beam. As such the tube would have more sensitivity than a tube without it, such as Farnsworth's 'image dissector'.

In January 1930 all RCA television research was taken over by Zworykin, who moved his laboratory to the huge Victor Plant in Camden, New Jersey. Here he and Ogloblinsky produced many two-sided camera tubes. But they were hard to build (they were full of electrical and mechanical defects) and the resulting pictures left much to be desired.

Finally by July 1931, Zworykin and Ogloblinsky, who had been joined by Harley Iams, Arthur Vance, Sanford Essig, and Les Flory, had decided to take a new approach. They proposed to build a camera tube with a single-sided target, that is, one in which the electron beam and the light from the subject impinged on the same surface. Many variations of the single-sided design were built and tested. On 9 November 1931, the first tube displaying 'good' pictures was tested. Zworykin now named this tube the 'iconoscope' ('icon' for image and 'scope' to see). A patent covering this new design was filed on 13 November 1931. At last Zworykin and David Sarnoff had a camera tube that had the same potential as the kinescope. But the iconoscope was not revealed for two more years to the public.

In fact, the kinescope was now so bright that it was causing considerable flicker at the 24 frames per second rate in use. This was based on 35 mm sound film speed. On 19 July 1932, Randall C. Ballard of the RCA Zworykin laboratories applied for a patent for 'interlaced' scanning. This solved the problems of both flicker and limited bandwidth. While not a new idea (it had been done with Nipkow discs) this was the first time it had been applied to a cathode ray tube.

Each frame was divided into two fields (48 fields per second) and then intermeshed so that it provided a continuous 24 frames per second picture. An odd number of lines (81 at the time) was necessary to make this system work. This important patent was soon incorporated into the RCA (and later the EMI) patent structure. At first it was done with a mechanical scanning disc, but by 1935 an all-electric interlaced scanning generator was finally designed and operated.

In April 1931, it was announced in England that a new holding company, Electric and Musical Industries Ltd. (EMI), had been formed by merging the HMV Gramophone Company with the Columbia Graphaphone Company Ltd. As the business depression was now world-wide, it was decided that by combining facilities, they could bring about certain economies of operations. A silent partner was RCA, which owned 27 per cent of the new company. David Sarnoff sat on the EMI Board of Directors.

EMI's first television project was to perfect a television system for the transmission of film based on the RCA/Zworykin kinescope. EMI's engineers from HMV included William F. Tedham (who was in charge of the project), C. O. Browne, R. B. Morgan, J. Hardwick, and W. D. Wright, formerly of Westinghouse. From Columbia Graphaphone came Isaac Shoenberg, Allan Blumlein, P. W. Willans, and others. Sarnoff sent the EMI laboratories at Hayes, Middlesex, several kinescopes for experimental purposes. RCA now had a powerful ally in its race for domination of the new television industry.

The EMI laboratories were also privy to the Zworykin experiments with an electric camera tube at Camden. Sometime in the summer of 1932, William Tedham and Dr Joseph D. McGee (who had come to work for EMI in January 1932) took it upon themselves to build an electric camera tube. According to McGee, it worked quite well for a short period of time. Dr McGee claimed that as it was not an 'official' (sanctioned) project it was not reported to the Director of Research, who was now Isaac Shoenberg. At any rate, it was the first working camera tube built in England. A patent for it was filed on 25 August 1932.

Early in 1933, EMI proposed to the General Post Office that it be allowed to go ahead with a television service. They suggested that with a few minor changes in the BBC's ultra-short-wave radio transmitter in London it could go ahead and produce receiving sets by the autumn of 1933.

Baird Television Ltd., which had been running an experimental low-definition (30 lines at 12.5 frames per second) television service for the BBC in London since September 1929, was quite upset by this and demanded that there be a competition for such a service. A demonstration to the General Post Office in April 1933 proved that EMI's system was far superior to that of Baird's. In May 1933, Capt. A. G. D. West became technical director of Baird Television Ltd. and immediately started a crash programme into cathode ray tube reception.

On Monday, 26 June 1933, at the Eighth Annual Convention of the Institute of Radio Engineers in Chicago, Illinois, Dr V. K. Zworykin presented a paper, 'The Iconoscope: A New Version of the Electric Eye'. In this paper he revealed the existence of the new RCA camera tube, the iconoscope. He made much of the fact that it used 'charge storage', which made it quite sensitive. However, just as with the kinescope in 1929, it was neither publicly exhibited nor demonstrated. Zworykin then went to Europe in the summer of 1933 and revealed the plans for the iconoscope to Isaac Shoenberg of EMI in England and Fritz Shröter of Telefunken in Germany. A camera tube laboratory was set up at EMI at Hayes with Dr J. D. McGee in charge. By 24 January 1934, the first EMI camera tubes were producing fair pictures. EMI raised its television standard to 240 lines at 25 frames. On 12 May 1934, Hans G. Lubszynski and Sydney Rodda of EMI applied for the first patent on a new, improved iconoscope camera tube. This new tube was called the Super-Emitron.

The rivalry between Baird Television Ltd. and EMI led the BBC and General Post Office to set up a committee to settle their differences. This was under the chairmanship of Lord Selsdon. It sent delegations abroad to study the state of the art in the United States and Germany.

On 24 May 1934, the Marconi Wireless Telegraph Company and EMI Ltd. merged to form Marconi-EMI Ltd. This powerful cartel left the Baird Television Company with Fernseh AG and the (English) General Electric Company as its only allies. GE was developing picture tubes. Fernseh was developing both an intermediate film system (using film that was speedily developed and projected) and the Farnsworth 'electron camera'.

In the summer of 1934, Philo Farnsworth gave the first public demonstration of all-electric television by a demonstration unit at the Franklin Institute in Philadelphia. His system consisted of his image dissector tube, an all-electronic scanning and sync generator, and his magnetically focused picture tube. The entertainment consisted of vaudeville talent, athletic events, and appearances of various politicians. Each programme was of fifteen minutes' duration.

The First Television Services

On 14 January 1935, the Selsdon Committee made its recommendations to Sir Kingsley Wood. It stated that a high-definition television service should be started in London with two companies, Baird Television Ltd. and Marconi-EMI Ltd. furnishing the technical apparatus. The transmission standard was to be at least 240 lines at 25 frames per second.

On 22 March 1935, the German Post Office (DRP) opened what was called a 'regular' medium-definition (180 lines at 25 frames per second) service from Berlin. It consisted primarily of the projection of motion picture film; no live coverage. It was not a success. The picture quality was quite poor. No television receivers were ever sold, programming was sporadic, and as a result of a disastrous fire it went off the air on 19 August 1935.

The competition between Baird Television Ltd. and Marconi-EMI was fraught with difficulties. The two companies would not exchange any information and would not cooperate in any way. At the Alexandra Palace, EMI planned to use a 'live' studio equipped with four Emitron cameras along with a 35 mm film projection unit. Baird Television Ltd. relied on a studio equipped with a flying spot scanner, an 'intermediate film' (a high-speed film developing process) system, a 240-line telecine Nipkow disc film transmitter, and the Farnsworth 'electron camera'. While Baird Television relied on the 240-line sequential scanning standard, Marconi-EMI proposed to use a new high-definition 405 lines at 25 frames per second interlaced (the Ballard method) television system.

The Eleventh Olympic Games were held in July–August 1936, in Berlin, Germany and were shown by television. The coverage was by the German Post Office (DRP), which was using iconoscope cameras furnished by Telefunken, intermediate film vans for outdoor events, and the Fernseh (Farnsworth) electron camera. Most viewing was done in the Olympic Village and in selected theatres throughout the city. Sadly, the transmitted pictures were quite unsatisfactory. They were unstable, having low image detail, and suffered from severe flicker.

By contrast, the opening of the London Television Service in London in November 1936 was a tremendous success. Both the Baird and Marconi-EMI systems were demonstrated and it was obvious from the start that the Marconi-EMI high-definition 405-line interlaced picture was far superior to that of Baird's 240 lines, a tribute to Isaac Shoenberg and his staff.

The programming, under Cecil Madden, included game shows, musical numbers, drama, and a variety of 'outside broadcasts' that covered everything from the Coronation to cricket matches, boxing, and exhibitions. A steady stream of visitors from the United States (and elsewhere) were amazed at the uniformly high quality of the pictures, the regularly scheduled programmes, and the coverage of remotes (outside broadcasts).

The Marconi-EMI 405-line interlaced 25-frame standard was chosen in February 1937. This marked the beginning of modern television broadcasting as we know it today. The only problem was the high cost of the receivers. These were manufactured by Baird, Cosser, Ferranti, GEC, HMV, Marconi, Ecko, and several others. Costing from 37 to 170 guineas, less than 3,000 sets found their way into homes in London. Baird Television turned to large-screen cinema television.

On 30 September 1938, the London Television Service telecast the arrival of British Prime Minister Neville Chamberlain from Munich ('Peace in our Time') at Heston Aerodrome by means of its 'outside broadcast' unit. This was covered by three Emitron cameras and relayed 'live' to the Alexandra Palace were it was rebroadcast while actually happening. This was the first actual broadcast by television of a major news event as it occurred.

With the success of the London Television Service, David Sarnoff decided, in October 1938, to start a television service in the United States. This was to begin with the opening of the New York World's Fair in April 1939. Six American set manufacturers promised to have receivers ready for sale.

Television made its semi-formal debut in the Untied States on 30 April 1939. There was a speech by President Franklin Delano Roosevelt and shots of the Fair's activities. However, David Sarnoff had 'jumped the gun' and a week earlier (20 April 1939) had made a telecast dedicating the RCA Exhibit Building. While there was much enthusiasm for the new American system, few television receivers were sold to the American public. The National Broadcasting Company/RCA system was not able to provide a high-quality service similar to that of the London Television Service.

On 7 June 1939, Harley Iams and Dr Albert Rose of the RCA Laboratories announced details of a new camera tube called the 'orthicon' ('orth' for linear and 'icon' from iconoscope) which used a low-velocity electron scanning beam. It was considered a great improvement over the Zworykin iconoscope, which used a high-velocity scanning beam. Picture resolution was between 400 and 700 lines and it was supposed to be 10–20 times more sensitive than the iconoscope. Work on this new tube had begun in 1937, when Dr Albert Rose had joined Harley Iams at RCA.

The London Television Service was now a great success. Over 500 sets a week were being sold. By September 1939 over 20,000 sets were in use in the London area. However, with the invasion of Poland by Nazi Germany and the start of World War II, the station was shut down with no advance notice on 1 September 1939. This was as if actual war conditions were being observed. The transmitter was turned off and all of the cameras and other equipment were carefully packed and stored away for the duration.

Television progress was lagging in the United States. NBC's experimental programming was sporadic and of very poor quality. Very few sets were being sold due to their high prices and there was very little public interest. In order to overcome this apathy, the Federal Communications Commission (FCC) stated that a commercial service could begin on or after 1 September 1940. RCA immediately announced a great sale of receivers at reduced prices. This upset the rest of the radio industry (Philco, Zenith, and the DuMont Laboratories). They feared, as in radio, that the NBC/RCA television transmission standards would become the official USA standard giving RCA another monopoly.

As a result, a National Television Systems Committee (NTSC) was formed in July 1940, to produce one set of universal standards agreeable to the entire industry. It would not do for the United States to have more than one set of transmission standards. A single 'lock and key' situation was needed in order that all receivers could receive the same pictures.

The NTSC submitted a report to the FCC in January 1941. It proposed a new set of technical standards for American television. Among them was a new 525-line standard and the use of FM for the audio portion. In May 1941, the FCC agreed to these standards and announced that commercial (sale of programmes) television could start in the USA on or after 1 July 1941. The issue of colour was to be taken up later.

On 1 July 1941, commercial television programming began in the USA. However, it was a lukewarm affair. Only NBC/RCA had paid, sponsored programming. CBS and DuMont, beset by technical problems, offered only limited fare. For the rest of the year, there was only minor television programming. Out of twenty-two licensees, only seven were actually broadcasting.

The bombing of Pearl Harbor by the Japanese on 7 December 1941 quickly put a halt to most programming in the United States for the rest of the war. Television returned to the laboratory, where it was to become a tool for guided missiles and long-range reconnaissance.

At first this war work depended on the newly developed RCA orthicon camera. But it had many defects and was not as successful as promised. Its war use in guided missiles and for reconnaissance was limited. The RCA Laboratories decided to improve its performance. The result was the development of the new highly sensitive tube called the image orthicon in 1944.

This tube was developed by Dr Albert Rose, Paul K. Weimer, and Harold B. Law of the RCA Laboratories. As a result, RCA came out of the war with a tube so sensitive that it could be used in normal room light. It was first demonstrated on 25 October 1945, at the Waldorf-Astoria Hotel. The original image orthicon camera was equipped with a single lens, but soon it was furnished with a four lens turret and an electronic viewfinder. This tube assured RCA supremacy in the development of post-war television all over the world.

With the war over, the BBC readied the Alexandra Palace for the resumption of telecasting. On 7 June 1946 it returned to the air. Although they had a chance to change their standards they decided to go along with the original 405-line standard.

In the United States some fifteen television stations went back on the air. They were still using their old iconoscope and orthicon cameras, which were slowly replaced with the new RCA image orthicon. With the rapid growth of television in the USA in the early 1950s, the need for programme material to fill expanding schedules was tremendous. As in radio, the big production centres were in New York, Chicago, and Los Angeles. Since the United States was divided into three different time zones, a major problem was broadcasting the same programme at the same hour across the country. In radio, this was done by means of magnetic recording of the audio programmes.

Recorders and Cameras

In television, this problem was temporarily solved by ABC, NBC, and DuMont with the co-operation of Eastman Kodak by the introduction of a system of television film recording called 'kinescope recording'. This was accomplished with a special motion picture film camera that photographed the television image on the face of a special picture tube. This film record could either be quickly processed and shown within a few hours, or more likely was processed and shown at a later, more convenient time. This was mainly done on 16 mm film. The accompanying sound was either recorded directly on the film or for better quality in some instances was recorded separately on a magnetic track. (Similar recording techniques were also started in Great Britain for basically the same reasons.) By 1953, it was reported that 100 million feet of film would be required each year for television recording in the USA.

However, this was an expensive, wasteful method. It was evident that a more efficient, less costly system of television recording was needed. The obvious alternative was to record the picture on magnetic tape, as was done with audio. But because of the wider bandwidth used by a television picture this presented some formidable problems. The first effort to solve this problem was by John T. Mullin, who was associated with Bing Crosby Enterprises in Los Angeles. He altered a standard audio recorder from the Ampex Electric Corporation of San Carlos, California, and gave the first demonstration of video signals recorded on magnetic tape on 11 November 1951. In order to get this wide-band signal on to magnetic tape, he ran the recorder at high velocity past stationary heads. He later used a multitrack high-speed approach that consumed an enormous amount of tape. Similar high-speed projects were being undertaken by RCA, the BBC Research Laboratories, and others.

The Ampex Corporation, now in Redwood City, decided to solve the video recording problem using a rotating head approach. This would allow them to run the magnetic tape at a normal speed of 15 inches per second. In December 1951, Charles Ginsburg was hired to build such a device. He was joined by a student engineer, Ray Dolby, and by June 1953 they were able to demonstrate very crude pictures. The project continued in September 1954, with the addition of Charles F. Anderson, Alex Maxey, Fred Pfost, and Shelby Henderson.

This ingenious team produced a revolutionary transverse recorder that was demonstrated at the National Association of Radio and Television Broadcasters Convention in Chicago in April 1956. It was a machine with a rotating four-head drum that used two-inch magnetic tape running at 15 inches per second. In addition to the picture, it included both a cue and audio track. The picture quality was quite good (better than any kinescope recording) and the resolution was over 320 lines. Playback of picture and audio was instantaneous, no processing was necessary.

This new recorder completely changed all television programming. No longer was a local station forced to show a programme as it came off the network feed. It could be played at any convenient time. The first videotaped network broadcast was made by CBS TV with *Doug Edwards and the News* from Television City in Hollywood on 30 November 1956. 'Time shifting' of television material had begun. The Ampex revolution was underway.

In September 1959, a different kind of video recorder was introduced by Norikazu Sawasaki of the Toshiba Corporation of Japan. It also used a rotating head system. However, the magnetic tape was scanned by a single head in a 'helical-scan' (slant-track) machine. This had many advantages as it could be run forward or backward, at various speeds and be still-framed for stop motion. (The Ampex Corporation also had a helical machine in their laboratories in 1959, but had decided not to reveal it in order to protect its original transverse machines.) This new helical format (but with two heads) slowly superseded the original Ampex machines and later became the industry standard.

By 1961, Ampex added a host of features to the basic machine. This included 'Intersync', 'Amtec', 'Color-Tec', and a rudimentary Electronic Editor. Finally, in April 1963, Ampex introduced EDITEC, the first electronic videotape assembly device. Not only did the videotape recorder enable 'time shifting', it made editing of programme material as easy as pushing a button.

In the USA, the battle for a compatible colour system continued. CBS had perfected its 'mechanical' colour system and it was adopted by the FCC in September 1950. However, this required a different set of transmission standards. But David Sarnoff and RCA were determined that only a colour system that could be fitted (electrically compatible) into the regular 6 MHz monochrome FCC USA channel should be adopted. As a result a second National Television Systems Committee was formed in 1950. Through the efforts of the major radio manufacturers, including Hazeltine, General Electric, Zenith, and Philco, a new set of transmission standards was agreed upon and was adopted on 17 December 1953. This meshed a colour system into the existing standards and was the basis for every new colour system later adopted throughout the world.

There was much effort made to improve the performance of and reduce the size and weight of new video recorders and cameras. In June 1962, Kurt Machein of Mach-Tronics Inc. of Mountain View, California, introduced the MVR-10, the first one-inch helical recorder. In 1964, for the BBC, the Ampex Corporation introduced the VR2000, the first 'high-band' (higher recording standard) video recorder with excellent colour quality. In July 1965, the MVR Corporation of Palo Alto, California, demonstrated the first single-frame video disc recorder. It could be used for 'instant playback', including still frames. In April 1966, the Westel Company of San Mateo, California introduced the Westel WRC-150, the first self-contained one-inch portable television camera with a video recorder. In April 1967 the Ampex Corporation introduced the first battery-operated portable colour video recorder, the VR3000.

In 1964 the N. V. Philips Company of the Netherlands introduced the 'plumbicon' (lead oxide) camera