TELEVISION

THE LIFE STORY OF A TECHNOLOGY

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demonstration for Hugo Gernsback left the electronics promoter and publisher "under the influence of what I consider to be the most marvelous invention of the age" (Fisher and Fisher, 1996, 45).

The expense and difficulty in using and aligning the prisms drove Jenkins to the Nipkow approach. He did so reluctantly because the Nipkow system was not easily scalable. Two square inches of video display required a 36-inch disc; doubling the picture size would require a 6-foot diameter disc—"a rather impractical proposition in apparatus for home entertainment, even if it were possible to get power enough out of the house wiring to turn the disc up to speed" (Fisher and Fisher, 1996, 89). In addition, the Nipkow systems needed tremendous amounts of light to illuminate each pinhole as it scanned its line of image elements.

By the spring of 1925 Jenkins was explaining his system at the annual meeting of the Society of Motion Picture Engineers while failing to interest Westinghouse in his system. On a Saturday in June, Jenkins demonstrated to government officials his mix of lenses and Nipkow discs. General Electric provided the thallium-based photocell and neon glow lamp for the display, which was highly sensitive to changes in electrical current. His system broadcast on one channel from naval radio station NOF in Anacostia, Washington, DC, an image of a model Dutch windmill whose blades were moved by the breeze of an electric fan in motion. The group watched the video, which was "not clear-cut" but "easily distinguishable," on a 6" by 8" television receiver using a magnifying lens in Jenkins's laboratory at 1519 Connecticut Avenue Northwest. On a separate broadcast channel, an assistant at NOF predicted the motion of the blades' motion. *The New York Times* and *Washington Post* Sunday editions made this a page-one story, quoting the inventor to the effect that "the process would not be perfected until baseball games and prize fights could be sent long distances and reproduced on a screen by radio" (Udelson, 1982, 27).

The secretary of the navy looked for practical uses: "I suppose we'll be sitting at our desks during the next war and watching the battle in progress." Jenkins replied, "That's perfectly possible, Mr. Secretary." Was it television? Curiously, the inventor coined his own term, "radiovision," and his content "radiomovies." Television was aligned with the nineteenth-century technologies of telegraphs and telephones, which connected sender and receiver by cable. Having no illusions about the quality of the imagery, Jenkins highlighted the connection between his accomplishment and the modern entertainment media of the day. Unable to sell the system to either the government or the larger corporations, and protected by his patents, Jenkins began to build his own audience among radio enthusiasts seeking a new niche in which to pioneer now that broadcasting had become mainstream.

JOHN LOGIE BAIRD

Scotsman John Logie Baird matched Jenkins, albeit with far fewer resources beyond his remarkable mind. Baird was born in 1888 with an eccentric technical imagination, acquired perhaps when seriously ill as a two-year-old. After earning a technical certificate in 1912, he championed a variety of peculiar inventions and business ventures, none of which had any relation to any other and none of which proved profitable for long. He continued to be sickly and prone to cold feet, leading his London doctor to refer Baird to the healthier climate of Hastings in England's southeast during the winter of 1922–1923. There, "coughing, choking and spluttering, and so thin as to be transparent," Baird tried to invent a glass, rust-free razor and air-cushioned shoes with predictable results (Fisher and Fisher, 1996, 27).

With his savings steadily evaporating, in the spring the failed inventor-entrepreneur visited the town library and went for a long walk. He stopped at Fairlight Glen, overlooking the English Channel, where William the Conqueror led the Norman fleet that invaded England in 1066. There Baird's thoughts brought him back to vision at a distance, aided perhaps by an article on television in *Wireless World and Radio Review*. He had explored the concept of television as a teenager and now thought that, twenty years later, the necessary technological components existed to make a Nipkow-disc system possible.

The virtue of Baird's approach was that he had no idea how hard it would be to make television work, much less make it work well. He had, however, a tremendous passion that drove him in all his endeavors. It also attracted assistants willing to work or volunteer for someone with a vision. This attraction was a vital asset when the visionary had little mechanical aptitude or money. In June 1923, after a couple of months struggling with some local enthusiasts to turn a hatbox, some knitting needles, bicycle lamp lenses, batteries, and vacuum tubes into a Nipkow-disc television system, Baird advertised in *The Times* for a volunteer to help make it work. The major challenge involved the large selenium photocell, with its slow response time and a reaction to light that generated as much unwanted electronic noise as electronic signal. By July 26, he and his assistant had progressed far enough for Baird to invest in his first television patent. From July 1923, he began transmitting his first images over wire, so that after the first demonstration in November a reporter could typically anticipate the day when "we may shortly be able to sit at home in comfort and watch a thrilling run at an international football match, or the finish at the Derby" (Burns, 2000, 43).

Baird showed instead immobile silhouettes of crosses, letters, and other symbols through his spinning spiral of bicycle lamp lenses. The content had far to go, his camera and receiver were connected by cable, and his display offered a picture four inches square, perhaps 20 lines to a frame, and flickering at 20 frames a second. Nonetheless, when he began public demonstrations in January 1924, the national *Daily News* publicized his triumph in adding sight to sound only two years after the British Broadcasting Company (BBC) began formal radio broadcasting. Most usefully the recognition got him £50, the equivalent of ten weeks' skilled labor, from his father, and the approach of a prospective investor, publisher J.W.B. Odhams.

Before agreeing to Baird's offer of a 20-percent interest in his television in return for £100 and more business contacts, Odhams arranged for the donation of some expensive vacuum tubes from an engineer at the BBC and another demonstration to be evaluated by the engineer. With the improvements Baird could transmit moving silhouettes, but as might be expected, the engineer reported that Baird's technology was some distance from a commercial product, a view affirmed by the editor of the *Broadcaster*, a radio magazine. Odhams declined to invest but Baird gained his contacts anyway.

In February an article in *Radio Times* entitled "Seeing the World from an Armchair: When Television is an Accomplished Fact" suggested that the technology was the next big trend in wireless communications. After the obligatory references to the prospect of watching sporting events "or, for that matter, a battle," the author revealed that Baird and a C. F. Jenkins in the United States had both transmitted images through television systems (Burns, 1998, 152). In April a series of demonstrations for the press and the resultant articles led to the investment of £200 by Will Day, who supported Baird's efforts over the next twenty months in return for a share of Baird's first television patent.

Yet Baird himself did not even define what he had done as true television: that required the transmission of reflected light off a moving object, preferably over the air. Up to mid-1924 he focused on picking up images of silhouettes on a filmstrip so that the selenium cell had only to respond to the intense lamplight projected around the silhouette. The next step was to televise the reflected light off an object. As Baird calculated it, this required an increase of a thousand times more sensitivity by the camera to respond to far less light and show a passable gray scale. In June he wrote his patron that he had made the selenium cell "work by reflected light—that is, objects, not transparencies." His mistake was in adding confidently, "I feel quite certain that there are no insurmountable difficulties in the way of success" (Burns, 2000, 59–60).

Those surmountable difficulties took sixteen months to resolve. Day's investment disappeared and required additions as Baird filed for patents, bought batteries and tubes, and struggled to make his selenium cells show consistently a sharper, moving image from reflected light. He was, to a degree, the prisoner of his background and interest in mechanical and chemical engineering, for he resisted Day's encouragement to use photoelectric cells. The selenium was slow to respond but easy to use and relatively sensitive to light; the photoelectric cells responded quickly but were expensive and relatively insensitive. He had some electrical circuitry skills, for one of his 1924 patents applied differential calculus to replicate the light intensity from an image in the electrical current emitted from the selenium.

But Baird focused on the mechanism in two ways. First he added a serrated shutter revolving up to ten times faster than the Nipkow disc and a motorized ring of selenium cells. He thought that by pulsing the light on a series of cells he could nullify the lagging response. But this also required more synchronization and more voltage for the extra motors, and in July 1924 Baird nearly electrocuted himself in a 1,000-volt accident that made the local paper and resulted in his eviction from the apartment.

His second approach involved the cell itself and efforts to improve its sensitivity. This resulted in impractical and practical advances. After a dispute over Baird's progress or lack thereof in September, Day arranged for him to move his lab to a garret in Soho, London, closer to his patron, the following month. After settling in, Baird visited the Charing Cross Opthalmic Hospital in search of an eyeball. Having read that the eye's sensitivity to light was due to a fluid in the retina called visual purple, he convinced the chief surgeon to give him one. Baird's dissection was a messy failure. During 1924 Baird also began immersing electrodes in a colloidal selenium electrolyte. By suspending particles of selenium in a fluid, Baird increased the surface area of the photoconductor and its sensitivity by up to three orders of magnitude.

His focus on the light shutter, colloidal photocells, and the eyeball show how much the constant financial crisis affected the development of his system. The lack of money meant that the simplest solution was the best, regardless of its prospects for long-term development. When trying to demonstrate progress in a new technology to investors, however, that could be a virtue. Baird's persistence and the sheer fact of his televised images, unique in Great Britain, resulted in spasmodic publicity and haphazard reward. A neighbor in Hastings referred the owner of Selfridge's department store to Baird with the suggestion that television would be a "startling exhibit" for the store's anniversary (Burns, 2000, 75). In April 1925 George Selfridge paid Baird £60 for three weeks of transmissions of silhouette images from a system made of "[s]tring, cardboard, pieces of rough wood with Meccano parts, bits of bicycles and strange scraps of government surplus," as a friend of Baird's recalled (Burns, 2000, 73). Keeping the 3,000-volt system in order and dealing with a curious and affluent public exhausted the inventor, but it also resulted in the donation of several thousand dollars worth of batteries and vacuum tubes by two companies. But the inventor's demonstrations and sales pitches failed to attract other, larger investors. Reviews like that in the leading science journal, *Nature*, did not encourage it: "Mr. Baird has overcome many practical difficulties, but we are afraid that there are many more to be surmounted before ideal television is accomplished" (Burns, 1998, 158).

Thus Baird remembered his meeting with the general manager of the Marconi Wireless Telegraph Company as follows:

> "Good morning."
> "Good morning."
> "Are you interested in television."
> "Not in the very slightest degree, no interest whatsoever."
> "I am sorry to have wasted your time." [Baird had waited half an hour.]
> "Good morning." (Fisher and Fisher, 1996, 48)

Visits to newspaper offices turned out little better. Editors regarded the wild-maned Scotsman as another wireless "lunatic who should be watched carefully since he may have a razor hidden" (Fisher and Fisher, 1996, 48). Everyone who visited Baird's pathetic laboratories expressed astonishment and respect that he could show any transmitted video at all, but at the same time they could not see a commercial future for Nipkow disc television.

Frustrated by Baird's lack of communication and apparent lack of progress, Day wanted out. He had spent nearly £500 by May 1925 but expected Baird to raise additional funds as well as carry out the research and development necessary to a commercial product. This is an unreasonable expectation for most inventors, much less "a wretched nonentity working with soap boxes in a garret" as Baird described himself later (Fisher and Fisher, 1996, 52). But in June the two men incorporated Television Limited, so that Baird could sell shares in the company's stock, capitalized at £3,000, with the intention of buying back Day's investment.

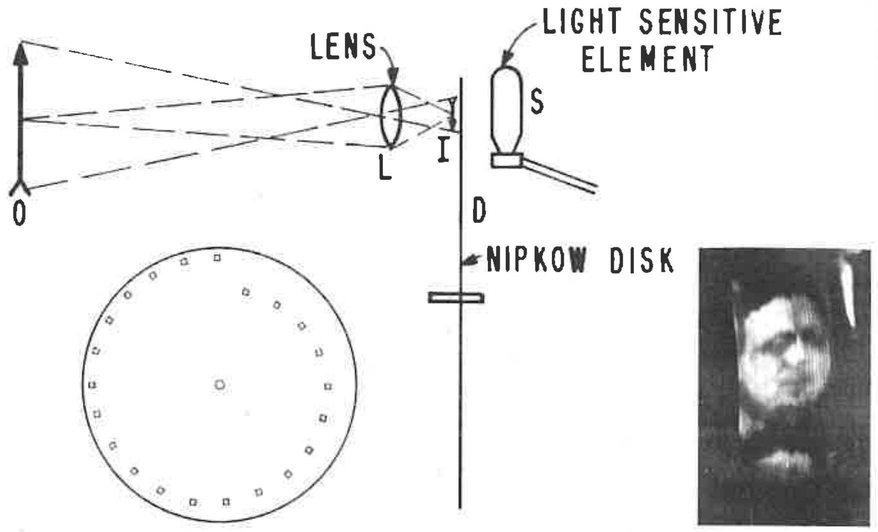
Baird spent less time on stock pitches than with Stookie Bill, the head of a ventriloquist's doll that he used in tests. Any televised object needed a lot of light to show up on his neon lamp display, which replaced the light bulb behind the Nipkow disc in the receiver. The neon lamp was much more sensitive to changes in electronic frequencies sent by selenium

cell, and on Friday, October 2, Baird finally obtained some gray scale on Stookie Bill's garishly painted face. It appeared as "a white oval, with dark patches for the eyes and mouth, [with] the mouth . . . clearly seen opening and closing" (Fisher and Fisher, 1996, 57). Baird raced down three flights of stairs to recruit a live subject: William Taynton, an office boy. Taynton retreated back downstairs when Baird went to the receiver, and the inventor had to pay him two and a half shillings to sit under the intense lights, thereby becoming the first person on TV.

Baird was excited with the success, nervous that a rival might beat him to a public demonstration, and down to £30 in savings. Some time in the next two months he reached back into his own entrepreneurial history and contacted Captain O. G. Hutchinson, a former rival in Baird's foray in the soap business. Hutchinson, an Irishman, was a natural salesman and liked the prospects of what Baird showed him. He bought Day's investment in December, and after the holidays proceeded to drum up Baird's technology.

On January 4, 1926, Hutchinson applied to the Postmaster General for a license to transmit television from four cities in the Great Britain using a 250-watt transmitter on a wavelength of 150–200 meters. Three days later, Baird showed Hutchinson's moving head to reporters for the *Daily Express*, and the *Evening Standard*. In between, Baird largely resolved the problem of the burning of the subject with the 16,000 candlepower necessary to resolve a 1-inch square image by reversing the placement of the light source and photocell. On Tuesday evening, January 26, Television Ltd. invited members of the Royal Institution and a reporter from *The Times* to a demonstration and forty people showed up. Dressed in formal attire, they clambered up the stairs to the landing outside Baird's attic rooms, waiting while groups of six entered to see the "faint and blurred" images of Stookie Bill and live talking heads. The "play of expression on the face" was apparent even to the reporter and led one television expert in the audience to admit, "Baird has got it. The rest is merely a matter of pounds-shillings-pence" (Burns, 2000, 90; Fisher and Fisher, 1996, 59).

Or so Hutchinson would have the public believe. He told one reporter that he had already ordered the construction of 500 "televisors," which would be sold for £30 and, when connected to a home radio, allow consumers to "look-in" as well as "listen-in." This was unlikely as he had yet to hear about the broadcast application and had no funds with which to pay a manufacturer. Perhaps the negotiations for a share of the business in return for the production of receivers explained the evaluation of Baird's system by an anonymous engineer in April 1926. Baird's Nipkow disc used 32 bull's-eye lenses from bicycle lamps, which scanned an area ten inches high and eight inches wide. This image was resolved down to a display one-ninth as



The second face captured on John Logie Baird's version of a Nipkow-disc television system was that of investor Oliver Hutchinson, in 30-line definition, in 1926. David Sarnoff Library, from Alfred Dinsdale, *Television* (1926)

large, although a magnifying lens could double it. Was the picture commercially appealing? The engineer could make out various facial movements but wrote that

> it would be very difficult to recognize an individual previously unknown . . . . The apparatus as now developed gives a crude image which is not even physically pleasant to view . . . . While the existing type of apparatus would undoubtedly achieve a temporary market the public would heartily tire of the results . . . . Those well-known personalities . . . would be scared off television by the present reproductions so that deserving developments later on would be hampered in securing support. (Burns, 2000, 92, 93)

More demonstrations and publicity followed, including a full page in *The New York Times* in March and a visit early in February from the Admiralty's leading television researcher. He failed to find a practical solution to the use of television in aerial reconnaissance by June 1926, but he was impressed by Baird's accomplishments and encouraged him to replace the selenium cell with a thallium sulfide photoelectric cell, which offered more sensitivity and a greater frequency response. In July, Alexander Russell, a fellow of the Royal Society, reported in *Nature* that his visiting group saw "living human faces, the proper gradation of light and shade, and all movements of the head, of the lips and mouth and of a cigarette and its smoke faithfully portrayed. . . . Naturally the results are far from perfect" (Burns, 1998, 165).

The next step was transmission over the air. Baird would have to transmit video over AM radio frequencies of 5 kHz; basing his calculations on reproducing the human face, he calculated that recognizable images could be picked up, broadcast, and displayed in a 30-line scan with 7:3 aspect ratio, sent twenty-five times every two seconds. He obtained an engineer's permission to use a BBC transmitter, and broadcast three times before a manager put an end to the unauthorized tests. With the approval of the Postmaster General for the experimental television broadcasts on July 15, however, Baird and Hutchinson could begin transmitting from the roof of Motograph House in Long Acre, London. To pay for it, Hutchinson filed to expand the company's capitalization to £9,050, or nearly $50,000. By the end of 1927 in a booming stock market, he had attracted 43 investors, and was preparing to make television a commercial reality.

Debate continues on the relevance of Jenkins's and Baird's work to the electronic systems that nations began adopting little more than ten years later. Their work spurred the first boom in television in the late 1920s and early 1930s, when the novelty of receiving moving pictures appealed to thousands of radio enthusiasts. Compared to the market of tens of millions of radio listeners and the quality of programming available to them, however, their embrace of the technically limited systems meant nothing. It had no bearing on the development of or marketing for electronic television some fifteen years later, save for awareness that the quality would have to be significantly higher in many respects. A useful analogy is the story of Lev Termen, who developed and demonstrated a 64-line system for his doctoral thesis at the Polytechnical Institute in Leningrad in June 1926. The Soviet Union abandoned mechanical television and purchased a complete electronic system from RCA in 1937. Nonetheless, those self-selected few working with these inventors saw live television before anyone else on earth.

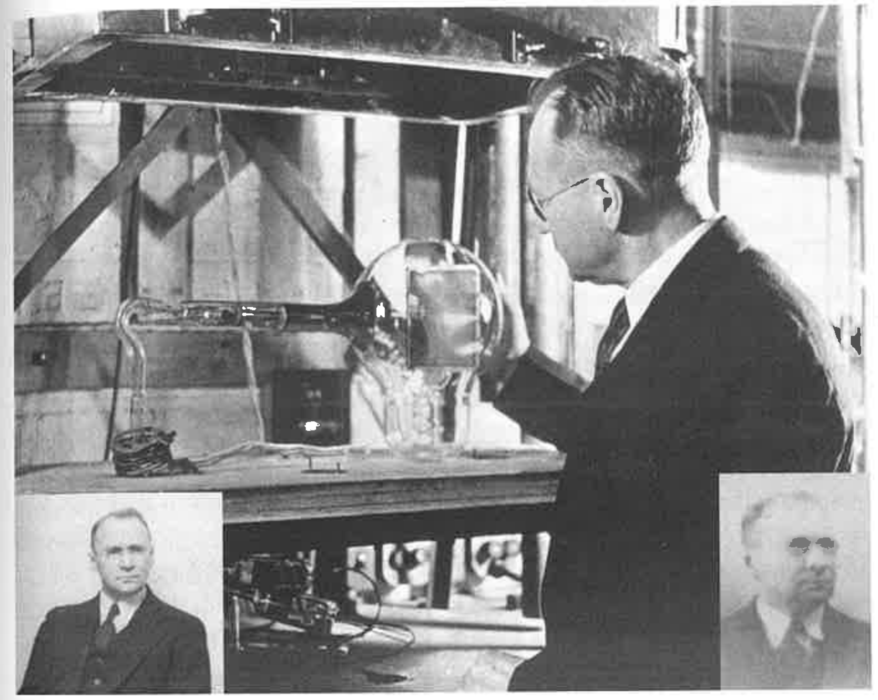
on one side of a photoelectric mosaic while an electron beam scanned the other. Now Zworykin and his team tried another of Tihanyi's proposals and suggested a single-sided approach, where the light from an image and the scanning electron beam both struck the same surface. It was a counter-intuitive suggestion, since one could expect the electron beam to destroy the photosensitive surface's storage capacity.

To his team's surprise and for reasons never satisfactorily explained, a tube with a surface consisting of insulated silver rivets made by Harley Iams, Les Flory, and Sanford Essig gave promising results. The next challenge was a practical surface, since scaling up the number of rivets promised to be expensive. The group tried various ways of depositing and insulating silver particles as pixels, but in July Essig made a serendipitous mistake by over-baking the image mosaic to accomplish the breakthrough. By November RCA filed the first patent for Zworykin's Iconoscope, and over the next two years his seven-man group refined the techniques for fabricating the components and assembling them into a practical tube. RCA announced Zworykin's breakthrough in June 1933, leading to publication of an article in multiple technical journals and a European tour for the scientist.

THE PROBLEMS WITH PATENTS, 1932–1938

RCA also began buying up the patents of international inventors of numerous, unbuilt, single-sided, camera tubes. It could not, however, buy up Farnsworth's image dissector patent position. Instead it tried to disallow the claim to an electrical (i.e., electronic) image in the inventor's 1930 patent, number 1,773,980. In May 1932, the Patent Office declared an interference claim on behalf of Zworykin's still-pending 1923 application against Farnsworth's patent for a television system using an electronic image. RCA's lawyers asserted that Zworykin had explained his concepts to fellow Russian émigrés as early as 1919; Farnsworth's lawyers claimed that Zworykin "had shown no conception of an operative device prior to Farnsworth's patent" and therefore his application could "not constitute a reduction to practice" (Godfrey, 2001, 74). The case against the legitimacy of Farnsworth's claim rested on three issues: the date of conception, for which Farnsworth's lawyers produced both his teacher Justin Tolman and Farnsworth's 1922 drawings; the date of reduction to practice, meaning here the application date for the relevant patent; and the date of the device's operation.

On the first test, RCA's lawyers convinced the patent examiner that Tolman's testimony was "vague and incomplete," the 1922 sketches too



Vladimir Zworykin examines a freshly evacuated iconoscope camera tube in RCA Victor's lab in Camden, New Jersey, sometime in 1934–1935. The first video imaging device to store light as electronic charges between scans, the iconoscope improved television-camera resolution by an order of magnitude. Compare the photo of Zworykin on lower left with the televised image on the lower right, with John Logie Baird's Nipkow-disc image on page 36. David Sarnoff Library

crude. On the second, Zworykin had obviously filed his application four years earlier than Farnsworth (Stashower, 2002, 216). The court concluded, however, that testimony by and on behalf of Zworykin regarding the date of operation was "not convincing" (Godfrey, 2001, 75). The physicist was too honest to dissemble on what he proposed in 1923 and what he understood later about charge storage, regardless of Westinghouse's efforts to backdate his 1925 insights into the earlier application. Moreover, for reasons known only to the legal counsels for Westinghouse and RCA, the latter company could not draw on Westinghouse's internal reports or the 1925 tube. The history is not clear, but the two corporations had their own conflicts over the rights to Zworykin's television work in East Pittsburgh before 1928. Meanwhile Farnsworth's lawyers used his notebooks to document the operation of his system in 1927 and 1928 using the electrical image that was at the heart of the case.

In July 1935, the examiner ruled for Farnsworth. Zworykin's 1923 application had no right to claim an electrical image as defined in Farnsworth's patent because Zworykin did not originally specify the "discrete globules capable of producing discrete space charges" and therefore did not generate "an electrical image that is scanned to produce the television signals" (Fisher and Fisher, 1996, 236). These were original to his 1925 patent, but RCA had to defend the earlier application because of the patent claims filed by other inventors in the two years between Zworykin's applications. RCA regrouped, rearranged its arguments, and appealed the decision to an appeals board in January 1936, only to be denied in March.

RCA's attempt to claim the concept of electronic video imaging had backfired. In a triumph for lone inventors with good lawyers, Farnsworth gained priority for a basic component of any television system where the image would be moved through vacuum inside a camera tube. The iconoscope did not require this feature, but as the 1930s wore on, it became clear to RCA's technical staff that the next generation of camera tubes would draw on Farnsworth's electronic image and low-velocity scanning.

Sarnoff and RCA could have pursued their case in the civil court system but did not. A version of Zworykin's 1923 application eventually issued to Westinghouse in 1938, and RCA, Farnsworth, and other inventors continued to contest claims to other basic aspects of electronic television, including the storage principle and low-velocity, interlaced, and sawtooth scanning techniques. Despite claims that Farnsworth's company lost licensing opportunities because of the patent interferences, RCA had done him a favor. While there was no prospect of a market or a broadcast standard in the mid-1930s for even a working system, RCA established Farnsworth as the source for several essential television patents. Licensed access to these provided Farnsworth's only profit through 1938: $69,000, against $1,034,000 in expenses.

Compared to Farnsworth's costs, 15 percent of which paid for filing patents and defending and asserting the basic claims therein against other people's patents, by 1940 RCA had spent over $9,250,000 on television. Patent expenses accounted for 23 percent of this sum, and $2,650,000 represented research and development costs. The rest paid for field tests, manufacturing costs, and NBC's program expenses. Yet the return on all of this rode on concepts that were legally if not uniquely Farnsworth's. RCA had to include him in the patent pool it shared with GE and Westinghouse. After lengthy negotiations, led by an ex-RCA patent licensing executive, Farnsworth's company negotiated the first nonexclusive patent exchange agreement with RCA in October 1939. After nine years, Farnsworth had

finally gained access to an exclusive club of major American corporations at a fraction of the cost RCA invested in the system.

SYSTEMS ENGINEERING AT RCA, 1931–1937

Television is more than a camera and display. Engineers have to integrate those devices with each other through a transmission system that synchronizes and amplifies the video and audio signals, maintains the frequencies, or channels, on which they are broadcast, and overcomes noise and interference from sources internal to the technology and external to the channel. This system, the "black box" understood only by technical experts, interacts with and is subsumed within the broader systems of commerce, politics, and art. The national government, since it controls the electromagnetic spectrum that envelops its citizens, has to decide where to set the standard for transmission, reception, and quality of television broadcasts. Economically, these technical requirements are tied to the cost of the equipment: the receiver to the home consumer, the studio and transmitter equipment to the radio station investing in the new technology. These costs are tied esthetically to the quality of the programs that justify the system in the first place. Production of television content fell between the sophistication of Hollywood film production and the faster pace and smaller budgets of the radio station. Directors, writers, camera operators, lighting and set designers, makeup and costume specialists, sound engineers, and their staffs all had to work out acceptable levels of quality in their fields for national and local programming.

Developing the system and the data necessary for evaluation is an interactive process. Information from early component and system field tests contribute to the calculations of ideal requirements; further tests result in feedback to the requirements, revealing new approaches, improvements, or limitations that the researchers have to address. There may be bottlenecks in particular subsystems that hold back the overall output, but they can also result in leading-edge technologies that overcome flaws elsewhere in the system. The system should be greater than the sum of its parts as engineers and scientists exploit complementary advantages among components and minimize their flaws.

Throughout the 1930s, under Sarnoff's leadership and with corporate financing, RCA pushed steadily forward with the design, development, and testing of an electronic television system suitable for broadcasts across a continent. Led by Elmer Engstrom, RCA's engineers carried out five field tests between 1931 and 1937. It was an incremental process of increasing knowledge through practice and it ensured that the system RCA would propose to the federal government would operate as expected at an objectively derived level of quality. The investment in these tests established the value of the system, the equipment that RCA would make and sell, and the patents that it would license to the rest of the broadcast and radio industries. What was the goal? The television committee of the RCA-influenced Radio Manufacturers Association (RMA) in 1932 wanted reasonably priced, "quiet and satisfactorily illuminated picture equipment for the home" (Slotten, 1998, 82).

The first test, in 1931–1932, used broadcasts from the new Empire State Building and represented the last gasp of Nipkow television at RCA. For it became apparent that Zworykin would not meet his deadline and that 120-line Nipkow television would not provide the quality of reception desired. One benefit was RCA's discovery that the so-called very high frequency (VHF) region of the electromagnetic spectrum, between 40 and 80 MHz, was acceptable for television broadcasting, despite the interference from motor ignitions. This was significantly higher up the spectrum from the 2 to 3 MHz used in earlier transmissions and it indicated that there was space for high-definition television as well as radio on the airwaves. But, as Engstrom wrote, "an image of 120 lines was not adequate unless the material from film and certainly from studio was carefully prepared and limited in accordance with image resolution and pickup performance of the system." In addition the increasing brightness of the CRT in the receiver resulted in screen flicker that "was considered objectionable" at 24 frames per second (Burns, 1998, 412).

Two years later Engstrom's groups staged two more tests, this time in Camden. The first, early in the year, featured the debut of the iconoscope with its 240-line, 24-fps video. The second involved a wireless relay of video at 44 MHz from the Empire State Building to Arney's Mount, New Jersey, and then 79 MHz to Camden. The engineers put the cameras on themselves, test patterns, cartoons, movies, and outdoor subjects, and concluded that they needed to increase the power of the transmitter, increase the definition of the image, and resolve the annoying flicker that appeared at 24 fps with the ever-brighter kinescopes.

The second issue posed an interesting question: how much definition was necessary for moving images on a television to match the quality of motion picture film? During the 1933 tests, Engstrom carried out a series of experiments with volunteers to answer this based on visual acuity, just noticeable differences in resolution, the size of the display, and the viewer's distance from the display. His results confirmed what others had calculated

for televised stills, that around 400 lines offered the equivalent of home movies shot on 16mm film.

During another set of tests in 1934, RCA increased the definition to 343 interlaced lines and the frame rate to 30 per second. Randall Ballard applied for the basic patent in electronic interlaced scanning, in which the electron beams scan odd and even lines in alternate frames. The human eye blends two consecutive frames into a complete image, thanks to the retention of vision. Interlacing requires an odd number of lines and processing is eased by using numbers comprised of odd factors less than ten: thus 343 equals $7 \times 7 \times 7$. Using 60 fields with half a picture, thus reduced to 30 flickerless frames, in this arrangement also avoided interference with the national power grid frequency of 60 Hz because the frame rate is one of its divisors. The company's engineers also developed an electronic impulse generator to handle synchronizing and blanking signals, finally making RCA's system completely electronic.

In May 1935 Sarnoff announced during RCA's annual meeting a million-dollar plan to field-test RCA's system in the New York area. This included construction of a state-of-the-art transmitting station in New York City; manufacture of about 100 receivers for observation of the reception up to 45 miles away in the metropolitan area; and development of programming to test studio broadcast techniques. Two weeks later, RCA began 4MHz field tests from its Empire State Building transmitter. Studio production and motion picture scanning took place at NBC Studio 3H in Rockefeller Center, which was wired to the transmitter through both a coaxial cable and a UHF microwave signal. RCA executives and engineers watched a picture a little more than five by seven inches in area. The tests helped RCA's research staff improve the transmitter and receiver antennas. They also simplified circuitry that reduced the effects of electrical interference and multipath distortion, or signal reflection, off buildings. By the tests' conclusion in 1937, RCA had raised the frame definition to 441 ($3 \times 3 \times 7 \times 7$) lines, and its executives petitioned the FCC for approval of a standard.

SETTING A STANDARD, 1928–1938

The question remained, how high was high enough for the definition of the image? Without a standard answer, no one could invest in any network infrastructure or component production with any certainty, and the household consumer would not buy a receiver that would become obsolescent as the definition increased. RCA had an answer that not everyone in the industry agreed with. Neither Philco nor Zenith, as leading radio manufacturers, nor DuMont, as an aspiring television company, wanted it to monopolize television technology. The correct standard for television was a question to be settled by the U.S. government.

The Federal Radio Commission (FRC) had initially permitted experimental broadcasts using 10-kHz channels in 1927. A year later Charles Jenkins began campaigning for a television standard and commercial licenses. The RMA's Television Standardization Group supported a 48-line, 15-frame system in which scanning of images took place from left to right, top to bottom, in keeping with the clockwise motion of the Nipkow spiral. The RMA also recommended 60-line transmission, which ignored Sanabria's 45-line broadcasts in the Chicago area. All of these formats raised questions about a synchronization standard: was it to be part of the transmitted signal or resolved by the viewer with a remote control?

If the FRC had agreed in 1928 to a standard based on the RMA's assertion that "a large potential audience in the broadcast band is already at hand," then television would have been frozen in a very crude form indeed in the United States (Udelson, 1982, 43). The FRC declined to rule, however, asserting the need for an acceptable public standard, and that bar kept rising with the claims and demonstrations of various inventors and companies. The FRC did, however, retain the left to right, top to bottom scan that is still used today, the legacy of the nineteenth-century graduate student in Berlin.

Based on a recommendation for minimally acceptable video by RCA's laboratory director, Alfred Goldsmith, the FRC began licensing five 100-kHz channels in January 1929 in the shortwave spectrum between 2 and 2.9 MHz. RCA's researchers published the first article on the technical standards necessary for commercial television that September. Because television stations several hundred miles apart and on the same channel still interfered with each other's signals, it became clear that more bandwidth would be necessary for "true television service of permanent interest to the public" (Udelson, 1982, 41). By 1931, the FRC added three experimental VHF channels between 43 and 80 MHz, with bandwidths between 1.8 and 20 MHz.

The FRC, which Congress reorganized as the Federal Communications Commission (FCC) in 1934, continued to encourage the radio industry to agree on a standard before asking for government approval. Late in 1935, after a tour of RCA's, Philco's, and Farnsworth's labs and demonstrations, the FCC concluded that the companies needed to improve their systems further. A year later it opened hearings on the issue at which Sarnoff laid out RCA's position. RCA had already demonstrated its complete system in April 1936, where research supervisor Ralph Beal said that "home television is at least eighteen months away" (Abramson, 1995, 150). Sarnoff, therefore, felt no urgency for commercialization. In his statement, he balanced RCA's interest in the allocations of higher frequencies of the electromagnetic spectrum for experimentation, while the public enjoyed current technology in the lower-frequency regions once manufacturers and the government agreed to a standard.

Some competitors were less certain than Sarnoff that RCA's standards or preferred pace of innovation should set the course for television. Eleven companies, most of which had not worked on television technologies, asked the FCC how far RCA's control of broadcasting "will be allowed to extend into the television field" (Slotten, 1998, 84). The FCC kicked the technical issues back to the RMA for resolution while it evaluated the social factors, most of which boiled down to an affordable system for the average American, and the interests of other industries—the press and Hollywood, as well as radio—in seeing innovation take place slowly, if at all.

RCA had already recommended the RMA involve itself in the development of the new system. In the mid-1930s, seven companies were involved with the technology: RCA, Philco Radio & Television, Farnsworth Television, Allen B. DuMont Laboratories, GE, Don Lee Broadcasting System in Los Angeles, and Zenith Radio Corporation. With the exception of Farnsworth, RCA aided the others by providing information from its research, testing licensees' equipment, free consultations on design issues, and service as a clearinghouse for hundreds of new patents relevant to television.

The RMA's Committee on Television began meeting in April 1936. Members, besides RCA's representatives, included engineers from Farnsworth, Philco, Hazeltine Service Corporation, and Bell Telephone Laboratories. RCA feted the other members with demonstrations and a lavish banquet in July at which Sarnoff praised his competitors at Philco and Farnsworth: listeners "mustn't think that RCA was everything in television" (Stashower, 2002, 221). On the basic question of a broadcast standard, the committee adopted Philco's recommendation for a 6-MHz bandwidth for each television channel, and something more than 300 lines per frame interlaced sixty times a second. A month later, the committee agreed on 440 to 450 scanning lines with a 4:3 aspect ratio for the display, which also happened to be the ratio for 35mm film.

While the broadcasters, manufacturers, and government debated how to broadcast television, RCA began transmitting on the RMA standard up to 90 miles away in June 1937, and demonstrated it to thousands of visitors to NBC in Rockefeller Center. When RCA introduced its 441-line television to the Society of Motion Picture Engineers convention in

October, the screen was far brighter, in black and white rather than the black and green, thanks to Humbolt Leverenz's new phosphors, with a 7-inch by 10-inch display. Sarnoff, who addressed the society, also announced a projection system for theatres, which provided a video image 12 feet square. By 1938, scientists and engineers had improved the sensitivity of the iconoscope by a factor of twelve in six years.

In December 1937, close to the timetable RCA's Beal predicted in 1935, the RMA committee forwarded its standard to the FCC. Most of the membership regarded it as provisional, good for use during continued field experimentation with transmitters and receivers. Yet within that standard, described as flexible enough to permit technical improvements, RMA members continued to disagree. During the spring of 1938, RCA even sided with Farnsworth on one issue, and against it on another. As the group settled some technical issues, other issues arose, and the number of television subcommittees rose over 1938 and 1939, complicating the prospect of agreement.

For Sarnoff, the only obstacle to commercialization now was the development of programs, not more technology. He had already begun to argue this point but, with the economic recession in 1937, did not push the point. Over 1937–1938, however, NBC staged over 250 studio broadcasts; in 1938, RCA and NBC engineers began testing mobile television units in New York and Washington, DC, that could transmit live video feeds on location by microwave dish back to the transmitter.

THE BIRTH OF AMERICAN TELEVISION BROADCASTING, 1939

To prod the FCC among manufacturers and the public, Sarnoff told the members of the Radio Manufacturers Association (RMA) in October, 1938, that RCA and NBC would begin regularly scheduled television broadcasting with the opening of the New York World's Fair in six months. "Television is now technically feasible," he asserted. "The problems confronting this difficult and complicated art can be solved only from operating experience" (Bilby, 1986, 132). The broadcasts would cover only the 50-mile radius around the Empire State Building and take place for two hours a week, without advertising, since NBC would be using its experimental license until the FCC approved a standard. The Columbia Broadcasting System (CBS), which had bought an RCA transmitter and installed it atop the Chrysler Building, was rumored to be considering regular television broadcasts, and Sarnoff urged manufacturers to take advantage of their licensing

agreements to draw on RCA's intellectual, technical, and production facilities for making their own receivers.

Was this the best way to resolve the debate? Sarnoff made his decision based on the advice of his technical, manufacturing, broadcast, and marketing executives. If they were ready to produce a system meant for a mass market, so was he. He also knew too well that he had pushed RCA's board to invest ten million dollars in television's innovation over the last twelve years. Finally, he acted on pride, alternately reluctant to admit that some of the opposition might have a point about refining the standard that RCA and the RMA proposed, and furious with resistance based on impractical technologies and corporate self-interest.

Exactly six months later, on a brisk and cloudy afternoon in front of the RCA pavilion at the fairgrounds in Queens, David Sarnoff ignored the raw April weather and read a 7-minute speech to an NBC television camera and microphone. A few chilled engineers and assistants watched nearby, and about 100 people watched Sarnoff speak on RCA's new TRK-12 televisions at the RCA Building in Rockefeller Center. It was actually ten days before the Fair's official opening but Sarnoff always had a strong sense of anniversaries. "Today we are on the eve of launching a new industry based on imagination, on scientific research and accomplishment. . . . Ten days from now this will be an accomplished fact" (Sarnoff, 1968, 100).

On April 30, President Franklin Roosevelt opened the Fair as the first president on television. For the next eighteen months, thousands of visitors trooped through RCA's exhibits and saw a live television pickup of those behind them. They also saw RCA's $995 receiver, its cabinet crafted from transparent Lucite plastic, with its 12-inch CRT pointed vertically at a mirror on the underside of the cabinet lid. Over the next year, NBC televised 601 hours of programming to its New York audience. RCA, GE, DuMont, Philco, and a couple of other manufacturers rolled out sets in the spring of 1939, while others began planning for production in the next year.

Few consumers bought the receivers at prices between $400–600, however; radios and phonographs sold for $10–250, and one could hear an enormous amount of professional content on either system. By comparison NBC broadcast live day-time events like college sports and fashion shows from department stores, and evening programs featured boxing and ice hockey from Madison Square Garden along with old movies, none of which cost much to produce. In addition, beyond the uncertainty of the FCC's stand on commercial standards, Germany's invasion of Poland on September 1 changed the focus of RCA's manufacturing and research activities. Two days later, Sarnoff ordered RCA production divisions to begin

On a cool and overcast April 20, 1939, RCA president David Sarnoff stood in front of the RCA Pavilion at the New York World's Fair in Queens and announced the beginning of regularly scheduled, electronic, television broadcasts in the United States. Several hundred viewers watched him on 441-line, monochrome, 12-inch displays. Sarnoff's move served to focus the Federal Communications Commission on approving a 525-line broadcast standard in 1941, based on RCA's ten years of innovation. David Sarnoff Library

reorganizing to meet the needs of the armed forces. Consequently, RCA Victor's sales division curtailed earlier ambitions for the innovation of television. Instead of 75,000 receivers, it hoped to sell 25,000 in 1940; by the spring of 1941, when RCA stopped making home television sets for the duration of World War II, it had sold not more than 2,500 receivers.

Yet the company continued to encourage other companies to join in, providing portable equipment to the Don Lee Broadcasting System in Los Angeles; demonstration equipment to Westinghouse, Bell Labs, and Stromberg-Carlson; receiver components to Zenith Radio; and CRTs and related equipment to amateur enthusiasts. On October 2, RCA signed a nonexclusive cross-license agreement for patents with Farnsworth Television, which added another ally to RCA's marketing efforts. The sooner consumers saw televisions for sale, the sooner Farnsworth could receive his royalties.

RESISTING A STANDARD, 1940–1941

As the RCA-led rollout languished, however, one industry newspaper called it "Sarnoff's Folly" (Fisher and Fisher, 1996, 289). Meanwhile the standards on which the RMA committees had been working came under new criticism. Over the previous three and a half years, the RMA standards groups agreed unanimously or voted with a strong majority for one approach over another. Philco now recanted its earlier approval on several issues and DuMont, which never joined the RMA, claimed that it could raise the number of lines per frame from 441 to 625 and adjust the scanning standard and frame rate frequency across a wide gamut of options. Sarnoff was furious, calling the opponents "scavengers" and "bloated parasites who feasted on the products of RCA research" (Stashower, 2002, 223). In return Zenith ran an ad that showed him as a "Televisionary" King Kong, destroying the radio industry (Bilby, 1986, 132).

The FCC began new hearings on the standards in January 1940. It revisited the RMA's process and focused on the fear that a standard fixed too soon would prevent further technical innovation. While most of the RMA's members favored limited commercial broadcasting with the current standards, Zenith joined Philco and DuMont in opposition. CBS, the other leading broadcaster, could not offer the FCC an opinion on what to do, but its chief executive, William Paley, had little interest in buying television equipment for the network. RCA reported optimistically on the sale of 130 receivers at reduced prices using installment payments, and predicted that manufacturers could sell 25,000 sets in 1940, 60 percent of which would be RCA's.

The commission's continued indecision reflected in part the rotating chairmanship of the 1930s, and now reflected the politics of its new chairman, James Fly. Fly's long experience with the exploitative nature of electric power utilities while working for the Tennessee Valley Authority gave him a deep dislike of monopolies. RCA and Sarnoff's behavior with regard not only to television technology, but to its control of two NBC broadcast networks, reinforced this attitude. Consequently he was only too eager to believe the claims of television entrepreneur Allen DuMont that he could build a receiver compatible with a wide range of frame rates and scanning lines, and then Peter Goldmark's suggestion that the country move straight to color.

On February 29, the FCC issued an Order for the regulation of telecasting without deciding on a standard. The Order reflected what the commission saw as insufficient consensus among the RMA's membership. It declared that "emphasis on the commercial aspects of the operation at the expense of program research is to be avoided," and established two types of television broadcast stations: one for experimental research and the other for experimental programming (Slotten, 1998, 93). The FCC feared that establishment of a standard while permitting expanded programming would result in a frozen technology, with no incentive on the industry's part to continue to improve the quality of the system. It also warned members of the industry—that is, RCA—from trying to establish a de facto standard, but encouraged them to broadcast an undefined but "limited" amount of commercial programming (Udelson, 1982, 148).

Sarnoff met with Fly early in March. He explained RCA's plans for making and selling up to 25,000 receivers in the New York area in conjunction with its limited commercial broadcasting from WNBT in September 1940. After seeing the newspaper ad that RCA would use to promote the sale, Fly complimented Sarnoff on the plan. He was less pleased when the campaign began in March in the *New York Times* and *Herald Tribune*. The FCC promptly eliminated the experimental programming licenses and called for new hearings in April. Its press release accused RCA of doing what the February order warned against, harming the public by intimidating its competition into abandoning innovation at the same time that it threatened to leave large numbers of the public with obsolete sets.

Major newspapers in New York, Philadelphia, and Washington, DC, criticized the overregulation of the FCC and its "alien theory of merchandising." Distributors and merchandisers decried the loss of new jobs as a result of the decision. Fly's categorization of CBS and Philco as the "little fellows" bullied by "Big Business" rang hollow to many observers

(Udelson, 1982, 149). It also drew the attention of Senator Burton Wheeler, who called the principals, in particular Fly and Sarnoff, in for a hearing before the Interstate Commerce Committee.

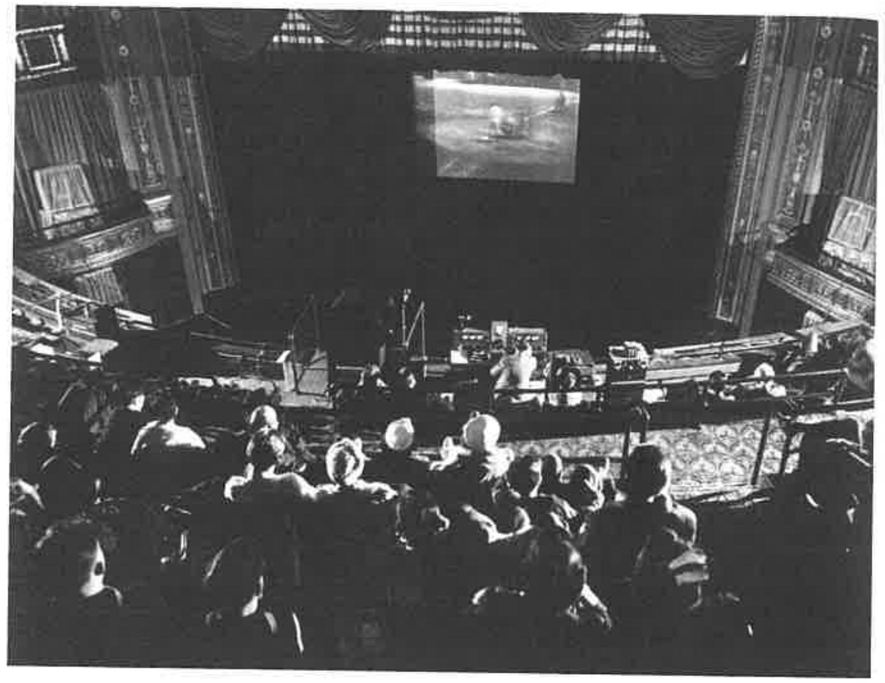
Fly had already opened the new FCC hearing by emphasizing that it was not intended to cover new ground or the design or marketing of receivers, but whether commercial activity in programming and receiver sales would freeze the "art" of television. It was a curious way to justify a hearing just five weeks after the first one, and he had some difficulty explaining it to the senators. Fly likened television systems to those involving a lock and key. If either is changed, the other is useless, and Fly wanted to give Philco and DuMont the benefit of showing whether their latest innovations would improve the standard before establishing one based on RCA's work of the previous ten years.

Besides RCA, DuMont, Farnsworth, GE, and Zenith had designed receivers for the RMA's 441-line, 30-frame interlaced standard. Philco and DuMont still opposed adopting that as the FCC standard, favoring lower frame rates and higher line densities per frame. For them, the possibility of increased flicker with lower frame rates and the need for a dimmer picture to mask it was offset either by DuMont's claims for its phosphors or by the need for higher line densities for the large picture tubes in development. Witnesses agreed that they could build receivers that could receive two or more standards but disagreed on the additional cost. They also generally agreed that they could improve the quality of reception significantly within the RMA standards.

To show that it was continuing to innovate, RCA demonstrated the state of its current work in television, including microwave relays, antennas, phosphors, picture tubes, its new Orthicon camera tube, and a 15-inch by 20-inch home projection television. Of the 600 engineers and scientists employed in electronic research at RCA, 100 worked on television, half of them full time; 40 more developed and designed commercial equipment. Sarnoff, asked by President Roosevelt to have lunch with Fly, refused: "Mr. President, this problem is not in the stomach but in the head. There's no room for compromise. The public either will or will not be allowed to have television" (Lyons 1966, 220).

THE NATIONAL TELEVISION SYSTEMS COMMITTEE, 1940–1941

To resolve the impasse, Fly asked Walter Baker, a vice president at GE and the RMA's director of engineering, to organize a new standards group,



Acutely aware that the new television industry would need prerecorded content to fill expanding hours of broadcasting, RCA tried to convince Hollywood that television could help the movie business. In the winter and spring of 1941 it allied with Twentieth Century Fox to screen live events using a high-voltage projection TV in the balcony of the New Yorker Theatre on 54th Street in Manhattan. David Sarnoff Library

the National Television Systems Committee (NTSC) that would be more inclusive than the RMA. Baker invited all interested and technically competent parties to join, and documented their discussions with printed minutes of each meeting. Forty-one companies participated in the NTSC's work under nine subcommittees, which began technical and subjective tests on the proposals made in the April hearings. Staff used lab space at RCA, GE, Philco, Hazeltine, and DuMont for eight months to examine signal synchronization, scanning lines and frame frequency, AM and FM sound, color television, and UHF transmitter range.

The NTSC submitted its report to the FCC in January 1941; the major change involved using FM for the sound channel. Color television, which CBS had demonstrated using a three-color filter wheel on a wider ultra-high frequency channel, was tabled but encouraged in further research. It also rejected DuMont's flexible standards. Again, DuMont, Philco, and

Zenith dissented, leading to another hearing in March. Only at the start of this hearing did NTSC consultant Donald Fink recommend increasing the scanning density to 525 lines (3 × 7 × 5 × 5) from 441. The increase had been possible since RCA's George Brown invented a vestigial sideband filter in 1938 that nearly doubled the horizontal resolution possible in a given bandwidth. Tests on viewers at Bell Laboratories showed that different line densities represented a trade-off in horizontal resolution, from side to side, and that few people noticed the difference between the two choices—at least on contemporary CRTs.

On May 2, the FCC finally approved commercial television broadcasting, effective July 1, for eighteen 6-MHz channels using 525 lines per frame, 30 interlaced fps, and FM sound. Aside from shifts in channel assignments in the electromagnetic spectrum, the 1941 standard remained the basis for analog television broadcasting in North America for the rest of the century and beyond. Each station was obliged to run at least 15 hours of video a week. Only WNBT in New York committed to that quantity before the war and began telecasting sponsored by, among others, Sunoco gasoline and Bulova watches. The latter's ad, the first, featured a clock face ticking for a minute; NBC charged four dollars for the afternoon spot and eight dollars in the evening.

Yet when the Federal Communications Commission approved the television standard, RCA's attention was elsewhere. Beyond servicing the television receivers already sold so that they could receive the higher number of lines, the company focused its sales efforts on established products. Its telecasts through NBC did not reach beyond the 5,000 receivers in the New York City area, and it engaged in little professional studio production for two reasons. First, it was expensive, and second, it was still extremely hot for performers under the lights needed to pick up a suitable image. Farnsworth's image dissector had required over 94 kilowatts of lighting indoors; early iconoscopes required one-fourth that amount, or about 240 100-watt light bulbs. Hugh Downs, who read the news once for the 400 television owners in Chicago in 1943, recalled that he had once "looked, momentarily, on the face of the sun itself. Never have I felt such sheer withering force of light as I felt during that tormented quarter-hour" (Ritchie, 1994, 94).

The solution to practical cameras lay on the one hand with incremental engineering, and on the other in the radical transformation afforded by a quite different application. RCA's staff had pushed television from non-standard low-definition imagery to the cusp of mass-market quality in just over ten years. But its official birth in 1941 resulted in a stillborn infant. Over the next four years, the interruption in commercial service caused by the American entrance into World War II led to far better cameras and an improved, cheaper, and finally profitable system. We can measure its success by its durability and persistence as a framework for later standards. As we will see in the next chapter, however, that successful life was not predetermined.