5b[†] Television and Video: Sampling Spacetime

Annotations–Bibliography–Picture Credits–Acknowledgments–Endnotes

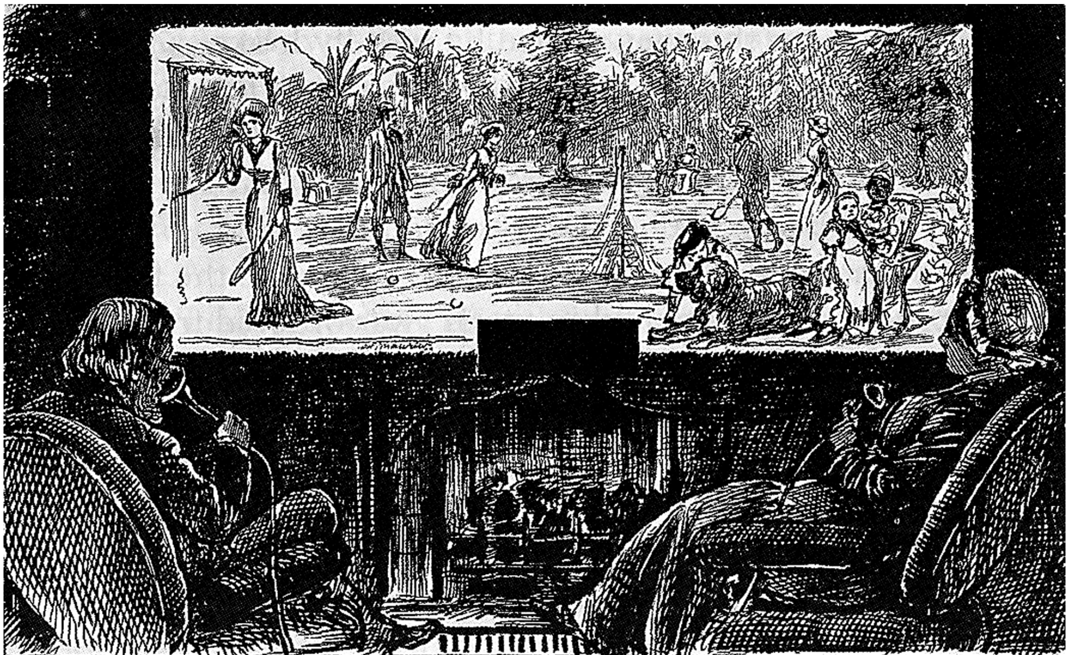


Figure 5b.1

Every evening, before going to bed, Pater- and Materfamilias set up an electric camera-obscura over their bedroom mantel-piece, and gladden their eyes with the sight of their Children at the Antipodes, and converse gaily with them through the wire.

Paterfamilias (in Wilton Place). Beatrice, come closer, I want to whisper.

[†] This chapter was originally Chapter 6 in the manuscript of my book, *A Biography of the Pixel* (MIT Press, 2021), where Chapter 5 was devoted to Movies and Animation, Chapter 6 to Television and Video, and Chapters 7 and 8 to Digital Light. It was dropped from the final publication to shorten the book to marketable size. Here I awkwardly rename it Chapter 5b to indicate its logical ordering within the book had it been included in the published version.

Beatrice (from Ceylon). Yes, Papa dear.

Paterfamilias. Who is that charming young Lady playing on Charlie's side?

Beatrice. She's just come over from England, Papa. I'll introduce you to her as soon as the Game's over?

— *Punch's Almanack for 1879*[1]

The Edison phonograph was so exciting that *Punch* readily attributed yet another wonderful invention, the telephonoscope (figure 5b.1), to the Wizard of Menlo Park. And he happily fed the fantasy with vague pronouncements about a "far seeing" machine that he was working on. But he wasn't. The closest approach he would ever make to it was the Kinetoscope peep show in 1892—and that was mostly W.K.L. Dickson's doing. Video conferencing, and then *Zoom*, wouldn't exist until full Digital Light arrived over a century later. But there were two dreamers on opposite sides of the world who, within just a few decades, did actually implement a non-interactive version of Punch's concept. They called it *television*.

One was Philo T. Farnsworth, whose melodiously corny name makes us chuckle. It captures his rural roots as a farmer's son in Idaho, a good, hard-working, home-grown Mormon boy. It's a perfect name for an innocent genius who would be the prey, and ultimately the victim, of television's great self-promoting tyrant, David Sarnoff.[2]

Vladimir K. Zworykin was the other dreamer, his name harsh to American ears. He came from a wealthy Russian Orthodox family whose land and large home were confiscated in the Russian

Revolution. He fled to America and lived most of his life here—perhaps longing for his native land but certainly not its government. Although he did all of his major work in the U.S., he never did rid himself of a pronounced Russian accent. Sarnoff celebrated him and crowned him the Inventor of Television, even if it wasn't quite so.[3]

We've met Zworykin before. The word *programming* was born in his office at a meeting with Johnny von Neumann. At the dawn of Digital Light, Zworykin's group of engineers rushed to create Selectron, a digital memory for von Neumann. But they lost the race for the first electronic computer memory to Freddy Williams and Tom Kilburn in England, who used their simpler memory design to build the first computer, Baby.

Twenty years earlier, though, another race important to Digital Light took place, the race to the first electronic television. Who won the television race? Was it Farnsworth, who won the official priority battles? Or was it Zworykin, touted as the Inventor of Television by the mighty Sarnoff in the marketing battles? Did Zworykin get at least one high-tech win in the 20th century?

National pride is at stake in the answer. Statues and stamps state the case (figures 5b.2 and 5b.3). There are two statues of Farnsworth in the U.S., including a strikingly lanky one in Washington in the Capitol Building's Hall of Statuary, but none of Zworykin. [N.B. this is no longer true, the Capitol's version has been swapped, scheduled for 2020, for a statue of the first Utah congresswoman.] And the U.S. issued a postage stamp featuring Farnsworth, but never Zworykin. There are two statues of Zworykin in Russia, one of them in Moscow. A former Soviet republic, Macedonia, issued a postage stamp in his honor.[4]

Because of Zworykin's nativity, Russians claim the invention of television. Is Vladimir Zworykin another Russian whom Americans don't credit, like Vladimir Kotelnikov? In a nationalistic sense, it doesn’t matter because the Americans win either way. We can count Zworykin as one of us, because he certainly did.

Figure 5b.2. Farnsworth’s statue in San Francisco (left) and Zworykin’s in Moscow.[5]

Figure 5b.3. Farnsworth (formerly) in the Capitol Building, Washington, DC (left) and Zworykin in Murom, Russia, in front of his family's home (top right), and their postage stamps. Zworykin's stamp (bottom right) features a drawing of his Iconoscope tube (1931).[6]

Russia isn't nearly so keen on claiming the other native, David Sarnoff. Nor would Sarnoff have ever admitted that he was Russian. He was born in a tiny shtetl Uzlyany near the big city of Minsk. Both are now in Belarus but were squarely in Russia's Pale of Settlement when he was born. The Pale was that part of the empire that was *for* Jews. Like most Jews, the Sarnoffs weren't allowed to live beyond the Pale. And Russians typically disclaimed Jews as Russians even if they were born in the empire. Sarnoff would never talk about his Russian origins—he hid his foreign birth remarkably well—but he remained a proud, practicing Jew the rest of his life.

The family was poor but talented. Both his grandfather and granduncle were rabbis—intellectuals—who soon spotted the boy's intelligence. He could be a rabbi too. By age five, they had guided him into Talmudic studies. He lived with the granduncle for four years of intense, lonely study, away from his family.

But then, at age nine, it all changed. In 1900 he emigrated to New York City to rejoin his father, leaving both Russia and rabbihood—and pogroms and poverty—far behind. His family joined millions of other Jewish immigrants who swept into America.[7]

After his father died, young Sarnoff took many jobs to help support his family. One would define his life. At fifteen, and freshly proficient in English from night school, he decided that he wanted to be a writer and determined to get a job at the New York *Herald*—as a reporter, of course. Sarnoff never thought small. By mistake he entered the wrong office in the right building. It was the Commercial Cable Company, and they immediately offered him a job . . . as a messenger boy. He grabbed it.

The Commercial Cable Company laid undersea cables and profited from transatlantic telegraphy. It was cofounded by the same man who owned the *Herald*, so it was really an extension of the newspaper. That was close enough for Sarnoff. He could chat with reporters when he delivered messages to them. But more importantly the clattering new technology surrounded and captivated him. He soon owned a key, mastered Morse code, and sat in with the telegraphers themselves, sending and receiving the news. But when he insisted on a three-day absence without pay to sing—a surprising and unheralded talent—in Rosh Hashanah and Yom Kippur services, Commercial Cable fired him.

Sarnoff lost no time. Key in hand, he immediately applied at a company that had just arrived in New York, t he American branch of the Marconi Wireless Telegraph Company. They hired him as an office boy—not as the telegrapher that he now fancied himself to be. The new job changed his life. It brought him into the orbit of Guglielmo Marconi, already famed as an inventor of radio and compared in legendary wizardry with Thomas Edison.

Marconi fascinated the young Sarnoff. Within months Sarnoff had, with sheer chutzpah, forced himself on the inventor. Marconi wasn't offended but rather liked the kid's style, and soon took him under his wing. Sarnoff reveled in the attention. He mastered the smart dress and social grace of his stylish mentor, whom New York women found particularly attractive. Sarnoff became Marconi's trusted messenger, smoothing the path between liaisons—a note here, a delivery of flowers there. Before long Sarnoff spoke impeccable English, and suppressed all evidence of his immigrant background.[8]

And the two of them discussed the wonders of wireless communication. Marconi gave Sarnoff full access to the technical files of the company, and little by little Sarnoff made himself invaluable. In later years Sarnoff would say of the surprising relationship, "We were on the same wavelength." In frequencyspeak, naturally. By the time radio broadcast had grown into a serious business, Sarnoff had been introduced to all the right people and was perfectly placed to take over.

The birth of RCA, the Radio Corporation of America, in 1919 was symbolic of that moment. The U.S. government thought radio technology was so important to the security of the country that it urged and blessed the formation of RCA. To keep radio technology in the U.S., it was intentionally designed as a monopoly. The large electric companies pooled their patents in this American creation, profiting from them while they maintained American control. These companies included General Electric—descended from Thomas Edison's empire—American Telephone and Telegraph (AT&T), and the American branch of Marconi Wireless Telegraph Company. It eventually even included GE's archrival, Westinghouse, where Zworykin worked. That's how

Sarnoff, on his march to the top of RCA, learned of the other Russian immigrant who would be fundamental to his television empire.[9]

While Farnsworth was still a teenager plowing fields in Idaho, Sarnoff was sitting in an office near the top of the Woolworth Building, the tallest skyscraper in New York City, as general manager of RCA. Sarnoff was just thirty. Only five years later NBC, the National Broadcasting Company, was formed as a division of RCA, and his name was among those on its 1926 charter. Two years later he was acting president of RCA, and two years after that its full president.[10]

RCA owned all the important radio patents—that was why it was created. Everybody else paid license fees to RCA. Every radio that was sold in America contributed something to RCA's earnings. It was indeed a monopoly and was eventually found guilty of abusing that status in Sherman anti-trust proceedings. As Sarnoff took on the nascent television industry, he exercised the same monopolistic patent practice that had worked so well for radio.[11]

And Sarnoff, true to tyrant ways, wasn't one to let truth get in his way, as an early example reveals. He claimed throughout his life that he was the lone telegrapher on the mainland who was in touch with the sinking *Titanic* during those last terrible hours of the great ship, its sole connection to the outside world. No historian believes him. His own biographer summarizes a careful analysis of the event with these words, which might caution us about star-quality tyrants in general and the media treatment of them:

> In Sarnoff's own mind, undoubtedly the equation between fact and legend blurred as he continued reading in reputable publications of his singular feat. When he told the story in later years, he told it with the ring of truth, which it had undoubtedly become in his inner conviction.[12]

Another infamous example of Sarnoff's duplicity is the Dempsey fight. Sarnoff claimed that he was responsible for the radio broadcast of the "battle of the century," a boxing match between Jack Dempsey and Georges Carpentier in 1921. In his version he enlisted the help of Franklin D. Roosevelt and the daughter of J. P. Morgan. But his version is almost entirely fictitious. The real organizer was Julius Hopp. Roosevelt and the Morgan daughter were involved but not because of Sarnoff. Farnsworth biographer Evan Schwartz says, "The Dempsey broadcast was just one of several episodes that David Sarnoff selectively edited, embellished, positioned, sharpened, backlighted, and recast with himself in the spotlight."[13]

Like Edison and later Steve Jobs, Sarnoff was a strong personality who created a thriving industry and a famous research lab, who marketed the claims of *his* inventors with amazing perseverance and ruthlessness, who pounded competitors with patents. And who, true to type, marketed the myth of himself at every opportunity. At the height of his mythmaking, Sarnoff had himself proclaimed the Father of Television. A better fit would have been Godfather of Television.

But it *is* true that he took NBC from a radio network to the giant broadcast television network that we know today. And he created the RCA Laboratories in New Jersey, now called the David Sarnoff Research Center.[14]

Yet the lanky statue in the Capitol Building declares Farnsworth to be the Father of Television, not Sarnoff. And not Zworykin, Sarnoff's handpicked Inventor of Television. In there lies the story. The pitched battle for television pitted Farnsworth in the West against Sarnoff and Zworykin in the East. Farnsworth went from farming in Idaho to a startup company in San Francisco that was soon stealing television breakthrough headlines from mighty RCA. He wouldn't sell out, thus thwarting Sarnoff's quest for total control. Sarnoff's counterattack was to support Zworykin, his in-house engineer, and promote his claims over Farnsworth's in every possible way, legal or not. Sarnoff was Farnsworth's tyrant for decades, and eventually his nemesis. In order to sort through the blatant contradictions and heated claims, we resort to our technique of crisp definitions. As it has before, for computers and movies, this places several contenders out of the running (or into the annotations for honorable mention).

Television Defined

Television is the fully electronic taking, transmitting, and display of visual flow from the real world in real time. Changing pictures—visual flow—*in real time* is crucial to our definition. Just as we defined a movie system to be a camera, film, and a projector, a television system requires a camera, a transmission means, and a display device by definition here. It has to be electronic in every way—no moving parts allowed even for generating electric or magnetic fields—and it has to work end to end. Anything shy of that is *pre-television*.

We use this initial definition to draw early distinctions among the inventors, but will find it insufficiently precise. For a glimpse of the difficulties, consider the case of a still image as input. The visual flow into a camera is of an unchanging or constant scene. Should this count as television? No, of course not, but we will allow, and even admire, early instances of "television" doing just and only that. We'll revisit the definition of television as we come to understand just how unwatchable the early systems were. Meanwhile the initial definition allows us to prune the tree of inventions and inventors that didn't lead to Digital Light.

Pre-Television

The electronic requirement excludes any moving part, particularly the mechanical disks used by several inventors. The disk-based systems of early television were as much a dead end as those of early cinema. But both America and Britain had strong proponents of such pre-television systems who deserve attention.

Americans had Charles Francis Jenkins. We've encountered Jenkins before as an inventor of the movies, and that's why we bother to mention him. He was the co-creator with Thomas Armat of the Phantascope movie projector that became the "Edison" Vitascope projector. Armat forced Jenkins aside in the movie industry, and Edison took all his credit, so he turned his inventive skills to television. He created a system that featured spinning mechanical pieces. It was doomed, as all such systems were, making Jenkins a financial failure in television as he had been in movies. But he's honorably remembered as a player in both.[15]

A far different story was John Logie Baird (hard 'g') who was by far the most famous pre-television inventor. Even today the British generally believe that this Scotsman was the Father of Television—not Farnsworth or Zworykin, and certainly not Sarnoff.

Baird had several infamous money-making ideas before he graduated to television: a crème for hemorrhoids (which burned him), diamonds made in a pot of cement (which not only failed but brought down the electrical main power supply), undersocks for absorbing the water from soggy socks (which actually made money), a rustless glass razor (that cut skin rather too easily), and a cheap soap. He was outcompeted in this last category by Oliver George Hutchinson, so they went into the soap business together. Later Hutchinson invested in Baird's television company.

Baird's love life took an unusual turn too. He left his sweetheart behind in Scotland when he left for Trinidad to make a fortune there. The plan was that he would send for her later. But she didn't wait. When Baird finally returned, he was confronted by a married couple and came to an arrangement satisfactory to all three: The two men would share the woman. Which they did for years, apparently happily for all three. Baird must have been a remarkably persuasive fellow.

Despite Baird's humble technical beginnings, he did manage to build a system that recorded and transmitted visual flow. Unfortunately, it depended on a giant spinning disk that did not—could not—lead to the electronic systems that would form the basis of the television industry. It didn't and couldn't lead to Digital Light. Nevertheless, Baird remains in this treatment because, first, he's such a good story, and second and more importantly, late in the game he changed his mind. In an attempt to salvage his (pre-)television company from failure—and despite everything he'd fought against for years—he finally went electronic and partnered with Farnsworth.[16]

Farnsworth's Founding Story

> *There are some inventions which, although not yet existent, we may take for granted will be invented someday without any doubt whatsoever . . . The subject of this article,* Television, or Seeing at a Distance*, is one of these inventions.*
>
> — Hugo Gernsback, *Electrical Experimenter*, May 1918[17]

Philo Taylor Farnsworth—Phil to his intimates—told a simple and heartwarming story. In 1921 he was plowing a potato field in Idaho as a 14-year-old boy—daydreaming about his hero Albert Einstein—when he looked back at the freshly tilled field, saw the raster of raked rows there, and had his Eureka moment. That's how to make television work! To get a two-dimensional picture across the country, convert it to a one-dimensional signal—the plowed rows—and use radio to transmit it. Einstein's 1905 photoelectric effect would convert the photons of light, captured by a camera, to electrons for transmission. At the other end a cathode-ray tube would convert the transmitted electrons back to photons of light on a display. That's exactly what a CRT does. The problem was to make this happen so fast that moving pictures could be transmitted across country "live."[18]

Or something like that. Unfortunately, the story doesn't hold up well. There's no doubt that the original story came from Farnsworth himself, but it seems to have suffered in the retelling. For one thing, he might have been disc-harrowing a hayfield, not plowing a potato field. But there are two larger problems with the received story.[19]

First, there's the *boustrophedonic* problem. The word means "as the ox plows." The back-and-forth plowing pattern that farmer Farnsworth followed—alternating direction at each successive row—is not the raster, or raked, pattern of television which "plows" each row in the same direction.[20]

But the larger hole is that young Farnsworth already knew about scanlines. He knew about mechanical television attempts by the time he was 14. He was an avid reader of Hugo Gernsback's *Science and Invention*—formerly *Electrical Experimenter*, as in the epigraph. Gernsback talked about attempts to use the German Paul Nipkow's spinning mechanical disk, patented in 1884, to transmit pictures electrically, scanline by scanline. Television—seeing at a distance—was a frequent topic.[21]

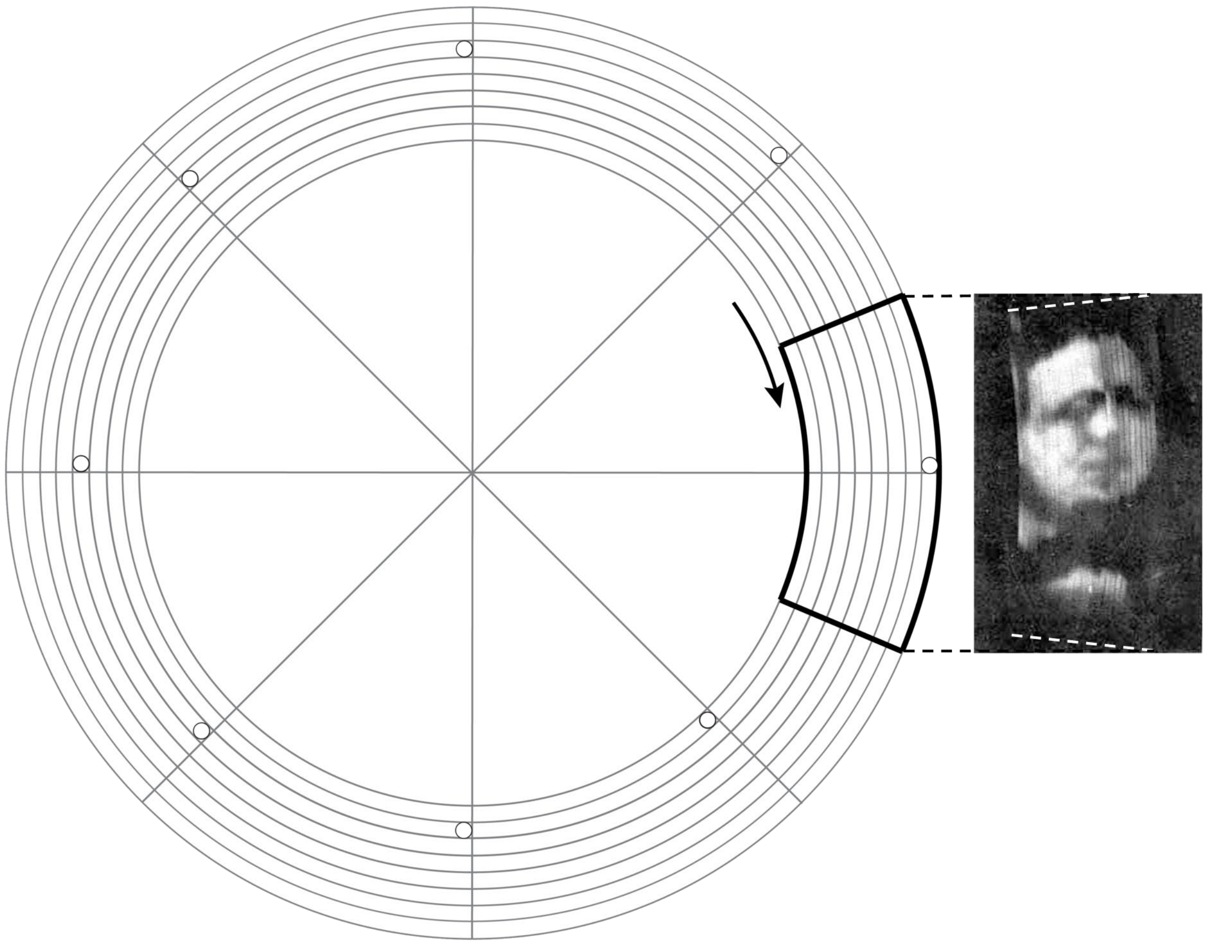


Figure 5b.4. A Nipkow disk (left) with 8 holes for 8 scanlines. The first Baird still image (right), c1926, with curved, almost vertical scanlines. Baird's disk was much larger than the one shown and had about 30 holes to produce the image shown.[22]

A Nipkow disk is punched with holes at ever increasing radii from its center, as shown in figure 5b.4 (left). Notice that the holes form a spiral. Now, consider the specially designated sector of the disk outlined in boldface in the figure. As the disk turns each one of its holes revolves, one at a time, through that sector, allowing light from an illuminated subject or scene to pass through a moving hole. Since each hole is at a different radius, it "sees" a part of the subject not seen by any other holes. Thus, the subject is "seen" or scanned along a circular arc. These arcs approach straight lines, called scanlines, only if the disk is gigantic compared to the special sector.

The brightness of the light that comes through a moving hole must be collected and converted to an electrical signal proportional to the brightness. The way this happens doesn't matter to us. The point is that a spinning hole receives at any one instant only a spot of light reflected from a subject. As the hole moves along its arc, the changing brightnesses seen through it become a changing electrical signal. Think of this as the "camera" of a mechanical system.

Then the electric signal passes down a wire to a "display." That wire is the transmission means.

The display is another giant Nipkow disk identical to the one in the "camera" and spinning in synchrony with it. The picture in the illustration above, the image of a man, was reconstructed using the display disk. The electrical signal on the wire from the camera drives a light source with brightness that varies in proportion to the electrical signal coming in from the camera. This light source illuminates the (boldface) sector of the disk. As each hole spins through the sector a scanline is painted on the receiving screen, one line at a time in the same order as recorded.

It's clear that a mechanical disk system that has giant spinning disks and a wire for communication works, but poorly and slowly. Baird's Nipkow disks had 30 or 60 holes (not the eight in the figure's left), so he used 30 or 60 scanlines. The plywood disks reached eight feet in diameter and spun at two and a half revolutions per second—a frame rate of only 2.5 frames per second.[23]

Baird managed to broadcast the recognizably human face in late 1925 or early 1926 with this huge and frightening contraption. It's easy to see why the British might claim that this was the first television—even flickering madly as it must have. But we consign Baird's mechanical beast to pre-television. It didn't scale to the speeds and number of scanlines that real television needed. Even old analog television of the last century had 480 scanlines (in the U.S.).

Farnsworth's key idea was that a television system had to be fully electronic. That's surely what he envisioned atop his plow (or disc-harrow), not the fact of scanlines. He was so excited by his electronic idea that he immediately told his classmates and family about it. Sensing something big, his father warned him to keep quiet, but in 1922 he sketched the idea for his high-school chemistry teacher, Justin Tolman, anyway (figure 5b.5, left). Tolman was so impressed that he saved the diagram. Many years later Tolman produced it in court—a drawing by a 15-year-old boy—in the patent case (figure 5b.5, right) that officially resolved the Farnsworth-Zworykin priority battle in Farnsworth's favor.[24]

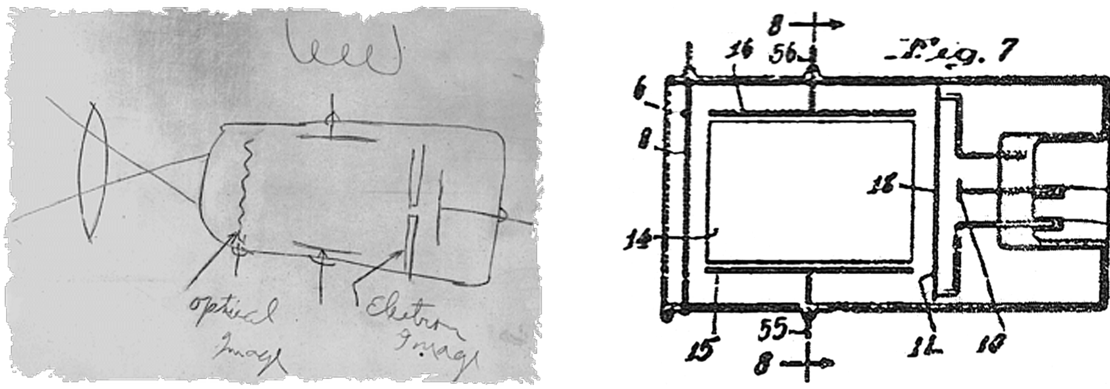


Figure 5b.5. Farnsworth's 1922 sketch (left) of a television camera, and the diagram in his 1927 patent application for Image Dissector.

Farnsworth believed that he needed a college education to turn the 1922 sketch into a reality. He was admitted to Brigham Young University in Provo, Utah, but couldn't afford to stay. In fact, he never did get a degree. Under financial pressure, he became a fundraiser for a charitable organization, a Community Chest branch in Salt Lake City.[25]

"Community Chest" rings a bell for anyone who's played the popular board game *Monopoly*. It's a stack of cards in the middle part of the board. Each player randomly gets an opportunity to turn up a Community Chest card and enjoy or suffer the consequences printed on it: *Bank error in your favor—collect* $75. *Doctor's fees—pay* $50. *Get out of jail free*. *From sale of stock you get* $50. And so forth.

In 1926 Farnsworth turned up a couple of cards, so to speak, at the Salt Lake City Community Chest that changed his life for good:

You're funded—collect $6,000. Two major fundraisers for Community Chest listened to Farnsworth's electronic television spiel and decided to fund the passionate nineteen-year-old inventor. The lead investor, George Everson, later remarked at the transformation of the halting young man into an eloquent "supersalesman" when he talked about his idea.

You made a friend—marry his sister. Farnsworth met Cliff Gardner at Community Chest. Cliff would become a close friend, and so would Cliff's sister, Pem. Farnsworth soon married Pem.

The new television partnership and the new couple set up shop in Hollywood, California. One of the first things the business did was spend all its money obtaining the 1927 patent for Image Dissector. Farnsworth's partners then went looking for more money. They had no luck in the Los Angeles area, but they tried San Francisco next and hit pay dirt.

Almost Silicon Valley

A new investment—of $25,000 for 60% ownership—came from a large California bank. The bankers also made available a lab facility at 202 Green Street in San Francisco at the base of Telegraph Hill. All Farnsworth had to do was make television transmission a reality within one year. There was no Silicon Valley yet, but this was a high-tech startup, with venture capitalists (sort of), and in San Francisco.

William Crocker ran the bank. He was son of Charles Crocker who had, with his business partner Leland Stanford, amassed an immense fortune from the transcontinental railroad. With his portion of this vast treasure Charles acquired controlling interest for his son William in what would become Crocker Bank.

From the preceding movie chapter we know that Stanford had aimed his financial support of Edward Muybridge at the horses, not moving pictures. But William Crocker did apply his money directly to moving pictures—the electronic version, as envisioned by Philo T. Farnsworth.

And horses *were* part of the Farnsworth story in a metaphorical way. Roy Bishop, one of the Crocker team, said after he agreed to back Farnsworth, "We are backing nothing here except the ideas in this boy's head. Believe me, we are going to treat him like a racehorse." In other words, they were bankers who closed a deal that depended on a 20-year-old *without collateral*. Venture capitalists do this sort of thing in the modern world—but not bankers. Obviously, Farnsworth was a persuasive fellow.

Plowing the Field vs Fielding the Plow

The Farnsworth founding story falters on the issue of plowed scanlines. But it has another problem—also about plows. It focuses us on a fundamental conceptual difference between Farnsworth and Zworykin.

There are two ways to scan a picture. The first is obvious in light of the plowing metaphor: Move the scanning point over a picture—plow the field. The alternative conception isn't so obvious: Hold the plow stationary and pass the field under it. Move the field, not the plow. We'll call this less intuitive notion "fielding the plow." It's like an old-fashioned typewriter with the paper passing left to right on a cylindrical platen under the typing head and then down the page with carriage returns. The paper moves, not the typing head where the keys strike the page.

Farnsworth's fame is based on fielding the plow. The scanning point is held fixed while the picture passes across it, row by row, under control of a magnetic or electric deflection mechanism. But Farnsworth didn't use that awkward phrase "fielding the plow." He called it "dissecting an image."

In 1927 when he patented the television camera that he had drawn for his teacher as a 15-year-old boy, he called it Image Dissector. It wasn't the already old idea of scanlines that young Farnsworth had seen while farming in Idaho. It was surely the unusual new notion of fielding the plow to generate them.[26]

Zworykin's fame would come from cameras that plowed the field. The moving "plow" transmits the image brightness it detects at each successive location in a picture to the outside world, along a wire say, or via a radio wave. (From here on, we'll assume that all metaphorical plowing is in raster, not boustrophedonic, order.)

Zworykin's Founding Story

Vladimir Kosmich Zworykin—son of Kosma—told a plucky story too. He was born to a well-to-do family on July 30, 1889, in Murom, in Imperial Russia, about halfway between Moscow and Kazan, Kotelnikov's birthplace. Zworykin's birth occurred right between Nipkow's invention of the spiral-cut spinning disk of 1884 and Ferdinand Braun's invention of the cathode-ray tube in 1897.[27]

Zworykin was nineteen when Boris Rosing of St. Petersburg, Russia, applied for a patent on a television display using a CRT. Rosing's May 1911 demonstration of the system was among the first for television display. This wasn't full television by our definition—just the display component. And it was quite crude. The camera was a couple of mechanical spinning mirrors. The images transmitted, via wires, were silhouettes of simple shapes—still pictures. But this was an important early step in electronic display of television. And young Zworykin was there.[28]

He was an electrical engineering student at the St. Petersburg Institute of Technology where he studied under Rosing. In early 1911 Rosing introduced him to a special project that he called *elec-*

trical telescopy—television. He took part in Rosing's experiments, built photocells and evacuated vacuum tubes for them, and perhaps was present at the demonstration of May that year. He always gave Rosing credit for first showing him the promise of electronic television.[29]

Then in 1914 Germany attacked parts of the Russian Empire. We recall that Vladimir Kotelnikov's family arrived in Kiev on the very day in August 1914 when the German army broke through that city's defenses. Russia began to tear itself apart during the remainder of the decade. Like Kotelnikov, Zworykin had a front-row seat at the tumultuous birth of Soviet Russia. But unlike Kotelnikov, he had no protectress. He avoided imprisonment another way. By the end of the decade, he had escaped to America—twice.

Zworykin began his service in the tsar's army as a private, but with a badge that designated him an engineer. His skill at radio communications was to benefit him numerous times. It soon got him promoted to lieutenant in the Russian Signal Corps. It was Lt. Zworykin who met and married Tatiana Vasilieff in a whirlwind romance in 1916—the beginning of a marriage as fraught with turmoil as the times.[30]

Lt. Zworykin was assigned to the Russian branch of the Marconi company, the Russian Wireless Telegraph and Telephone Company in Petrograd (the new name for St. Petersburg). While there, he mentioned his work with Prof. Rosing in television to the Marconi director. The excited director decided that when the war was over Zworykin would work with him on electronic television. This never happened, but it's intriguing in light of Zworykin's later involvement with Sarnoff and the American Marconi company.[31]

Zworykin Escapes Russia

Instead, things went sour. He and Tatiana separated after less than a year of marriage. And then things went severely sour as revolutionary events snowballed in Russia in 1917 and tossed Zworykin to and fro.

Tsar Nicholas II abdicated in the so-called February Revolution of 1917. It's "so-called" because it actually took place in March by the modern calendar, which hadn't yet been adopted in Russia. He abdicated on Mar. 2, 1917. Aleksandr Guchkov, a powerful friend of Zworykin's father, was instrumental in the abdication. In fact, Guchkov handed the order of abdication to the tsar for his signature.

Simplifying somewhat, two major factions then struggled to gain control of the country, the Bolsheviks and the anti-Bolsheviks. The Provisional Government was the first to form and take control in Moscow. It was anti-Bolshevik. Guchkov became its Minister of War.

Lt. Zworykin wore the tsar's uniform, so he was immediately in danger after the tsar's overthrow. He did what other officers did. He removed his officer's markings and kept the engineer's insignia. But it was his father's high-powered connection and his own radio expertise that saved him. Guchkov asked Zworykin to set up a vital communications station for the Provisional Government. Zworykin did so by exploiting his good relationship with the director of the Russian Marconi company in the same city, Petrograd. And with lucky timing, because Guchkov would lose his high position within months.[32]

Zworykin was walking a tightrope. He was called before a revolutionary tribunal, a frightening turn because former tsarist officers often never returned from such tribunals. But in his case a charge of inhumane treatment was refuted as a groundless fabrication. He walked away free—but on full alert.[33]

He wanted out of Petrograd fast. By mid-1917, Zworykin was living in a village just across the Dnieper River from Kiev having joined a military unit of volunteers which needed his radio expertise. Coincidentally, Kotelnikov would be in Kiev the following year, but our two Vladimirs never met.[34]

In late 1917, Zworykin decided to return to Petrograd. We don't know why he felt safe to do so. At the last minute, however, he changed his mind and headed for Moscow instead. We don't know why he felt safe to go there either. It might have been because the Marconi factory had relocated from Petrograd to Moscow. Once in Moscow, he learned from his sister of his father's death the previous month in Murom, his hometown. He immediately departed for there to see his mother and other family members.[35]

The death had caught Zworykin by surprise. Also startling was his discovery that a governmental agency had requisitioned the Zworykin's luxurious home for a museum of natural science. (The family mansion is just visible in the background of the photograph in figure 5b.3 of the statue of Zworykin in Murom.) His mother and sister, as widows, had been granted two of its rooms, but only temporarily. He tried to convince them to leave with him for Moscow, but they refused—"a fatal mistake" in his words. Many years later he learned that both had died in Murom, his sister during the Revolution and his mother during the Civil War that followed. Zworykin proceeded to Moscow alone.[36]

The Provisional Government lasted only until the more famous October Revolution of 1917, which actually took place in November by the modern calendar. The Bolsheviks, famously known as the Reds, then took over Moscow. Leon Trotsky created the Red Army for them and became its leader. Thus Trotsky assumed the position in the new Bolshevik government equivalent to Guchkov's former, but short-lived, role in the anti-Bolshevik Provisional Government.[37]

But the vast expanse of Russia was still up for grabs, and would be for five years. The anti-Bolshevik Whites (or White Guard, or White Army) retreated to headquarters in Omsk, Siberia, about 1,600 miles east of Moscow (see the map in figure 5b.6).[38]

Zworykin arrived in Moscow from Murom just in time for the October Revolution. The Bolsheviks immediately ordered that all former tsarist officers report for duty in the Red Army. That meant Zworykin. Under such pressure he chose to seek refuge with the Whites in distant Omsk.[39]

A final scare hastened his departure. A friend tipped him off that a warrant had just been issued for his arrest, for failing to register for the Red Army. The tipoff was a tremendously lucky break for him. He didn't even return home to pick up a few things. He had the friend drive him directly to the Moscow railway station.[40]

But travel to Omsk was difficult and indirect. He first went by rail to Nizhny Novgorod (see map), about 250 miles east of Moscow, then by boat to Perm, another 600 miles east. (East and west follow the 60th parallel in the map shown.) He sold some jewelry to buy the steamer ticket and get some cash.

The convoluted route included a stay in Yekaterinburg, another 200 miles east, and another fright. He was arrested by troops who were suspicious of his uniform and his explanations. Panic set in when he learned that Tsar Nicholas II and his family had just been executed in that very town. But—in yet another stroke of astounding luck—Zworykin's guards vanished overnight. They had fled ahead of advancing Czechoslavakian troops coming to aid the Whites. It was the Czechs who finally helped him reach Omsk.[41]

In Omsk he found a way to justify his leaving Russia, which must have seemed like a good idea to him at the time. A cooperative with offices in America agreed to assist him in the journey and commissioned him to gather engineering information. Also, the White government commissioned him to approach the Russian embassies of Copenhagen, London, and America to obtain radio equipment and bring it back to Omsk. At last he had a bona fide mission, a procedural way out of Russia, at least as seen by one of the parties in partial power. Apparently, he had papers to justify any path out of Russia he could manage.[42]

Figure 5b.6

Since the Reds controlled the west, the most obvious route out of Russian would have been the Trans-Siberian Railway through mostly White-held territory to Vladivostok in the far east. But portions of the railway were blocked by opposing forces. The only remaining and viable way out available to Zworykin was the far north, via the Arctic Ocean. Zworykin joined an Arctic scientific expedition for that purpose, went from Omsk up the Irtysh River to its confluence with the Ob River, then all the way up the Ob to Obdorsk (now Salekhard) on the Arctic Circle, from there west via icebreaker to Archangel (now Arkhangelsk), another Russian port on the Arctic Ocean, from there to Oslo and Copenhagen, then to London, then from Liverpool to New York City.[43]

To get a feel for the sheer size of Zworykin's meandering escape route through Russia, starting where it began in Moscow, consider this. Although the geography is upside down and backward, imagine Moscow as Chicago. In order to get from Chicago to Miami, he first traveled west from Chicago to Montana, then steamed down the Missouri River from its headwaters in Montana to the Mississippi River, on down the Mississippi to New Orleans, and then sailed from New Orleans to Miami. All this instead of taking a train from Chicago to Miami.[44]

Finally, on New Years Day 1919, Vladimir Zworykin, 30, a Russian engineer, arrived in New York City. According to the arrival papers, his destination was the Russian Consulate.[45]

Then he went back to Omsk! Perhaps he had left substantial cash there. Perhaps he thought that his political problems might have passed, that the Red threat had dissipated. Perhaps, and this is most likely, he felt obligated by his official missions. He claimed that he was ordered back by the Omsk government in the Spring of 1919. In fact, his arrival papers in New York clearly stated that he planned to return to Omsk. He returned even though the Bolsheviks would have arrested him immediately if he had encountered them.

The Trans-Siberian Railway path was free of blockage for his return, or so he thought. He left via Seattle, sailed to Yokohama, Japan, went from there to Vladivostok, the eastern terminus of the railway in Russia, and took it to Omsk, in a trip of over 4,000 miles lasting six weeks. He did have problems along the rail route, but the Whites were still nominally in charge there, so he managed to get through. There are hints in these stories of Zworykin's talent for talking his way out of tight places, by invoking the names of important people and befriending fellow engineers.[46]

His Omsk contacts instructed him on deal points to make with his new American business relations. So armed, he escaped again, still apparently unworried—or not unduly worried—by the prospect of arrest. Nevertheless, he determined that Russia was too unstable and made the momentous decision to leave for good. He was certain that in the U.S. he would find laboratories where he could practice his engineering. He reversed the Trans-Siberian Railway path from Omsk to Vladivostok to Yokohama and finally returned, via San Francisco, to New York in August 1919. It had taken him eighteen months to effect his two escapes.[47]

And not a moment too soon. The first news about Russia that he received in New York was that the Omsk government—and Zworykin's formal connection to Russia—no longer existed. The Red Army under Leon Trotsky had defeated the Whites.

Tatiana immediately joined Vladimir in New York, their on again, off again relationship still managing to hold. The arrival papers for both stated that they intended to stay in America— "forever" in her case and "indefinitely" in his. Within a few years both had naturalized as U.S. citizens.[48]

Zworykin didn't return to Russia for over a decade, and when he did it was as an American citizen to the Russia of the Soviet Union. In 1934 he paid a six-week visit, his defection presumably forgiven. On this trip he met the notorious Lavrenti Beria, who would head the NKVD (predecessor of the KGB) a few years later. Zworykin's skills impressed Beria, whose goal presumably was to attract him back to Russia. When Zworykin expressed a desire to see the Black Sea, Beria made it happen.[49]

We've met Beria before when discussing Kotelnikov, our other Vladimir. A committee consisting of Beria, Malenkov, and Stalin ran Russia during World War II. Kotelnikov had to invoke his protectress, Malenkov's wife, Valeriya Golubtsova, to keep him out of Beria's camps in the Gulag. But this would happen after Zworykin's visit.

Just prior to the visit, Kotelnikov had proved the Sampling Theorem, but we have no evidence that Zworykin knew the result—for many years anyway. Their paths again failed to cross.

Alan Archibald Campbell Swinton: A Clear Vision of Television

Before sorting out the roles of Farnsworth, Zworykin, and Sarnoff in the history of television, let's step back to the beginning. 1908 is a good place to start. Rosing's early experiments in Russia about then were crude and addressed only the reception half of the problem. Zworykin was only a student in Rosing's lab at the time, and Farnsworth was just two years old. But that year A.A.C. Swinton, a Scottish electrical engineer, published a remarkably astute description of fully electrical television in a letter to the prestigious scientific journal *Nature*:

> The problem of obtaining distant electric vision can probably be solved by the employment of two beams of kathode rays (one at the transmitting and one at the receiving station) synchronously deflected by varying fields of two electromagnets placed at right angles to one another and energised by two alternating electric currents of widely different frequencies so that the moving extremities of the two beams are caused to sweep synchronously over the world of the required surfaces within the one-tenth of a second necessary to take advantage of visual persistence.

> Indeed, so far as the receiving apparatus is concerned, the moving kathode beam has only to be arranged to impinge on a sufficiently sensitive fluorescent screen, and given suitable variations in its intensity, to obtain the required result.
>
> The real difficulties lie in devising an efficient transmitter which, under the influence of light and shade, shall sufficiently vary the transmitted electric current so as to produce the necessary alterations in the intensity of the kathode beam of the receiver, and further in making this transmitter sufficiently rapid in action to respond to the 160,000 variations per second that are necessary as a minimum.[50]

This would satisfy our definition of television—if it actually existed. It's astonishingly prescient given that nothing in the world at that time worked like the devices he described. Despite the now strange spelling *kathode*, the only major insufficiency is Swinton's refresh rate of 10 frames per second. It's entirely too far below the 50 or so frames per second rate that we humans require for persistence of vision. Such television would have flickered. But worse, it would have had very low resolution. The 160,000 variations per second at this low rate meant 16,000 variations per frame, or equivalently 400 variations along each of 40 scanlines. That's remarkably less than the 480 scanlines per frame that Americans would adopt as their analog television standard decades later, in the 1940s.

True to the brains-not-brawn British stereotype, Swinton never implemented any of the ideas of the *Nature* letter himself, but they were influential. He published three further such articles of increasing analytic detail between 1908 and 1921 in well-known places, including one in 1915 in Gernsback's *Electrical Experimenter*. No inventor could justifiably claim that he hadn't encountered

Swinton's well-thought ideas after that. However, his fellow countryman, John Logie Baird, didn't get the message even if he did read it. Baird stuck disastrously with his mechanical disks.[51]

And Swinton cheered him on—at least at first. After witnessing a Baird demonstration, he was said to have cried, "I have been converted! I have been converted!" and wrote the *Times* that television had arrived. But he eventually salvaged his reputation by realizing his error and denouncing Baird as an unscrupulous rogue out to fleece the public. Electronics *was* the right way to go after all.[52]

Television Samples Space in One Direction Only

It will come as no surprise by now that the Sampling Theorem is the means for understanding television. We use it twice in television. First, visual flow is sampled into *frames*, each a fully occupied (continuous, not sampled) rectangle of visual flow, at an instant. A frame has two space dimensions, horizontal and vertical, but no time dimension. The Sampling Theorem says, as explained in a previous chapter, that we can ignore the infinity of information between frames (samples) in the time dimension if we sample correctly. This is astonishing, but that's what the Sampling Theorem says.

But analog television samples again, and this is beyond what movies do. Each continuous frame is sampled into horizontal lines—the *scanlines*. A scanline has only horizontal dimension but no vertical dimension. The Sampling Theorem says that we can throw away the infinity of information in the horizontal strips between adjacent scanlines (samples) of the frame if we sample correctly. Again, this is astonishing, but that's what the Sampling Theorem says.

This is exactly analogous to ignoring the infinity of brightnesses between pixels or the infinity of loudnesses between soxels. Sampling works if the Sampling Theorem is honored—if sampling is done at (slightly greater than) twice the highest frequency in the Fourier representation. And just as for pixels and soxels, a continuous frame can be reconstructed from just the scanlines if the sampling has been done correctly. For display, the scanlines are spread vertically with a spreader and added together to reconstruct the frame they represent. The Sampling Theorem tells us this will work.

Similarly, continuous visual flow can be reconstructed from just the (reconstructed) frames, if the sampling has been done correctly. For display, the frames are spread in time with a spreader and added together to reconstruct the visual flow they represent. The Sampling Theorem tells us this will work too. I can't overemphasize the profundity of the Sampling Theorem.

Radio had already solved the problem of transmitting one-dimensional information—an audio signal—wirelessly across the world. The key idea of television was to piggyback on radio by turning two-dimensional information—visual images—into one-dimensional information. Visual flow is sampled into frames in the time dimension. Then each two-dimensional frame is sampled into scanlines. A visual scanline is like an audio signal except its meaning is brightness not loudness. Scanlines are lined up in order to create a continuing one-dimensional signal. Top to bottom becomes left to right. Then left to right becomes increasing time.

Figure 5b.7 is a simplified picture with just four scanlines per frame. The top scanline is scanned first, then each scanline in succession top to bottom. They are put into one-dimensional format by lining them up in succession, left to right, separated by "punctuation marks" represented by commas:

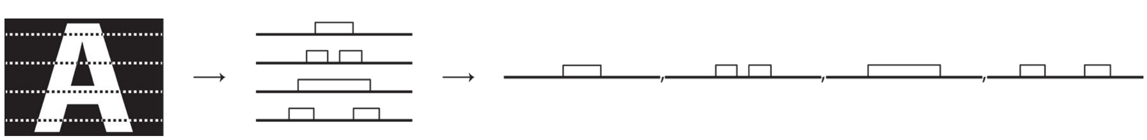


Figure 5b.7

Figure 5b.8 shows the next frame done similarly:

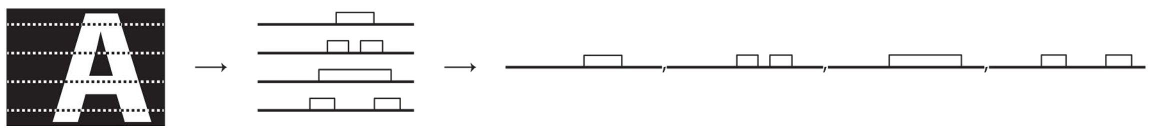


Figure 5b.8

Then other frames, similarly put into one-dimensional format, are lined up in temporal order, with semi-colons representing the punctuation marks between them, as in figure 5b.9. At top are two sequential frames in two-dimensional format, followed at bottom by their representations in one dimension. Time proceeds to the right in both rows of this figure.

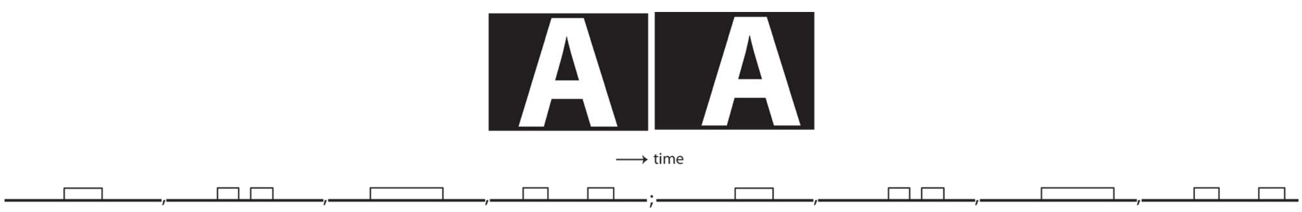


Figure 5b.9

The completely one-dimensional signal in the bottom row broadcasts as if it were an audio signal—as if the amplitude represented loudness of sound rather than brightness of light along a scanline. The display device at the other end—the so-called *television receiver*, or more homely *TV set*—turns this one-dimensional "sentence" back into a sequence of frames. And each frame becomes a sequence of horizontal scanlines painted down the receiver's screen in the same order as the television camera took them. Since radio transmission is at the speed of light, there is only a negligible delay between the camera and the TV set. It's "live."

A TV set spreads scanlines vertically—at display time and not before—and adds them together to regain the missing spatial infinity between them. And it spreads the frames in time sequence and adds them together to regain the missing infinity of visual flow between them. That's the Sampling

Theorem, again and again. In both cases, the spreader of the Sampling Theorem, or at least a good approximation to it, does the spreading.

That's ideally how television should work anyway. But there are a couple of problems in actual implementation of the ideal system. In real television the frames aren't instantaneous samples, and neither are the scanlines. And there's another problem, called fields.

Real Television

The film and the complementary paired fields of video are, of course, metaphorical descendants of the Newtonian infinitesimal so that both are doomed, as from a kind of original sin, to the irony of mapping relativistic perceptions upon an atavistic fiction of classical mechanics, long since repudiated, along with the simian paradoxes of Zeno that prefigure the calculus, by the sciences.

— Hollis Frampton, *Artforum* magazine, 1974. Tacked to the wall, Xerox PARC SuperPaint lab, 1974.

Dick Shoup's SuperPaint lab at Xerox PARC (Palo Alto Research Center) featured some of the earliest color pixels in the world—and the first intimate connection of a computer to a standard analog color television. Frampton's dense artspeak hung on the wall at PARC to entertain lab members and visitors. At best it's carefully crafted poetry about the technical beauty that is film and video technology. At worst it reflects the glaring ignorance in the arts and humanities of sampling and how the technology really works—its true beauty. But ignorance of Fourier waves and

Kotelnikov sampling was commonplace for anyone, like Frampton, on that side of the culture aisle.

What his tangled prose appears to say is this: Sampling can't work. You can't get to a continuum with discrete steps. Film and video are doomed from the outset because of the "original sin" of sampling. Both, Frampton says, are based on false premises, "long since repudiated." It's yet another statement of the deep-seated belief that digital is somehow lesser than analog. But we've seen that the Sampling Theorem *does* let us faithfully—and magically—reconstruct an original continuum from discrete samples of it, if done correctly. Contrary to Frampton, film and video are based on a rock-solid foundation. Nevertheless, as with cinema, television's original inventors didn't know that. Television too was created by inventors who didn't know about the Sampling Theorem.

As a result, real television is far from ideal. The American system introduced in the 1940s is a convenient example. This analog television system of the last century was called NTSC, for the National Television Standards Committee which specified it. (Or, irreverently, for Never Twice the Same Color.) England had a different system, and France another. There wasn't a global standard in the pre-millennial era, and that was a giant roadblock to media convergence. We bother to discuss the old analog standards because they continue to influence us in the era of Digital Light.

The American system sampled visual flow into 30 frames per second, and then sampled each frame into 480 visible scanlines. The first clue that something wasn't quite right is that 30. It's lower than the 50 or so refreshes per second that humans need to avoid seeing flicker.

The early inventors solved the flickering problem—sort of—by dividing each frame into two fields. A *field* is every other scanline in a frame—half the scanlines. Odd-numbered scanlines form one field, and even-numbered the other—and neither have anything whatsoever to do with plowed potato fields. Hold your hand in front of your eyes with the fingers spread and pointed at those of the other hand, held similarly. Now interlace the fingers of one hand with those of the other to get the idea of fields. These are "the complementary paired fields of video" in Frampton's epigraph.

The English reading order of a page of text is left to right then top to bottom—that is, raster scan order. So imagine reading the even numbered lines of text first before returning to the top of the page to read the odd numbered lines. That's the *interlaced* version of raster scanning. The way we actually read is *progressive* scanning, one line after another, no skipping.

The naïve idea is that the two fields are painted so rapidly in succession on the eye that they schmudge together, through persistence of vision, into one complete frame. A new field is presented to the eye every sixtieth of a second, so that solves the problem of refreshing the eye often enough—60 fields per second. Since it takes two fields to make a complete frame, the frame rate is 30 frames per second.[53]

But figure 5b.10 shows the fundamental flaw in this idea. On the left are two successive fields of a ball rolling to the right. The ball rotates to a new position between fields. The trouble is that the fields aren't sampled at the same time. There's a sixtieth of a second delay between them. Instead of sampling 30 times per second, American television sampled at 60 "half frames" (fields) per second. This isn't the correct use of the Sampling Theorem. What the eye actually sees is indicated at the right.

Figure 5b.10

The picture isn't quite accurate because in reality the first field starts to fade from the screen as the other comes on. Nevertheless, it demonstrates the *combing* artifact, we might call it, inherent in interlaced scanning of moving objects or scenes. The use of interlaced fields rids us of flicker between frames, but gives us instead the unpleasant artifact of flicker between lines, or *interline flicker*.[54]

The interline flicker of combing causes the perceived picture to shimmer in an unpleasant way. It's especially annoying if there are narrow horizontal features in the scene, such as the lines painted on a basketball court, or the railings in a stadium, or window ledges in a cityscape. One field might pick up a horizontal line while the next field misses it—it falls in the cracks, so to speak. So the line appears to flicker on and off. Most of us have seen interline flicker so often that we've ceased to "see" it, but it's there in interlaced systems.

Interlace is a legacy problem that the modern world of Digital Light has inherited from the last century—an antediluvian artifact from before the digital flood. Evidence of it is the familiar 1080i format in today's High-Definition (HDTV) standard for digital television. That little suffix *i* stands for *interlaced*. If you watch closely, you'll see horizontal lines and edges flickering on a 1080i television. Alternatively, there is the 1080p format, *p* for *progressive*. A 1080p television doesn't have the interlace artifact because no scanlines are skipped. Both fields are completely populated with scanlines—both fields are actually full frames—so there is no interframe or interline flicker. Progressive television displays refresh at 60 frames, not fields, per second. All computer screens are progressive. It's only some television displays that have unnecessarily perpetuated interlace with its interline flickering into the modern world.

The Sampling Theorem doesn't apply to sampling only half a picture, the even scanlines, then later sampling the other half, the odd ones. That's as anti-theoretical as cinema's double flashing each frame. Both techniques defeat the Sampling Theorem in an attempt to keep the eye and brain happy by keeping the "flicks" at bay. But real television is even further off the ideal than cinema. The fields and scanlines aren't well-taken samples.

A proper sample in time is taken instantaneously, but scanning a line in television takes longer than an instant. The right end of a scanline is scanned after its left end. And scanning a field of 240 lines (half of 480) takes a lot longer. The lower right corner of a real television field is scanned well after its upper left corner. Nevertheless, the early inventors managed to accomplish fully electronic television despite their naïve compromises.[55]

Zworykin Gets Started in America

When Zworykin escaped to America in 1919, he believed he could land an engineering job that exercised his radio expertise. By 1920, within one year of his arrival, the giant Westinghouse—General Electric's archrival—had hired him at its research laboratory in East Pittsburgh, Pennsylvania. Writing patent applications there helped him overcome his difficulties with English. And his inventiveness impressed the company's patent officer.

But a salary dispute caused him to leave after about a year. It took another couple of years before Westinghouse begged him to return—to run any project he wished. There was high motivation for this about-face. Westinghouse had begun radio broadcasting and had finally been allowed into the monopolistic consortium of GE, AT&T, and RCA. It needed to contribute radio inventions, and its patent officer remembered Zworykin's talent for them. On his return to Westinghouse, Zworykin claimed his prize. He chose as his project the invention of all-electronic television. At the end of 1923 he applied for a broad-ranging patent on this topic, including a camera tube.

That patent was filed four years before Farnsworth's Image Dissector patent, so it would appear that Zworykin had a priority lead on Farnsworth. The filing date of a patent tells us when the inventor had the original idea, but it's the issuance date of the patent that actually matters. A patent formally boils down to a list of *claims* about the inventor's idea. Outside parties can officially argue the validity of individual claims in a process called *interference*. An interference can cause the rejection of a particular claim without invalidating the entire patent. When all problems with the various claims of a patent have been settled, the patent issues and becomes legally binding.

For years there was much controversy about whether a camera built as Zworykin described in his 1923 patent filing would actually work. Formally this took the form of eleven interferences on the patent's claims from competing companies and inventors—several from Farnsworth. Each had to be adjudicated by the U.S. Patent Office. All this conspired to delay the issuance of Zworykin's patent until 1936.[56]

Zworykin evidently built and operated some kind of television system showing still images in 1924 or 1925 and demonstrated it internally to Westinghouse executives. But Zworykin himself described the demonstration as less than successful, and Westinghouse, unimpressed, asked him to work on something else.[57]

The scorecard in the Farnsworth vs Zworykin battle on the eve of 1928 has Farnsworth with the most advanced camera tube, Image Dissector, patented in 1927. Zworykin might have had a superior system but reports suggest that he did not, that he wasn't ready for prime time and knew it.

Neither inventor had mastered all the parts of television as defined here. But that was about to change. The period 1927 to 1933 was crucial to the invention of television.

Farnsworth: First Television—Sort of

> *At this time [1927], Philo Farnsworth had the only operating camera tubes in the world. Yet, to this day, Farnsworth's pioneering efforts have gone relatively unknown and unappreciated.*
>
> — Albert Abramson, *The History of Television*, 1987[58]

In 1928 Farnsworth made his move. He went public with the first all-electric television. In early September, he demonstrated it to the press. A *San Francisco Chronicle* article featured a photograph of Farnsworth holding his Image Dissector camera tube in one hand and a CRT display tube in the other. That sounds close to our definition of television, but electric doesn't necessarily mean electronic. There was still one moving part. The voltage wave that he used to drive the rhythmic scanning of the scanlines was generated by a motor. And a motor rotates.[59]

But less than a year later, in July or August 1929, he jumped the final hurdle. He showed the first all-electronic television—with *no* moving parts. The December issue of the magazine *Radio* published a photo from the display of this system, the first such photograph.[60]

To show off his system to important visitors, Farnsworth set up a private broadcast system from his lab on Green Street in San Francisco to a building about a mile away. One of his favorite things to show was snippets of *Steamboat Willie* by Ub Iwerks and Walt Disney. He also was the first to broadcast the live face of a recognizable human being—his wife, Pem.[61]

Farnsworth was building the prototype television system. But to perfect it for market would require immense capitalization. Farnsworth's investors reasoned that only a giant electric company could shoulder such enormous costs. They began seeking such funds even before he completed the prototype. They offered their—Farnsworth's—patents, to General Electric.[62]

But GE wanted Farnsworth. They would buy the patents outright, but only if they could hire him. They also made it clear that all work he did at GE would belong to GE. In other words, GE didn't want to share with the Farnsworth startup company. They wanted to own Farnsworth himself and his patents completely. Although this buy-out arrangement would surely have suited Farnsworth's backers, it didn't satisfy him. He said No to the GE deal.

Meanwhile GE's archrival Westinghouse already had an in-house television inventor. Zworykin was poised to make his first major move only a little behind Farnsworth.

Zworykin's Kinescope: A Practical TV Set

> *The Kinescope changed the history of television for all time. For Dr. Zworykin had produced a simple but ingenious picture tube which made it possible to have a practical receiver in the home of the viewer, a device which the average person could operate, that required absolutely no technical knowledge to run, and could be viewed under almost normal lighting conditions.*
>
> — Albert Abramson, *The History of Television*, 1987[63]

Zworykin made an important trip to France in late 1928. What he found enabled him to leap ahead of Farnsworth at the display end of television—to a practical TV set. A lab he visited showed him an advanced display tube that used electric, not magnetic, fields to aim the cathode ray. He hired one of the wizards there, Gregory Ogloblinsky, who had built it, and brought him back to Westinghouse—and also one of the new tubes.[64]

About a year later he patented the Kinescope picture tube. He built it with Ogloblinsky's help by improving on concepts he had picked up in France. Historian Abramson called it Zworykin's "greatest triumph" because it would lead to a practical receiver in the home of the viewer. A couple of days later Zworykin presented a paper about Kinescope at an IRE (later renamed the IEEE) meeting in Rochester, New York. Importantly, he didn't show it in operation. And it wouldn't be shown publicly until 1932, by which time Zworykin would have developed an electronic camera.[65]

While this was happening in the back rooms, the public face of Westinghouse television was still mechanical—still pre-television. In April 1929 Westinghouse was granted a license for a (pre-) television station, the first ever issued. Their system featured 48 scanlines, 16 frames per second. By June they were broadcasting two hours per day, often showing a Felix the Cat doll (figure 5b.11) rotating on a turntable in the studio (and—count them—using 60 scanlines by then).[66]

Figure 5b.11. Felix the Cat featured in the first licensed (but pre-television) broadcasts, 1929

Westinghouse refused to turn Zworykin's electronic television into product. But worse, the U.S. stock market suffered the great stock market crash of 1929, and the Great Depression began. Television development of any sort went into hibernation for several years.

The state of the Farnsworth vs. Zworykin battle before the hiatus was this: The Farnsworth team in San Francisco was making advances at both the camera and the display ends of electronic television, and the Zworykin team near Pittsburgh was making notable progress at the display end. There were other teams in the world at work on parts of the television problem. The most notable, because of its consequences in the world of Digital Light, was the display tube work of Takayanagi in Japan.[67]

Takayanagi and Japanese Television

Kenjiro Takayanagi of Hamamatsu (roughly halfway between Tokyo and Osaka) Technical School, Japan, was a contemporary of Farnsworth and Zworykin. In 1928 he published pictures from his display tube, which had 40 scanlines. At the time it was the most advanced electronic display in the world, but shy of television by our definition because it lacked an electronic camera. By the next year Farnsworth was making strides on the camera end. And Takayanagi's actual lead on the display end didn't last long because Zworykin soon outdid him with his Kinescope display. But since Zworykin didn't show Kinescope publicly until 1932, Takayanagi held the apparent lead much longer. He should be better known than he is.[68]

In 1929 Takayanagi announced, with a patent application, that he was also working on a television camera. It was based on an electronic notion, called the *charge-storage principle*, that intensified the television signal and made "plowing the field" cameras possible. It was already known from the patent literature but hadn't yet been reduced to practice. Zworykin may have already figured it out, but he was keeping all his discoveries secret at the time.[69]

Takayanagi's next major move several years later was a tour of U.S. and European television labs, followed up by lengthy reports to the Japanese government. He noted the success of Zworykin's now no-longer-secret camera tube and enlisted the aid of NHK and NEC—think of them as the NBC and GE of Japan—in building the first Japanese version of it. From this came the massive Japanese television industry.[70]

We pay particular attention to Takayanagi and Japan because the Japanese would inspire the giant leap of television into Digital Light at the millennium. They were the first to insist on *high definition* television, meaning (at the time) over 1,000 scanlines. Their original proposal was analog. The U.S. took this as a competitive move and responded with the High Definition TV (HDTV) standard, which is digital, a fundamental step toward the Great Digital Convergence.

Zworykin Visits Farnsworth

Suffering from the great stock market crash in late 1929, some of the investors in Farnsworth's company sought to sell the company or its patents. Without informing Farnsworth, they invited RCA to visit the San Francisco laboratory. Their move surprised Farnsworth, but it delighted him to learn that Zworykin himself, from Westinghouse, would make the visit.[71]

Thus ensued the most memorable encounter in early television. On April 16, 1930, the two competing inventors met face to face for three days. At the high point, Zworykin held Farnsworth's famous Image Dissector camera tube and proclaimed, before witnesses, "This is a beautiful instrument. I wish that I might have invented it." Farnsworth must have burst with pride, for Zworykin was one of the few people on earth who deeply understood what he had accomplished.[72]

But this visit was probably out-and-out industrial espionage. That Farnsworth was so forthcoming to Zworykin without the protection of a formal agreement—say a letter of intent—astonishes us now. Farnsworth naïvely had his team build an Image Dissector from scratch for his visitor. Farnsworth apparently didn't know—or was too naïve to care—that Zworykin had become part of RCA on April 1, 1930, the day that all television research at Westinghouse was turned over to RCA in Camden, New Jersey.[73]

Zworykin must have been truly impressed. While he was still in California, he contacted his lab at RCA in New Jersey and ordered them to start building Image Dissector tubes for in-house experimentation. By June he could write, "Ogloblinsky got very nice results with the transmitting tube, which is a modified Farnsworth type." In fact, they had more success with Image Dissectors they built themselves than Farnsworth did with his own.[74]

RCA passed on the financial opportunity. An internal memo stated, "Farnsworth had evidently done some very clever work, but I don't think that television is going to develop along these lines. . . . I think that Farnsworth can do greater service as a competitor." For one thing, Zworykin had been quite unimpressed by Farnsworth's display tube.[75]

Nevertheless, RCA tried to use the patent system to gain control over Image Dissector. Zworykin and Ogloblinsky applied for a patent in Mar. 1932 for improvements to it, but Farnsworth successfully won two legal objections (interferences). Then in May the Patent Office decided against RCA in its claim that Zworykin's patent of 1923 covered Image Dissector. This gave Farnsworth a major victory and complete control of Image Dissector technology. Clearly RCA needed another approach to cameras.[76]

To the outside world Farnsworth was ahead. A May 1931 article in *Journal of the Royal Society of Arts* praised him, "He is about the only important worker making use of strictly electrical methods for transmission." Fielding the plow was briefly ascendant over plowing the field.[77]

Zworykin's Competitive Response: Iconoscope

The industrial espionage had given Image Dissector to RCA for all practical purposes, but legally they couldn't use it. So, Zworykin and his team, particularly Ogloblinsky, had to invent a way around it. They finally developed a new idea for a camera tube—one that plowed the field—and called it Iconoscope. Zworykin applied for a patent on it in November 1931. He had an answer to Farnsworth.[78]

Iconoscope was important. Historian Abramson states simply, "For all intents and purposes, the disclosure of the Iconoscope marks the beginning of the age of electric television." RCA now had with Iconoscope and Kinescope both a practical electronic camera and a practical electronic display. There was still a long way to go in the development of television in the home, but the most difficult pieces were in place. Modern electronic television descends mainly from Zworykin's inventions, not Farnsworth's.[79]

But what about Farnsworth's earlier developments? It's true that he was there first with electronic television, but his display wasn't bright enough nor large enough to be practical. Zworykin's Kinescope won on the display end for ultimate practicality. And Iconoscope soon surpassed Image Dissector in capabilities and became the technology that was inherited by the television industry. So Zworykin won on the camera end too. Plowing the field ascended and became the dominant mode.

Sarnoff Finally Meets Zworykin

While Farnsworth and Zworykin made television history with their technological developments, Sarnoff amassed power at RCA. But RCA was still devoted only to radio. It was Zworykin's next move that inspired Sarnoff to embrace television. He would turn RCA into *the* television powerhouse in the U.S.

Westinghouse had refused to support Zworykin's television developments. His Kinescope demonstration to Westinghouse executives had been less than exciting, and they had asked him to find something else to do. Someone at Westinghouse suggested that, if he wished to pursue television, he should approach Sarnoff.

This famous meeting occurred in December 1928 or January 1929. Nobody seems to know the exact date. After Zworykin's presentation, Sarnoff asked him how much it would cost to develop television into a commercially viable technology. In one of the grandest underestimates in technological history, Zworykin confidently told him it would take two years and cost $100,000. Sarnoff gave him the go-ahead. It would actually take decades and cost tens of millions, even in 1930 dollars worth one-fifteenth of today's dollars. (Farnsworth had given an even sillier estimate—of $6,000—to his initial investors. Convinced that it wasn't nearly enough, his second investors gave him $25,000 more.)[80]

Sarnoff began to consolidate all the parts and patents of the RCA monopoly under his control. In April 1930, during the same month that Zworykin met with Farnsworth, all television development at Westinghouse near Pittsburgh was transferred to an RCA production facility in Camden, New Jersey, directly across the Delaware River from Philadelphia. In 1931 Sarnoff established the RCA Laboratories there and put its television group under Zworykin.[81]

Sarnoff Offers to Buy Farnsworth

But Sarnoff didn't yet control Farnsworth. So, in May 1931 when he heard that Farnsworth's lab needed money, he journeyed to San Francisco himself to visit the lab with the intention of finally owning Image Dissector. He offered $100,000 for it and the services of its inventor. That's an interesting number because it's exactly what Zworykin had told him would be the total cost to develop television, with Zworykin himself included. But this was a year or so later, and Sarnoff was beginning to appreciate what the development might actually cost.

Sarnoff was too late. Farnsworth didn't attend the meeting with Sarnoff in San Francisco because he was—at the very same time—in Philadelphia finalizing a deal with Philco to keep his company funded. When Sarnoff understood that he couldn't get Farnsworth, he departed the San Francisco facility saying, "There's nothing here we'll need." From that moment on, the rivalry between RCA and Farnsworth greatly intensified.[82]

Philco was the Philadelphia Storage Battery Company. Despite the mundane name, it was the largest manufacturer of radios in the U.S. and had to pay royalties to RCA for use of all radio patents. Philco resolved to break that subservience in the new television market. Farnsworth's system was the only alternative to Zworykin's RCA system.

So Philco offered Farnsworth a deal that he could accept. They would support his research, and he would own his inventions. But he had to agree to move to Philadelphia and run a lab atop the Philco plant. He accepted the offer in June 1931 and moved his team there.[83]

But two years later the deal was dead. Philco and Farnsworth just didn't get along. Furthermore, RCA delivered an ultimatum to Philco: Either drop Farnsworth or lose RCA patent licensing rights for radio. Thus, another opportunity to stop the Sarnoff-Zworykin juggernaut failed.[84]

Baird Soldiers On

During these years of the first flowering of electronic television, our most famous pre-television inventor, John Logie Baird, managed with a series of stunts to keep the public curious and his financial backers happy. In 1925, for instance, he demonstrated his mechanical television to the public at Selfridge's famed department store in London. In 1928 he claimed that his television signal was received on board the *S.S. Berengaria* a thousand miles at sea (the very liner that would bring Kotelnikov to New York City a few years later, then Turing.) But a report that same year stated, "The Baird system is hopeless, after all."[85]

Nevertheless, Baird continued to flog mechanical television. Baird Television was the first to make an experimental broadcast in Europe, from its studio in September 1930. It was a victory, of sorts, but a crude one. The format used was a paltry 30 scanlines at 12.5 frames per second.[86]

It emboldened him nevertheless to proclaim, as late as October 1931, that he saw "no hope for television by means of cathode ray bulbs." This was pure bravado since Farnsworth had accomplished all-electronic television by this time, and Zworykin was close to it.

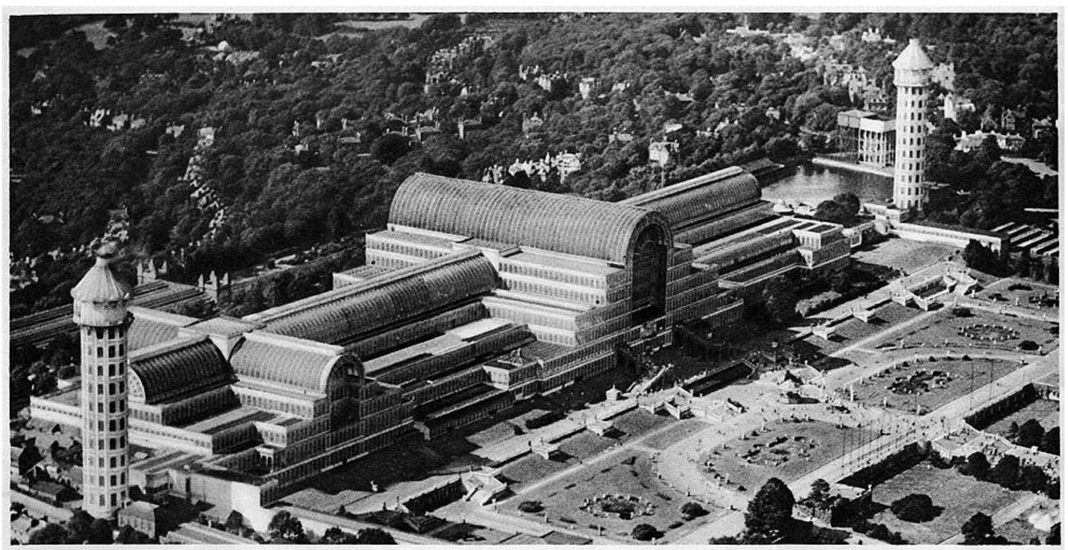
The only thing that saved Baird Television from complete financial ruin was its purchase in 1932 by Gaumont-British Films—the English branch of the great French movie company. This set the stage for a faceoff in England between Farnsworth and Zworykin, though both were in disguise.[87]

Baird Partners with Farnsworth: The Battle for Britain

The crucial battle pitted Baird Television against EMI. The three letters stood originally for Electric and Musical Industries, a company which sprang from a business deal with RCA. So EMI based its approach on RCA's—Zworykin's—Iconoscope. Baird attacked the American technology, "Dealing with EMI . . . would be dealing a heavy blow at British industry and directly assisting an American concern."[88]

The British Post Office suggested in April 1933 that the two companies give demonstrations. Not surprisingly, EMI's electronic approach was superior to Baird Television's mechanical approach. Finally Baird was forced to change his mind. To remain competitive he'd have to embrace electronics.[89]

He did it rapidly. By July he had hired away an EMI engineer who knew everything that RCA was doing. In September he demonstrated a CRT-based system with 120 scanlines per frame and 25 frames per second, the rate that would become the British standard. Baird Television began broadcasting from the famed Crystal Palace (figure 5b.12) and by October was showing a system with 180 scanlines. The rivalry between Baird Television and EMI was intense, and the scanline escalation wars had begun in earnest.[90]



BEFORE THE FIRE: A PANORAMIC AIR VIEW OF THE CRYSTAL PALACE—A HUGE STRUCTURE OF IRON AND GLASS COVERING 25 ACRES: SHOWING THE SOUTH TOWER (PARTLY OCCUPIED BY THE BAIRD TELEVISION COMPANY) ON THE LEFT, THE NORTH TOWER ON THE RIGHT, AND THE GARDENS ON THE EASTERN SIDE.

Figure 5b.12

The final skirmish began the following year. The British Broadcasting Corporation decided to hold a series of tests pitting Baird against EMI, and to choose one of them as the supplier of its equipment.

Baird needed an electronic camera for consideration by the BBC. EMI had its version of Iconoscope, so the only functioning camera available to Baird was Farnsworth's Image Dissector. Baird made a deal with Farnsworth to import one to England, and German manufacturer Fernseh licensed Farnsworth's technology to build a version of Image Dissector for European use. Lines had been crossed. Baird was no longer purely British either, and electronics-based Farnsworth was keeping mechanics-based Baird in play.[91]

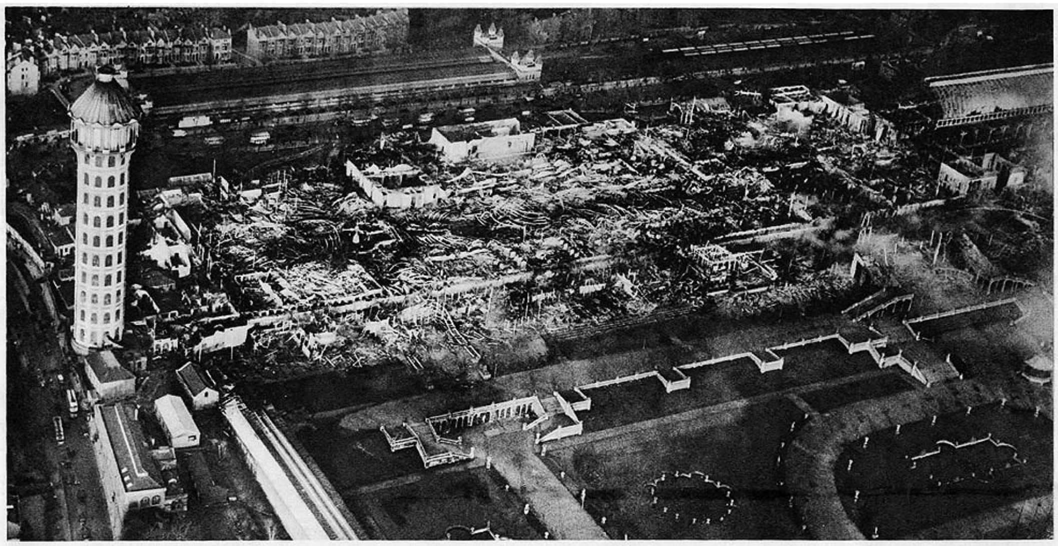
The End of Baird and Farnsworth in Europe

The Selsdon Committee, chaired by Lord Selsdon and tasked with deciding the future of British television, visited television labs in Europe and the U.S. Finally, in January 1935, the Committee made its recommendations: (1) A "high definition" television service should be established in London. (2) Both Baird and EMI should be given the opportunity to supply the equipment, to be received by the same receivers. (3) Resolution should be at least 240 scanlines, 24 frames per second. (4) And the BBC should control the service.[92]

The Selsdon Committee's report pitted Farnsworth against Zworykin, disguised as Baird and EMI—and nobody else. The final battle in Britain then was between these two old adversaries.

Baird held with 240 scanlines, progressive, but increased the frame rate from 24 to 25 frames per second. EMI, working with the British Marconi company, competed by pushing their system to 405 scanlines, interlaced, 25 frames per second.

Baird demonstrated its 240-scanline progressive system with a broadcast from the Crystal Palace. EMI revealed the specifications for its 405-scanline interlaced system, and they were more advanced and sophisticated than Baird's. Historian Abramson's summary: "The end of 1935 found Marconi-EMI with the most advanced television system in the world. By this time, they had passed up every other company, including RCA. Baird Television Ltd. was desperately trying to catch up in technology but had started too late. Even with the able assistance of Philo Farnsworth and its German ally, Fernseh A.G., the Baird Company's efforts were to be in vain."[93]



AFTER THE FIRE: AN AIR PHOTOGRAPH, FROM THE SAME POINT OF VIEW, SHOWING THE VAST MASS OF WRECKAGE AFTER THE BULK OF THE CRYSTAL PALACE HAD CRASHED, AND ONLY THE TWO TOWERS (THE SOUTH ONE HERE SEEN ON THE LEFT) REMAINED STANDING.

Figure 5b.13

The penultimate face-off in the European television wars was at the infamous 1936 Olympics in Berlin, where black American sprinter Jesse Owens put the lie to Adolf Hitler's claim of the superiority of the "Aryan race." These were the first games ever covered by television. The Germans used both Zworykin and Farnsworth cameras, built by German firms Telefunken and Fernseh, respectively.[94]

In November 1936 the final battle began with the opening of the London Television Service. Baird won the toss to be the first to broadcast. But the Baird system was almost immediately in trouble. The Farnsworth camera, still in development in Europe, failed to work and had to be withdrawn. Then a few days later a disastrous fire at the Crystal Palace (figure 5b.13) destroyed the Baird research laboratory. In February 1937 the BBC formally announced that EMI—with a system fundamentally derived from Zworykin—had won. Baird was soundly defeated, and hence his partner Farnsworth too.[95]

One of the first uses of the winning system was the broadcast from London on September 30, 1938, of the return of Neville Chamberlain from Munich when he waved a document signed by Hitler and himself and delivered his infamous "peace for our time" message. It was apparently the first television broadcast of a major news event as it was actually happening. America followed just months later, on April 30, 1939, with a broadcast of President Franklin D. Roosevelt opening the World's Fair in New York City.[96]

The Triumph of Zworykin and Sarnoff

The Great Depression lasted much longer than anyone expected. After a decade the world was still suffering from its effects. But with all his competitors subdued and the Depression finally lifting, Sarnoff decided to take television mainstream. On April 20, 1939, he went before an NBC Iconoscope camera—Zworykin's—and dedicated the RCA exhibit at the upcoming World's Fair that was to open in New York City. And on April 30, television made its formal U.S. debut. President Franklin D. Roosevelt officially opened the World's Fair, and his speech was broadcast.[97]

There were even a few TV sets that could receive the broadcast, but not many. A couple of days after FDR's speech, six manufacturers announced plans to fill the void. Among them were GE, Philco, and RCA. They would build TV sets that received the signal that NBC broadcast—Zworykin's signal. Even Farnsworth Television and Radio Corporation announced that they were raising millions of dollars so that they too could manufacture TV sets. The resolution had edged up to 441 scanlines by this time, but there was no official standard yet to solidify the industry. So far it was just Zworykin's "standard" by default.[98]

Sarnoff Finally Settles with Farnsworth

Riding high now, Sarnoff sought to consolidate RCA's hold on television. There were many patents embodied in television as it existed in late 1939. RCA had developed many of them and bought many others from competitors. But Farnsworth still owned some of the crucial ones, and he wouldn't sell.

The Patent Office had come down squarely in Farnsworth's court. The priority claim launched on Zworykin's behalf based on his 1923 patent application was finally put down. In the proceedings, Justin Tolman dramatically revealed the drawing made by his 15-year-old student, Phil Farnsworth, back in 1922 (figure 5b.5, left). But it carried no weight and wasn't needed in the final ruling on July 22, 1935, that "Philo Taylor Farnsworth, junior party, be awarded the priority of invention on his system of television."[99]

And in October 1939 in a dramatic departure, RCA folded on the issue of complete ownership of patents. It announced a deal with Farnsworth Television and Radio Corporation to license the Farnsworth patents and pay royalties for them. To historian Abramson, "This agreement was a tremendous victory for Philo Farnsworth and represented full recognition of his valuable contributions to the field of television."[100]

In fact, during Senate committee hearings about television standards in April 1940, Sarnoff described Farnsworth as "an American inventor who I think has contributed, outside RCA itself, more to television than anybody else in the United States . . . He had made significant inventions!"

With the “outside RCA itself” he left room for Zworykin at the top of his list no doubt. By this time he had settled with Farnsworth, so had nothing to lose by praising him.[101]

Television stations were needed to get television out of the labs and into the world. The job of the Federal Communications Commission was to license these stations, but it needed a standard against which to issue the licenses. Sarnoff, in his typical way, tried to force RCA’s system as the de facto standard. The FCC, unhappy with this move, asked why shouldn’t, say, Philco’s new 605-scanline system be considered instead? So the Senate committee held the aforesaid April 1940 hearings on the standards issue and invited both the FCC and RCA to work out their differences.

In July the National Television Standards Committee was set up to establish the U.S. television standard. Within a year the committee issued its recommendation—the NTSC standard—and it was adopted. Official U.S. television broadcasting began on July 1, 1941, using the new standard, and it continued to be the U.S. standard for over half a century. Pearl Harbor in December slowed the adoption of television for the duration of World War II. Then color was added and television as we know it began in earnest in the 1950s, two decades after the first successes of Farnsworth and Zworykin.[102]

Who Invented Television?

It’s a fool’s errand to find a single inventor of something as complex as last century’s electronic television. Movie systems were essentially ready to go public and commercial in 1895, the year of their birth. Like baby horses they were a bit wobbly on their legs but they were soon gamboling about competently. But after Farnsworth’s proof of concept of television in 1929, there were still almost two decades of development to go before prime time.

Let's face it. Television as invented by Farnsworth in 1929 was unwatchable. And Zworykin's television just a few years later—RCA had it internally by 1933—wasn't much better. Farnsworth was first, no question about it, according to our initial definition of television. But both systems flickered badly, and neither had interlace to fix it. Both suffered from too few scanlines, too low a frame rate, not enough brightness or contrast, and too small an image—only a few inches square typically. And worse, both were plagued with a host of esoteric electronic flaws, such as visual noise, ghost pulses, ghost images, a bluish or greenish cast, loss of rectangularity, scanlines that "dropped out," and "tears" in the visual fabric of the displayed image. There were hundreds of problems to solve, captured in as many patents. There were contributions from engineers world-wide—not just from our two main protagonists.

For example, we mustn't forget the French influence. Zworykin gained the basic inspiration for what became the Kinescope display tube on his trip to France in 1928. He also brought back with him Ogloblinsky, who would become a key member of the Zworykin team. Historian Abramson takes pains to show that Zworykin was the orchestrator of many inventors and their inventions rather than The Inventor.[103]

There have been claims that Zworykin's Iconoscope was simply superior to Farnsworth's Image Dissector. That would justify giving the prize to Zworykin perhaps. But according to historian Abramson, "One thing must be made clear: the early Iconoscope was never as sensitive as it was claimed to be; nor, conversely, was the Image Dissector as insensitive as RCA and others claimed it to be." Careful analyses of the two from disinterested parties, and shorn of company marketing hyperbole, showed that they were remarkably similar. The July 1939 issue of the *Journal of Applied Physics* was devoted to television, newly announced to the world at the World's Fair in April. One of the journal articles reported that "the sensitivities of the two competing camera tubes, the Iconoscope and Image Dissector, were not as far apart as had been indicated."[104]

RCA could have swung its weight behind either technology. If RCA had licensed the Farnsworth patents in 1930 instead of trying to develop around them, Image Dissector technology might have been the winner. That is, Image Dissector might have been developed into the winning camera tube if Sarnoff had backed it with all the resources he had applied to Iconoscope. But Sarnoff refused to license, and Farnsworth insisted on it. Farnsworth refused to sell out to Sarnoff. It was an impasse.[105]

In other words, it was a close race. But Abramson gives the crown to Zworykin, not because he was first but because all of last century's television descended from his principal influence rather than from Farnsworth's. However, it's not just camera and display tubes that matter, whether Zworykin's or Farnsworth's. It's the whole system, and both inventors—and many others—contributed to the final patent mix over many years. Sarnoff finally had to license Farnsworth's patents to clear RCA's path to commercial television.[106]

The fact that RCA and Sarnoff were guilty of dirty dealing with Farnsworth doesn't change the fact that RCA's tube technology dominated the world of television when it came of age in the 1940s. It finally became watchable.

So, who invented television? It wasn't Sarnoff. He was the tyrant who provided a protected space for Zworykin and his team. And he certainly didn't protect Farnsworth—who wouldn't submit to such protection anyway. Sarnoff was powerful and competitive, and he marshalled the huge finances that television required. Most importantly he had a vision of the business of television that guided the complex enterprise. He was crucial to the foundation of the television industry, but of course he didn't have the know-how to create television technology.

The easy answer that Farnsworth invented television isn't satisfactory because what he showed in 1929 wasn't good enough. It was enough to satisfy our initial definition of television, but it didn't lead to Digital Light. Zworykin's system did because, with the backing of the Sarnoff business machine, it eventually won the commercial race to television and hence influenced the future of television right up to the digital version introduced at the millennium.

Thus, we could say that Farnsworth won the race to the proof of concept of television and Zworykin won the commercial race to actual television. But it's misleading. It's easy to name one person, but high technology doesn't work like that. The "high" in high technology is a signal that it's a technology higher than any one person can handle. Both men led teams of experts who, together, won the respective races.

Postlude

Philo Taylor Farnsworth won the priority battles and finally managed to get Sarnoff to license rather than buy his inventions—both Pyrrhic victories. In 1938 he and Pem bought a 60-acre farm in Maine with a 200-year-old farmhouse. They restored it, and the exercise restored Farnsworth's physical vitality, exhausted by his television battles. He built a laboratory on the farm and retired to it as the Farnsworth company proceeded without him. He sold off his stock in bits and pieces to finance the farm and lab.

But he suffered from depression. The television industry surged, its story told by Sarnoff, not himself. The good Mormon boy turned to alcohol, tobacco, and painkillers—and addiction to all of them. Then his Maine estate burned down, with no insurance—his own Crystal Palace disaster. He finally agreed in 1949 to sell Farnsworth Television and Radio, and it ceased to be a part of the American television scene. He died a broken man in 1971. But Pem kept his story alive. Utah schoolchildren mounted a campaign to honor him, and the statue in the Capitol is testimony to their success.[107]

John Logie Baird died poor and unrecognized in shabby surroundings in 1945, waiting for the War to end so that television could finally take off. His son, Malcolm, has kept his memory alive with a website and documentary coverage. His American counterpart, Charles Francis Jenkins, died brokenhearted, according to friends.[108]

Kenjiro Takayanagi became an advisor to the Japanese government. He argued that NHK Lab should be created and worked for many years at JVC (Victor Company of Japan). Under his leadership and that of his students, Japan became a dominant player in the manufacture of television components and a major force in the advancement toward the high-definition television of today. Takayanagi died in 1990, shy of the millennium. He is called the Father of Japanese Television and highly honored in Japan.[109]

Gregory Ogloblinsky was the most important inventor at RCA except for Zworykin. He died in an auto crash in 1934, never to see his inventions flower nor to share the glory with Zworykin.[110]

Vladimir Kosmich Zworykin was lavished with praise and honors the rest of his life. Although he always denied that he was the Father (or Inventor) of Television, he quietly relished the title. The FBI hounded him during the 1940s and 1950s, including the infamous McCarthy era, as a possible Communist. This, as is clear from his biography, was a ridiculous accusation, and he was eventually cleared. Tatiana finally divorced him on the grounds of desertion, and he married a second time, happily.[111]

David Sarnoff became immensely wealthy and powerful. On December 7, 1944, he was promoted to brigadier general in the U.S. Army for helping Eisenhower with communications systems. Everyone but his closest friends called him General after that—an aggrandizement he insisted on. General Sarnoff's version of television was *the* story for many years simply because he said so. His final major battle was for color television, against his new archrival, CBS, the Columbia Broadcasting System. The solution he backed was officially incorporated into the NTSC standard.[112]

Video

Video takes the real time out of television. Video didn't exist until the important invention of *videotape* as the storage and editing mechanism comparable to film in the movies. A full video system requires a camera, a videotape recorder and playback, and a display. Videotape removes the real-time requirement, and video relaxes the no-moving-parts dictum. Reels of videotape have to spin, and the tape moves between them, but that's the only movement allowed.

Video didn't become a practical reality until the 1950s, but its beginnings date back almost as far as (real-time) television. To Russia yet again. In 1922 Boris Rtcheouloff obtained the first patent for the recording and playback of a television signal "by magnetic means." In 1928 John Hays Hammond Jr. applied for the first American patent on a video recorder.[113]

As with television, there were many steps to the invention of video. But we concentrate on only one of them because it matters to the history of Digital Light. Videotape gave us the ability to edit television, but at first it allowed only imprecise edits. The important advance we mention here is the invention of a precise edit in video, just as film has.

A precise edit is easy and natural in film. You can see the frames on a strip of film simply by holding it up to a light. Then a cut with a razor straight across the film precisely separates two successive frames. Anybody can do it. Place the first frame of a new piece of film so that it abuts the last frame on the film you just cut. Then use a piece of clear sticky tape to attach the old piece to the new one. That's one edit in film.

Videotape is not so easy because you can't see the frames. All you see when you inspect a piece of videotape is a plastic backing coated with a fine brown powder. This powder is made of what you can think of as iron filings. Microscopically each particle of the powder is a tiny needle-shaped fragment of iron. And each tiny bar of iron will change directions in the presence of a magnet. The varying brightness of a television signal are recorded on videotape as varying orientations of these tiny bars. A single television scanline is recorded diagonally across the videotape. There is nothing visible on the videotape to show you the angle of the diagonal.

A television frame is recorded on videotape as a parallel sequence of those diagonal paths. There is nothing visible on the tape that indicates where a frame ends and the next one begins. It's storied that persons have actually accomplished videotape edits with a razor blade, but it's not something a sane person would want to try. Videotape can be edited, practically speaking, only electronically.

The Ampex Corporation of California created the first broadly successful videotape format and player and recorder. A team there led by Charles Wilson developed the famous Quad videotape machine that was of suitable quality for use by the broadcast networks, like NBC and CBS. It recorded on videotape that was two inches wide.[114]

But the Quad had two major problems. The first was tape wear. Some of the magnetic particles rubbed off each time a videotape was recorded. So a given strip of videotape could be reused only a few times, say four.

Its more serious problem was the one intrinsic to videotape—imprecise edits. Suppose you wanted to make a single edit using Quad videotape recorders. You would need two of the giant machines—each about two refrigerators in size—for source and target videotapes. The target videotape is the one that you are assembling from other pieces of videotape, such as the one on the source Quad.

The idea of a videotape edit is easy to state: You select a place on the target videotape where you want to begin recording from a source videotape. And you select where you want to record from on the source videotape. But you can't simply line up the two tapes and push a button to make the edit. This is because the Quad machines work only "at speed," meaning that 30 frames per second must be speeding past the recording head of the target machine when it is ready to record. And 30 frames per second must be speeding past the pickup head of the source machine when it is ready to be recorded from. You can only push the button to make the edit when both machines are at speed.

This is what it feels like to make a tape-based video edit: You back each machine up a couple of seconds shy of the place where you want the edit to happen. Then you start both giant machines running. By the end of the couple of seconds the machines are at speed and the edit point has been reached on both machines, more or less simultaneously. Then you push the edit button. That is, you push the record button on the target machine with the source machine selected as input. The act of pushing the button takes human time to execute, say a half a second or so. If you are lucky, the edit happens in the vicinity of the intended frames on the source and target videotapes. It's "fat" or "thumb-accurate" editing. Professional editors did get quite proficient at this, but even their edits weren't precise.

Only digital control finally made "frame-accurate" edits as common in videotape as they always were in film. But that took a while to happen. Television engineers were unfamiliar with digital control even as late as 1978. It took a young 18-year-old engineering student to jump the final hurdle. Bruce Laskin worked with us at the Computer Graphics Lab of the New York Institute of Technology on Long Island. He was sure that he could build a digital interface between our computer and a fancy new videotape machine that our patron, Dr. Alexander Schure, had just purchased for us. In other words, Laskin claimed he could make frame-accurate edits possible in video.

The International Video Corporation had created a serious competitor to the Ampex Quad—called the IVC model 9000. This was the new machine that Schure had purchased. It featured a new tape-movement technology borrowed from the computer industry that caused less wear on the videotape, permitting up to eighteen or so reuses of a tape. This solved one of the two serious problems with videotape. It was a crucial fix because we planned to record computer animations on videotape one frame at a time. Only the IVC 9000 could handle that amount of wear and tear on a videotape without destroying it.[115]

Laskin intended to fix the other serious problem, the lack of a precise edit. He consulted the video engineers at IVC about the possibility. They told him that a digital interface wasn't possible. He was convinced otherwise, and using their technical input he built one anyway. NYIT therefore had the first frame-accurate digitally controlled video editing machine in the world. It worked so well that our patron Schure outfitted the video center at NYIT with six of the big machines, all under computer control.

Many of the first computer animations of the group now known as Pixar were recorded at NYIT in the late 1970s on one of the modified IVC recorders. The group's computer rendered each frame as an array of pixels that were displayed on a color television set. The invisible digital pixels inside the computer were converted to analog spread pixels that were visible on a color display. By design that display honored the NTSC standard, as did the IVC recorder. So a frame on the display was in the form that the videotape recorder could accept. The next advance by the group was to go entirely digital, finally consigning videotape, like film, to oblivion.[116]

Television and Video Enter into Digital Light

Ed Catmull and I at Pixar had always considered John Whitney Jr. and Gary Demos to be our most serious competitors in the race to the first digital movie. In 1996 Gary approached me at a broadcast television conference with an astonishing claim. "Did you know that the new digital television standard is going to be interlaced?" At my shocked reaction, he begged me to join him and others in Washington, DC, to stop the Federal Communications Commission from formalizing such a bad idea into the High-Definition Television (HDTV) standard for America's digital television.

I was *not* shocked that it was my archrival, Gary, who approached me. No, I had great respect for him, a worthy adversary. It was interlace that shocked me. High-definition computer displays—with over 1,000 scanlines—were already commonplace, and they were invariably progressive. Interlace had been a clever solution to the flicker problem in the bad old analog days half a century earlier, but there was no reason at all for it in the digital world. In fact, people couldn't stand looking at an interlaced computer display. The interline flickering was intolerable—when displaying text especially.

We of the computer industry just assumed that the television industry would go digital "the right way." The shock was to discover that television's proposed notion of going digital was to slavishly digitize the old analog system, including interlace! With time running out and caught by surprise at the wrong turn taken by the television industry, ten computer companies formed a coalition in about 1996—*in one day*—to fight interlace. It included normally ferocious competitors—Apple and Microsoft, for example. But there was instant agreement among them that interlace was a mistake. There was no argument, not even one.[117]

The committee so formed at the eleventh hour was too late to stop interlace in the new HDTV standard—HDTV still mandates use of last century's frame rates (30, for example) and supports the outdated notion of interlace. But the computer committee was successful in getting progressive scan formats added as approved alternatives. Thus, despite the birthing pangs, HDTV helped usher in Digital Light at the millennium. One more medium, video, was guided into the Great Digital Convergence.

We can expect to see improvements in the television standard as computers get faster and Moore's Law continues to explode. One improvement would be to let temporal resolutions (frames per second) vary just as spatial resolutions (scanlines per frame, pixels per scanline) do, and there's no reason not to do that. Already the newly arrived world of Virtual Reality has found 120 frames per second useful in preventing dizziness when wearing VR goggles. It will probably be forces like VR that finally compel us to decouple from last century's ad hoc frame rates. Surely it's time to be rid of backward spinning wheels, interline flicker, and the quaint distinction between fields and frames.

To Digital Light

In the last six chapters we've become intimate with the three most important mathematical underpinnings of the digital world: Fourier waves, Kotelnikov samples, and Turing computations. We've explored two temporal manifestations of the Sampling Theorem: soxels in audio and frames in movies and television. And two spatial manifestations: scanlines in television and pixels in digital pictures. We've threaded our way through the conflicted and convoluted histories of three technologies that influence the modern digital world: computers, movies, and television.

Now we turn our attention to the completely digital case—Digital Light—digital in all dimensions. Visual flow is sampled into frames, and each frame is sampled into pixels. Or equivalently, each frame is sampled into scanlines and each scanline is sampled into pixels. Since the 2000 millennium, virtually all media have coalesced into this one universal medium, Digital Light, realized with the bit. This book celebrates that event, the Great Digital Convergence. The content of the medium is either taken from the real world, or created from scratch with computers, or is a mix of the two.

The next chapters emphasize the making, rather than the taking, of Digital Light. They demystify the creation of digital images and movies—and games and app interfaces and VR and . . . almost everything we now see except what the real world provides. Even automobile dashboards.

This is where geometry enters the story. We learn how to make curves, then surfaces, and then visibly interesting surfaces with color, lighting, and shading. Finally, we form them into objects and characters that move—and which move us.

The first surprise is that many curves in Digital Light are created with . . . the Sampling Theorem! But in reverse.

Annotations

2:*Punch's Almanack for*: *Punch's Almanack for 1879*, Dec. 5, 1878, with caption from its reproduction in Spehr (2008), 79: "This charming cartoon speculating that Edison would invent a television-like device appeared in Punch's Almanack for 1879. It reflects the amazement that much of the world felt when the introduction of the phonograph showed that the human voice could be captured and reproduced. It was drawn by the popular illustrator George du Maurier who gained fame later as the author of Trilby. Edison was familiar with the cartoon and the memory of it may have lingered in the back of his mind. The phonograph created the impression that Edison, the Wizard, was capable of working wonders and rumors that he was working on a 'far sight machine' or something to make images move cropped up from time to time. [LC. [Library of Congress]]."

The television picture depicted has a very large aspect ratio, about 2.5:1, as compared to HDTV's 16:9 = 1.78:1, but is near CinemaScope's 2.66:1 (often more like 2.4:1 in practice) in movies.

2:*One was Philo*: *Utah, U.S., Birth Certificates, 1903–1911*, https://ancestry.com [accessed Nov. 27, 2021, in all cases in this note], image online, Utah, file no. 83–A, Philo Taylor Farnsworth, Aug. 19, 1906, Beaver, Beaver Pct., Beaver Co., Utah, father Lewis E. Farnsworth, 41, of Beaver, born Beaver City, farmer, mother Serena Bastain [*sic*], 26, of Beaver, born Washington, Utah, housewife, no. of child of this mother 1, no. of children of this mother now living 1, filed Oct. 1, 1906, reg. no. 97, signed Ruth Reese, midwife.

1910 United States Federal Census, https://ancestry.com, image online, Washington, Washington Co., Utah, roll T624_1610, enumeration district 212, p. 4B, dwelling 52, lists Lewis E. Farnsworth, 44, a farmer born in Utah of a father born in Ohio and a mother in Scotland, and his (second) wife of five years, Serena A. (her first marriage), 30, born in Utah of Danish natives, and his son, Lewis F., 18, daughter, Vanessa, 10, son Ronald E., 13, all (by his first marriage) born in Utah, and his son, Philo Taylor, 3, and daughter, Agnes Ann, 1 4/12, both born in Utah. Serena had had the last two children, both surviving.

1920 United States Federal Census, https://ancestry.com, image online, Rigby Pct., Jefferson Co., Idaho, roll T625_292, enumeration district 180, p. 22B, dwelling 396, lists L. E. Farnsworth, 54, wife, Serena, 40, son, Philo, 13, daughter, Agnes, 11, son, Carl, 9, daughter, Laura, 7, son, Lincoln, 5, and daughter, Virginia, 5, all born in Utah (except Virginia, born in Nevada, of a father born in Arizona and a mother born in Utah).

Utah, U.S., Select Marriages, 1887–1966, https://ancestry.com, no. 2637, Philo Taylor Farnsworth, 19, born Aug. 19, 1906, Beaver, Utah, son of Lewis E. Farnsworth and Serena Bastian, to Elma Gardner, 18, born Feb. 25, 1908, Jenson [*sic*, Jensen, Uintah Co.,] Utah, daughter of Bernard Edw. Gardner and Alice Maria Mecham, married May 27, 1926, Utah, Utah Co., Utah (FHL 482949). Schwartz (2002), Author's Note, Elma Gardner went by the nickname "Pem."

1930 United States Federal Census, https://ancestry.com, image online, San Francisco, San Francisco Co., Calif., roll 206, enumeration district 308, p. 34B, dwelling 390, 3208 Lyon St., lists Philo T. Farnsworth, 23, a radio engineer born in Utah of Utah natives, his wife, "Elsie," 22, born in Utah of Utah natives, and son, Philo T. Jr., 3/12, born in Calif.

1940 United States Federal Census, https://ancestry.com, image online, Wayne Twp., Allen Co., Ind., roll T627_1025, enumeration district 2-31, p. 2B, dwelling 34, on Paulding Road, lists Philo Farnsworth, 33, lead executive of a television factory, born in Utah, wife, "Alma" G., 32, born in

Utah, sons, Philo "J.," 10, and Russell S., 4, both born in California, all but Russell had resided in Philadelphia, Montgomery Co., Pa., in 1935.

U.S., Find a Grave Index, 1600s–Current, https://ancestry.com, no. 3661, gravestone photograph, by Mike Reed, Provo City Cem., Provo, Utah Co., Utah, plot: south side, near the gate, "His wife | Elma Gardner | Farnsworth | February 25, 1908 | [empty] || Philo Taylor | Farnsworth | August 19, 1906 | March 11, 1971 | He loved his fellow man."

2:*Vladimir K. Zworykin*: *U.S., World War II Draft Registration Cards, 1942*, https://ancestry.com [accessed Nov. 27, 2021], Vladimir Kosma [*sic*] Zworykin, 52, of Taunton Lakes, Medford Twp., Burlington Co., N.J., born July 30, 1889, "Mourom," Russia, person who will always know your address: Tatiana Zworykin, Forest Hills, N.Y., employer RCA, Camden, Camden Co., N.J.

Zworykin is sometimes described as Jewish, but his biographer [Abramson (1995), 8] is quite clear that that he grew up in a town with 23 Russian Orthodox churches. "His parish church was next door," and the family attended it every Sunday. "His interest in the holy days led to an early devotion to the Russian Orthodox Church that languished as he grew older."

Omsk, Omsk Oblast, Russia, is about 800 miles east of Ufa (where Vladimir Kotelnikov had his lab in 1941), which is about 800 miles east of Moscow, and about 400 miles west of Novosibirsk. (Omsk is 1,663 miles on the Trans-Siberian Railroad from Moscow; Novosibirsk is 2,052 miles.) During the Russian Civil War (1918–1920), Omsk was the center of the anti-Bolshevik Whites, and held the imperial gold reserves.

Schwartz (2002), 283, "The following year [1950] . . . RCA memos informed all employees that these designations were official: only David Sarnoff was to be called Father of Television, and only Vladimir Zworykin was to be called the Inventor of Television."

3:*National pride is*: The statue of Farnsworth in San Francisco is at George Lucas's Letterman Digital Arts Center. The sculptor of the Washington, DC statue of him was James Richard Avati. [This statue is no longer in DC as of 2020.] There's a copy of it in Salt Lake City, Utah, in the state capitol. There is also a copy in Beaver, Beaver Co., Utah, near Farnsworth's birthplace.

However, the IRE (now the IEEE) had an award, 1952–1986, called the Vladimir K. Zworykin Television Prize Award. A list of winners shows that no prize was awarded in 1982 and 1985.

4:*Farnsworth's statue in*: Re Zworykin statue: "The opening ceremony of the monument to the inventor of television, the Russian-American engineer Vladimir Zworykin (1919, Russia – 1982, USA) took place in Moscow on July 29, 2013, the day of the 125th anniversary of the inventor. The authors of the sculptural composition 'Vladimir Zworykin – inventor of television' sculptor Sergei Goryaev, and architect Alexei Tikhonov. The monument appeared near the Ostankino pond next to the TV tower 'Ostankino.'" [https://vsuete.com/russian-american-engineer-vladimir-zworykin-monument/, accessed Nov. 29, 2021.]

5:*Farnsworth (formerly) in*: Re Zworykin statue: "The statue is in front of the mansion where he grew up" [<mercerspace.com/features/writer-carries-on-legacy-of-lesser-known-tv-inventor/>, accessed June 2, 2016, article written Nov. 21, 2013, by D. Hyatt. This website no longer exists. The closest I got to it was "A Father, If Not Founder, of Television," by Diccon Hyatt, Oct. 1, 2013, updated June 18, 2021, https://www.communitynews.org/princetoninfo/coverstories/a-father-if-not-founder-of-television/article_e6f5bd5f-0cdd-53f5-ac6c-729b074866e4.html, accessed Nov. 29, 2021. The updated article does not contain the quoted sentence]. A related article, "Writer carries on legacy of lesser known TV inventor," by Diccon Hyatt, Nov. 21, 2013, updated June 18, 2021, https://www.communitynews.org/archives/writer-carries-on-legacy-of-lesser-known-tv-inventor/article_a35d0c46-9cb6-50e6-b707-120878b8941b.html, accessed Nov. 29, 2021, "The room was located in the home of the aristocratic Zworykin family in Murom, a small city that sprawls along the banks of the Oka River. The Zworykins owned a fleet of huge wooden river-boats."

5:*Russia isn't nearly*: It was unacceptable for Jews to live beyond the Pale in Christian Russia, hence the current meaning of the expression as beyond what's acceptable. However, the expression's history usually refers more strongly to the English Pale in eastern Ireland, not the Russian Pale of Settlement. The English Pale was essentially a piece of England in Ireland. English law applied there but not beyond the Pale. England attempted in the 14th century to forbid use of the Irish language in the Pale and the intermarriage of Irish and English there. Those practices were beyond the pale.

6:*But then, at*: There is no evidence that Sarnoff or his family directly experienced pogroms. Sarnoff did recall the sickening sight in Minsk of Cossacks charging a large group of Russians who were demonstrating for greater political freedom under the Tsar: "I saw them lashing out with their whips, trampling women and children with their horses' hooves . . . It also trampled out of me any lingering feeling I might have had for Russia as my homeland" [Bilby (1986), 14].

7:*Marconi fascinated the*: I use Bilby (1986) as my principal source on Sarnoff, tempered by knowledge that Bilby was vice president of RCA's public relations department in the 1960s. See the bibliography for comments on *David Sarnoff, Encyclopedia of Television,* Dreher (1977), and Lyons (1966), as other sources. Fisher and Fisher (1996) adds additional material.

Schwartz (2002), 32–33, gives a well-written and detailed version of the sexual liaisons story.

Re chutzpah, an obituary for Sarnoff in *The New York Times*, Dec. 13, 1971, states, "Mr. Sarnoff was an admitted and unabashed hustler."

7:*The birth of*: This glosses over the scramble by the U.S. at the onset of WWI to seize and control all wireless (radio) patents for security reasons. Following the war, with intense legal battles, RCA was formed to maintain market control. For full details, see the excellent history of early radio, Gleason (1938).

8:*While Farnsworth was*: As part of a 1926 antitrust settlement against AT&T, RCA bought AT&T's broadcasting station WEAF, AT&T exited broadcasting. RCA soon turned the WEAF station and a fledgling network of other stations into NBC, with RCA majority shareholder, and General Electric and Westinghouse minority shareholders. Two years later, in 1928, Sarnoff became acting president of RCA and then in 1930, its president [Schwartz (2002), 29, 99–101]. See also Bilby (1986), chapter 2, and Abramson (1995), 40.

8:*RCA owned all*: On Oct. 4, 1929, Sarnoff's plan for RCA was adopted: RCA Victor was incorporated. RCA owned 50%, GE 30%, and Westinghouse 20%. Apr. 1, 1930, was the official handover date of all television research of GE, Westinghouse to RCA at Camden. On May 13, 1930, the Department of Justice filed an antitrust suit against RCA, GE, Westinghouse, and AT&T [Abramson (1987), 137, 148, 153].

My principal source on the history of television is Albert Abramson (1987), *The History of Television, 1880 to 1941*, an intensely detailed, blow-by-blow listing of the events and patents leading from the Nipkow disk to the creation of the American television industry, with an occasional editorial comment by the author. Abramson (1987), together with Abramson (2003), *The History of Television, 1942 to 2000* (essentially vol. 2 of the history), is the Bible of television historical research, but it's a difficult read. A careful, pleasant, and readable version of the entire history of television, including what we call pre-television here, is Fisher and Fisher (1996). A third Abramson book I use extensively is Abramson (1995), his biography of Zworykin.

8:*And Sarnoff, true*: Schwartz (2002), 28, goes so far as to show a photograph with this caption: "David Sarnoff, twenty-one, in an RCA publicity photo, in which he is purportedly operating a wireless transmitter in contact with the sinking *Titanic* in April 1912. In this airbrushed image, Sarnoff's head appears on someone else's body." I quizzed Schwartz about this photograph in a conversation at Pier 23 Café, San Francisco, July 10, 2016. He told me that he had seen the component photographs and the resulting airbrushed composite. Abramson (1995), 41, however, simply dismissed the myth as yet another one associated with Sarnoff without assigning blame to Sarnoff himself. See also Bilby (1986), 30–35.

9:*But it is*:The RCA facility in Camden, NJ, was renamed the RCA Laboratories in 1930 [Schwartz (2002), 160]. In 1941 new facilities for it were constructed in Princeton, NJ [Schwartz (2002), 275]. It was renamed David Sarnoff Research Center in 1951. When GE bought RCA in 1986, they donated the research center to the non-profit SRI International. In 1996 the center became the Sarnoff Corp.

10:*Television is the*: *Television* is of mixed heritage. *Tele-* is Greek for *far off*, *afar*, or *at a distance*. *Visio* is a form of the Latin verb *videre*, *to see*. In Middle English it came to mean *vision*, denoting *a supernatural apparition*.

11:*Americans had Charles*: Fisher and Fisher (1996), 39–46, has an enjoyable treatment of Jenkins, and clearly describes his mechanical scanning system, a pair of orthogonally rotating prisms. Jenkins is fully treated in a more recent biography, Godfrey (2014). I have relied principally on Abramson (1987), 53, 64–70, 121, 147, 169.

Abramson (1987), 64–65: in Dec. 1923 Jenkins demonstrated his Radio Vision apparatus. Hugo Gernsback of *Radio News* and Watson Davis of *Popular Radio* both witnessed it, but reported that it was crude and cumbersome. "As far as can be determined, these were the first witnessed demonstrations of radio-television ever reported." But this doesn't meet our criteria for first television because of the mechanical components.

Authors Fisher and Fisher (1996), 56–60, have four Fathers of Television, Baird being the First Father and Jenkins the Second. Farnsworth and Zworykin were, of course, fathers 3 and 4.

Another interesting pre-television also-ran was Lev Sergeyevich Termen, also known as Leon Theremin, inventor of the famous and eponymous musical instrument. Theremin demonstrated a system in Russia just shortly after the Jenkins and Baird demonstrations. Theremin's system used rotating mirrors and had a resolution of 16 scanlines, and was demonstrated in late 1925 [Glinsky (2000), 41–47]. His third system, shown publicly June 7, 1926, had 64 interlaced scanlines. His fourth version had 100 scanlines and was demonstrated to Stalin in June 1927, and immediately classified as top secret. It's a bit distressing that Abramson (1987) doesn't mention Theremin.

12:*Despite Baird's humble*: Fisher and Fisher (1996), 21–36, captures the idiosyncratic Baird in a chapter appropriately titled, "Puir Johnnie": "The Nipkow disk [the basis of the Baird system] was simply not fast enough and the holes in it could not possibly be made small enough or spaced closely enough ever to produce a system that would be good enough to make television an integral part of people's lives. | The fault was in the system; it was doomed from the start" [p. 36].

Abramson (1987), 60: On July 26, 1923, Baird filed his first of many patents, this one on a system utilizing a Nipkow disk. For the pre-television history of Baird, see also Abramson (1987), 86, 93, 105–118, 140–147, 176–178, 195–204. For the collaboration with Farnsworth, see Abramson (1987), 209–235.

12:*Hugo Gernsback, Electrical*: Gernsback's *Electrical Experimenter*, 1913–1920, became his *Science and Invention*, 1920–1931. The May 1918 *Electrical Experimenter* quotation is as cited in Schwartz (2002), 306.

12:*Philo Taylor Farnsworth*: I use Schwartz (2002) as my primary source on Farnsworth, in addition to the patent work of Abramson (1987). Schwarz was aided in his study by Pem Farnsworth, Phil's widow, who granted him extensive ("dozens of hours of") interviews. See Schwartz (2002), 20–27, and Fisher and Fisher (1996), 126, for the Farnsworth founding story.

The photoelectric effect is a phenomenon associated with certain materials. They emit electrons when struck by visible light. Einstein's 1905 contribution was to propose that light was composed of discrete particles, now called photons, as opposed to being a continuous wave. So in effect light particles (photons) caused the dislocation of matter particles (electrons) from certain materials. Einstein's theory explaining exactly how the photoelectric effect worked was a cornerstone of what we now call quantum theory.

13:*Or something like*: Fisher and Fisher (1996), 126–127, has him mowing a hayfield with a single-disc mower, "clearing the field." A disc (or harrow) is not a mower, but it does clear away an old crop, say hay, by gouging the soil like a plow, but in a different way. Schwartz (1992), 21, has it a single-disc harrow cultivating a potato field, presumably the version he heard from Pem. Single-disc systems are rare but perhaps the Farnsworths really did have only one disc. It makes the metaphor fit better.

The Brigham Young High School tribute page to Farnsworth, http://www.byhigh.org/History/Farnsworth/PhiloT1924.html, accessed Nov. 30, 2021, finesses the problems: "But plowing or disc-harrowing potato and hay fields all day gives one an abundance of time to think."

13:*First, there's the*: This story has to be told carefully. Sometimes it's told that *while* Farnsworth was plowing he observed his scanning of the field in horizontal scanlines and that led to his Eureka moment. The trouble with this version is that plowing is boustrophedonic. Schwartz (2002), 21, avoids the pitfall by having Farnsworth gaze back at his plowed field, but on his p. 27: "pictures needed to be encoded just as a plow traverses a field."

Fisher and Fisher (1996), 126–127, do point out that Farnsworth had to alternate directions at each row. And they also suggest that the story should be taken "with a grain or two of salt."

The Brigham Young High School tribute page to Farnsworth, continued from the note above: "After a while, a good plow horse knows when it is time to turn the plow and start the next row: a time for boredom or inspiration. When Philo looked over the newly plowed field as he was finishing, he saw evenly parallel lines, row after row. It occurred to him that an image could be sliced into such rows, back and forth, and then each row transmitted in a continuous sequence. Thus the 'raster' image was born."

There's a weak argument that television *is* boustrophedonic. Each scanline is painted out by an electron beam that moves left to right. Then the beam is quickly retracted to the left side and repositioned to paint out the next scanline. During the retrace no signal is transmitted. The clumsy metaphor for that reality has the farmer lift the plow at the end of a plowed row and return, very quickly, along the next row (or in the space between the just finished row and the next row to be plowed) without his plow engaging the earth.

13:*But the larger*: On 6 Jan 1884, Paul Nipkow, Berlin, patented the mechanical disk as a scanning device [Abramson (1987), 13]. "This is the master television patent, for it showed for the first time a means of systematically scanning an image." I demote its importance in this book because it's so clearly pre-television by our definition.

In 1935 Adoph Hitler declared Nipkow the Inventor of Television, in the most grossly nationalistic misuse of that title [Elsner et al (1994), 130; Fisher and Fisher (1996), 19].

A weak argument for the Farnsworth plowing story is that what he saw were straight horizontal scanlines rather than the vertical, slightly curved scanlines of the Nipkow disk.

14:*A Nipkow disk*: On June 25, 1926, Baird made the first photograph of a human face scanned by Baird Television Ltd. [Abramson (1987), 86]. The man was surely Baird's competitor then partner, Hutchinson (cf. the man on the left in the photograph reproduced on the fourth page of the photo insert following Fisher and Fisher (1996), 136).

15:*It's clear that*: There was nothing fixed about 60 scanlines in the early times. There were no standards. Jenkins [Godfrey (2014), 111–112] gave Gernsback a demonstration in his lab of objects moving, and transmitted by radio, at 60 scanlines in 1923; but he increased the transmission of stills to 100 scanlines in 1924.

15:*Baird managed to*: The actual number of scanlines in old American analog television was 525 per frame, but many of these weren't visible because they were electronically blanked between frames. The number of visible scanlines typically used was 480, but it was actually 484 plus two half lines. At the New York Institute of Technology in the 1970s we used 486 lines in our digital approximation of television to be consistent with the American video standard (and to cover the two half lines).

16:*Farnsworth's key idea*: The diagram was disregarded in the final judgment, however.

16:*Farnsworth's 1922 sketch*: The patent was issued in 1930. Plate 8 on the right picture corresponds to "optical Image" on the left one and plate 18 to "Electron Image."

16:*"Community Chest" rings*: *Monopoly* is currently owned by Hasbro, but was originally published in 1935 by Parker Brothers. Another, similar stack of cards is called "Chance."

17:*A new investment*: Later, in 1929, the Farnsworth company in San Francisco would hire engineer Russell Varian (then let him go in 1930, rehire him in 1931, and lay him off in 1933 for good). This ties early video directly to Silicon Valley. Russell and his brother, Sigurd, two Stanford engineering graduates, started the company Varian Associates in 1948 just below Stanford University. It was a founding company in what became Silicon Valley, along with Hewlett-Packard, another company formed by two Stanford engineering graduates.

The Green Street location is now honored with an historical marker.

17:*William Crocker ran*: In 1986 the Crocker bank was absorbed into the Wells Fargo bank.

18:*There are two*: In the next two paragraphs of the main text, the "picture" is not literally a picture in photons of the visual scene. It's a picture in electrons. In both cases, the camera captures a picture in photons (brightnesses). The photoelectric effect causes an image in electronic charges to be induced on a plate. This is the "picture" that is scanned (in the next paragraph) by a sweeping cathode ray beam, or which is electromagnetically focused (in the second paragraph below) little by little onto a receiving, fixed detector.

18:*Farnsworth's fame is*: On Apr. 5, 1925, Max Dieckmann and Rudolf Hell applied for a patent on an electric camera tube [Abramson (1987), 75]. "This method of scanning, in which the entire electron image was moved across an aperture, was the antithesis of the . . . method whereby the electron image was stationary but was scanned by an electron beam. Tubes of this type were later to be called 'image dissectors.' This patent was the first of its kind."

On Jan. 7, 1927, Farnsworth applied for a patent on a television system from San Francisco [Abramson (1987), 95]. "Philo Farnsworth devised a novel system . . . The camera tube (which was later to be called an Image Dissector) was essentially the same as that of Max Dieckmann and Rudolf Hell. However, their patent had not yet been issued and, as often happens in the field of invention, was almost identical. Still, where Dieckmann failed to get his tube to operate, Farnsworth was to succeed."

19:*Vladimir Kosmich Zworykin*: Zworykin's customary patronymic, son of Kosma, is written variously as Kosmich, Kos'mich, or Kusmich. The shortened forms Kosma or, as on the gravestone (see next), Kusma, miss the point.

Find a Grave, no. 103484571, gravestone [his second wife's] photograph, Princeton Cem., Princeton, Mercer Co., N.J., "Zworykin | Katherine | born 6 December 1888 | died 18 February 1985 | beloved wife of | Dr. Vladimir Kusma [*sic*] | born 30 July 1889 | died 29 July 1982." The obituary transcribed to this site states: "Dr. Zworykin, whose marriage to the former Tatiana Vasilieff, ended in divorce, is survived by his second wife, the former Katherine Polevitsky; a daughter from his first marriage, Elaine Zworykin Knudsen of Pasadena, and seven grandchildren. . . . His ashes were scattered on Taunton Lake, in Medford, N.J., where he resided." Elaine was the younger sister of Zworykin's daughter Nina [see note 48].

In 1897 German Ferdinand Braun invented the CRT [Abramson (1987), 20]. It was used for displaying waveforms. On Sept. 12, 1906, Max Dieckmann and Gustav Glage, Strasburg, applied for "the first patent using a cathode ray tube as a display device not *for* waveforms" [Abramson (1987), 25]. That is, it was a calligraphic display.

19:*Zworykin was nineteen*: On July 25, 1907, Rosing, in St. Petersburg, applied for a patent for a television system using a CRT for receiver (display) [Abramson (1987), 26–27]. Television historian Albert Abramson doesn't stint, "This patent of Rosing was second in importance to that of the original Nipkow patent of 1884." Since I demote the importance of pre-television's Nipkow here, that leaves Rosing's patent in first position, counting the way Abramson does. But Rosing's transmitter (camera) used mechanically rotating mirrors so was far short of a television system as defined here.

On May 9, 1911, Rosing, "In his witnessed notebook, he is said to have written [Abramson (1987), 36], 'On May 9, 1911, a distinct image was seen for the first time, consisting of four luminous bands.'" This was the first transmission at a distance, but not all electric.

19:*He was an*: In 1910–1912, Zworykin worked as a student in Rosing's lab and witnessed his success [Abramson (1987), 37]. He later gave credit to Rosing for introducing him to the idea of cathode ray television. That Zworykin was at Rosing's demonstration in May 1911 is a reasonable but unsupported conjecture. It's so claimed in Glinsky (2000), 38, who categorically states it as true but cites no evidence: "In 1911, with the help of his student Vladimir Zworykin, Rosing successfully demonstrated a crude system based on the patent," and "On 9 May 1911, Rosing and Zworykin successfully demonstrated the principle . . ."

20:*Zworykin began his*: One of my two principal sources on Zworykin is another book by the respected Albert Abramson, *Zworykin: Pioneer of Television*. Abramson is very clear that it's based primarily on an unpublished 105-page manuscript dictated by Zworykin to his RCA secretary and given to Abramson on July 21, 1976. Abramson sometimes takes issue with this manuscript, but often has nothing else on which to base his biography for the Russian years preceding Zworykin's final escape to America in 1919.

My other principal source is [Zworykin and] Olessi, *Iconoscope: An Autobiography of Vladimir Zworykin*, an unpublished manuscript, but nevertheless available online (see bibliography for this chapter). Olessi quotes Zworykin's writings extensively. Apparently, the manuscript used by Abramson (1995) is part of these quoted writings: From the Editorial Note: "Although Albert Abramson drew on Zworykin's typescript for his scholarly biography (*Zworykin: Pioneer of Television*, University of Illinois Press, 1995), this is the first time the complete memoir has been available, supported here by Olessi's framework." The manuscript that Olessi worked from had 124 pages, but the last 10 are not in the first person.

20:*Lt. Zworykin was*: The page numbers in the Olessi source [e.g., Olessi (1971), 42] refer to the pages of Zworykin's manuscript—see the bibliography for more detail.

21:*Lt. Zworykin wore*: For this and the next several paragraphs, see Abramson (1995), 26–33. See also Olessi (1971), 34–35, 40, 50: "Most of the officers removed them and began wearing red ribbons on their sleeves or red rosettes in their lapels." So presumably officer Zworykin did the same. Why they were red is unexplained in the sources.

22:*He wanted out*: From the Kotelnikov chapter, we know that the Kotelnikovs were in Kiev in 1918, their second trip to the miserable Kiev so memorably described in Bulgakov's *White Guard*.

But Zworykin was gone from Kiev by October 1917, so the paths of Kotelnikov and Zworykin couldn't have crossed.

22:*The death had*: Zworykin stated [Olessi (1971), 58], "I tried my best to persuade them to move to Moscow where they [would] be less conspicuous, but they would not leave their home. This proved to be a fatal mistake. I learned what happened to them only many years later.", Zworykin stated only that [Olessi (1971), 96], "I found that my Mother had also died in Murom during the civil war." The civil war followed the Revolution. Zworykin said only [Olessi (1971), 2] with regard to his sister Antonina that she settled in Murom and, "she died there during the revolution." He also learned at the time of his visit to Murom that an aunt had been murdered.

22:*The Provisional Government*: Aleksandr Ivanovich Guchkov, a wealthy industrialist, was a founder of the Octobrist Party in 1905 which attempted to save the tsarist regime via reforms. That failed, and Guchkov then submitted the Act of Abdication for signature to Tsar Nicholas II. The February Revolution of 1917 overthrew the tsarists and replaced them with the Russian Provisional Government. From Feb. to late Apr. 1917, Guchkov served as its Minister of War. The Provisional Government lasted until the October Revolution of 1917 when the Bolsheviks took over.

Leon Trotsky would assume the equivalent position as head of the Red Army when the Bolsheviks took over in the October Revolution. Trotsky's title was People's Commissar of Military and Naval Affairs of the Soviet Union.

23:*But the vast*: I will use "Whites" as roughly equivalent with "not Reds," although the detailed history of the years just after the February Revolution of 1917 is more complex. Specifically, the Whites aren't synonymous with the Provisional Government after the tsar's abdication, but both were anti-Bolshevik. The Whites (or White Guard, or White Army) supported Aleksandr Kolchak when he was "Supreme Ruler and Commander-in-Chief of All Russian Land and Sea Forces" of the Russian Provisional Government (or the Provisional All-Russian Government), centered in Omsk. The Civil War between the Reds and the Whites would last for five years after the Revolution, with the Reds ultimately victorious.

23:*The convoluted route*: Nizhny Novgorod was then known as Gorki, and Perm as Molotov. Omsk is just north of the border with Kazakhstan. The detour through Perm took him quite far north of the direct line between Moscow and Omsk. And his route was even more convoluted than indicated. It also included a rail trip into the northern Urals. As Abramson, his biographer, working from the manuscript written by Zworykin for him put it [Abramson (1995), 32–33], "Zworykin's escape route is very confusing. I have accepted his version most of the time, but there are times when I have had to deal with facts that just didn't fit. . . . Clearly, his manuscript must be used carefully, though it must also be admitted that in the middle of a civil war it is quite hard to go directly to one's destination and Zworykin never makes it clear whether he was trying to reach Archangel or Vladivostok."

A case in point is perhaps: Zworykin reported [Olessi (1971), 64] that he was under arrest in Yekaterinburg (Ekaterinburg in Olessi) when the Tsar and his family were executed there. That date is known to be July 18, 1918. Zworykin was on his complicated route to Omsk at the time. Yet he reports departing Omsk to the Arctic "at the end of July 1918" [Olessi (1971), 66]. It's hard to square that everything that transpired between those two events—interrogation, verification of credentials via slow communications with Moscow, several more days in jail in Yekaterinburg, the jail break, the rail trip to Omsk, lining up of orders from the cooperative and the government in

Omsk, waiting for the fighting situations in the vicinity to improve, departure to the Arctic—happened in less than two weeks, but perhaps it did.

Probably the answer lies in the change from Julian to Gregorian calendars which happened, for the Reds, in Feb. 1918. The Whites probably didn't change calendars then so were still using Julian dates and so perhaps was Zworykin in his memoirs. July 18, 1918, Gregorian (modern) would have been July 5, 1918, Julian. A departure on, say, July 31, 1918, Julian means that Zworykin would have had 26 days to accomplish everything, and that's reasonable. N.B. for the same reason the so-called February and October Revolutions of 1917 actually occurred in March and November (Gregorian, or modern, dates).

The Czech involvement was surely that of the Czechoslovak Legion which battled the Bolsheviks in Russia. From *Wikipedia*, Czechoslovak Legion, accessed Dec. 4, 2021: "By mid-July [1918], the legionaries had seized control of the [Trans-Siberian] railway from Samara to Irkutsk, and by the beginning of September they had cleared Bolshevik forces from the entire length of the Trans-Siberian Railway. Legionnaires conquered all the large cities of Siberia, including Yekaterinburg, but Tsar Nicholas II and his family were executed on the direct orders of Vladimir Lenin and Yakov Sverdlov less than a week before the arrival of the Legion."

24:*Since the Reds*: Obdorsk is now Salekhard, and Archangel is Arkhangelsk in Russian. A famous city on the Ob is Novosibirsk, the third largest city in Russia, which lies east of Omsk several hundred miles on the Trans-Siberian Railway.

25:*To get a*: Novakosky [quoted on Abramson (1995), 216] notes that Zworykin was sent on an official mission that enabled him to leave the country but does not mention that he was wanted by the police for failing to register as a former officer of the Russian army."

Obdorsk became Salekhard in 1933. The Irtysh-Ob river is the seventh longest in the world. The Missouri-Mississippi is the fourth longest.

25:*Finally, on New*: Zworykin stated [Olessi (1971), 70], "Finally the day of departure came and I boarded the *S.S. Mauritania* [*sic*] for the United States. This was my first trip on an ocean liner. I traveled first class . . . The trip across the Atlantic was uneventful and we arrived in view of the Statue of Liberty on New Year's Eve of 1919 and were held in the harbor until the next morning." However, the records below prove that he sailed aboard *S.S. Carmania* and arrived New Year's Day 1919. We can forgive him these small lapses. He also mentioned that he dined aboard with the future president of Peru, Leguia. Indeed, Augusto Bernardino Leguía was listed with Zworykin aboard the *Carmania*, and he did become president of Peru.

UK and Ireland, Outward Passenger Lists, 1890–1960, https://ancestry.com, image 223 of 237 online, for the *S.S. Carmania*, departing Liverpool, Dec. 21, 1918, for New York, "[Contract Ticket Number] 14833 [Names of Passenger] Zworykin, Wladimir [*sic*] A [Alien] [Class] 2nd [*sic*] [Port at which Passengers have contracted to land] New York [Profession] Engineer [Ages] [Adult Male] 30 [Country of which Citizen or Subject] Russia [Country of last Permanent Residence} Foreign Countries [Country of Intended Future Permanent Residence] Russia." Leguía was listed [image 218 of 237] in first class. Zworykin was listed in second class, but the arrival record, next, has both in first class.

New York, U.S., Arriving Passenger and Crew Lists (including Castle Garden and Ellis Island), 1820–1957, https://ancestry.com, images 59–60 of 64 online, first-class arrivals aboard *S.S. Carmania*, sailing from Liverpool, Dec. 21, 1918, arrived New York, Jan. 1, 1919, "[no.] 8 [name] Zworykin Vladimir [age] 30 [sex] M [married] M [able to read] Yes [speak] Russian | French [write] Yes [nationality] Russia [race or people] Russian [last permanent address] Siberia Omsk [name and address of nearest relative or friend in country from whence alien came] Home (Hotel Russia) Omsk [final destination] Siberia Omsk [has ticket to final destination] No [passage paid by] Self [in possession of $50] Yes [been in U.S. before] No [who joining in U.S.] Russian Consulate, N.Y. [purpose of coming to U.S.] In transit [intends to become citizen] No . . . [height, feet, inches] 5 10 [complexion] Fair [hair] Brn [eyes] Blue [marks] None [place of birth] Russia Omsk."

26:*His Omsk contacts*: *California, U.S., Arriving Passenger and Crew Lists, 1882–1959*, https://ancestry.com, images 115–116 of 698 online, line 25: "Wladiwir" Zworykin, arrived in San Francisco, Calif., June 9, 1919, aboard the *S.S. Siberia Maru*, having departed from Yokohama, Japan, May 24, 1919, age 30 years 6 months, male, married, engineer, reads, speaks Russian and English, writes, nationality Russia, a Russian person, last permanent address Omsk, Russia, name and address of nearest relative or friend in the U.S.: Russian Embassy, Washington, D.C., final destination: New York City, N.Y., no ticket to final destination, paid for passage himself, in possession of $50, had been in the U.S. before, in New York in 1919, to join someone at the Ansonia Hotel, N.Y., plans to stay indefinitely in the U.S., good health, 5 feet 8 inches, fair complexion, brown hair, blue eyes, born in "Mourom," Russia.

26:*And not a*: The Omsk government was then under Aleksandr Kolchak. See *Admiral Aleksandr Kolchak*, http://www.gwpda.org/naval/pers0002.htm, accessed Dec. 7, 2021: "His [Kolchak's] forces were defeated by late 1919, and in December 1919 he fled from Omsk to escape the Red advance. . . . Kolchak was handed over to the Socialist Revolutionaries of Irkutsk on 15 January 1920, and then turned over to the Bolsheviks when they arrived. . . . the Bolsheviks had him taken out to the river and shot on 7 February 1920."

26:*Tatiana immediately joined*: *New York, U.S., Arriving Passenger and Crew Lists (including Castle Garden and Ellis Island), 1820–1957*, https://ancestry.com, images 1–2 of 106 online, arrivals aboard *S.S. Oscar II*, sailing from Copenhagen, Aug. 26, 1919, arrived New York, Sept. 14, 1919, "[no.] 11 [name] Zworikina Tatjana [age] 31 [sex] f [married] m [occupation] housewife [able to read] yes [speak] russian [write] yes [nationality] Russia [race or people] russian [last permanent address] Germany Berlin [name and address of nearest relative or friend in country from whence alien came] friend, Wladinir [*sic*] A. Stern | Lundsgade 10, Copenhagen [final destination] D.C. Washington [has ticket to final destination] N.Y. [*sic*] [passage paid by] Self [in possession of $50] yes [been in U.S. before] no [who joining in U.S.] husband, Wladimir [*sic*] Zworikin [*sic*], Russian Embassy, Washington D.C. [plans to return] no [length of visit] forever . . . [height] 5 7 [complexion] healthy [hair] fair [eyes] gray [marks] no [place of birth] Russia Odessa."

Selected U.S. Naturalization Records–Original Documents, 1790–1974, Ancestry.com, image online, naturalization petition no. 54780, and acceptance. Vladimir Kosma [*sic*] Zworykin, a research engineer of Swissvale, Pa., was born July 17, 1888, Murom, Russia, immigrated from Liverpool on Dec. 21, 1918, arriving in New York on Jan. 1, 1919, aboard *Carmania*. He declared his intention to naturalize on Dec. 30, 1920, in Pittsburgh, Pa. His wife Tatiana was born Jan. 15, 1891 [! cf. her naturalization petition which gives the year as 1894], Moscow, and resides with him. He has one child, Nina, born June 3, 1920, Mount Vernon, N.Y, who now resides in Swissvale, Pa. He had resided in Pennsylvania since Feb. 29 [*sic*], 1923. All this from his petition for naturalization sworn May 5, 1924. He swore allegiance on Sept. 16, 1924, and was admitted as a citizen on that date. [I was unable to find this record and the one in the following paragraph, when I tried checking them on Dec. 4, 2021. The collection name has changed, for one thing, and the one cited is no longer in use. Nevertheless, I trust my transcriptions from the online records done several years ago, and assume the originals are stored somewhere, hopefully still online.]

Selected U.S. Naturalization Records–Original Documents, 1790–1974, Ancestry.com, image online, naturalization petition no. 58500, and acceptance, Mrs. Tatiana Zworykin. Mrs. Tatiana Zworykin, of Swissvale, Pa., was born Jan. 15, 1894, Moscow, immigrated from Copenhagen on Sept. 4, 1919, arriving in New York on Sept. 14, 1919, aboard *Oscar II*. Husband, Vladimir, was naturalized Sept. 16, 1924, in Pittsburgh, Pa. They were married Apr. 17, 1916. He was born July 17, 1888, Murom, Russia, who now resides with her. She has one child, Nina, born June 3, 1920, New York, who now resides in Swissvale, Pa. She had resided in Pennsylvania since Mar. 28, 1923. All this from her petition for naturalization sworn Dec. 4, 1924. She swore allegiance on Mar. 5, 1925, and was admitted as a citizen on that date.

Swissvale is a borough of Allegheny Co., Pa., 9 miles east of downtown Pittsburgh [*Wikipedia*, Swissvale, Pennsylvania]. George Westinghouse's Union Switch and Signal Co. was located there.

26:*Zworykin didn't return*: Zworykin would visit the Soviet Union at least three times [Abramson (1995), 137–142, 201; Olessi (1971), 98] in the 1930s (Aug. 1933, Sept.–Nov. 1934, Feb.–Mar. 1935). He had border troubles leaving the Soviet Union, and he had FBI troubles in the U.S., but he successfully negotiated his way through these difficulties. He visited Russia again in July 1962.

My reader and correspondent Prof. Dmitry Urnov informed me of a book (in Russian) by Vassily Petrovich Borisov, *Vladimir Kosmich Zworykin (1889–1982)* (Moscow: 2002), which contains a chapter on Zworykin's visits to the Soviet Union and lists his Soviet connections. Prof. Urnov made these points: (1) Zworykin was visited by Soviet experts in radioelectronics in New York before his 1933 visit; (2) he established relationships with Soviet colleagues and industry that were mutually beneficial and longlasting; and (3) that Zworykin returned at all was unusual for most of those who fled.

27:*The problem of*: Abramson (1987), 28–29, "This startling letter, dated June 12, 1908, thus marks the beginning of the concept of an all-electric television system including both camera and receiver." I've preserved his spelling of *kathode* (commonly used in the 19th century) but broken the description into three paragraphs to make it clear that he had all the problems of fully electric television clearly in mind. The actual letter to the editor was A. A. Campbell Swinton, "Distant Electric Vision," *Nature* 78:151 (published June 18, 1908). It begins with this: "Referring to Mr. Shelford Bidwell's illuminating communication on this subject published in *Nature* of June 4, may I point out that though, as stated by Mr. Bidwell, it is wildly impracticable to effect even 160,000 synchronised operations per second by ordinary mechanical means, this part, of the problem of obtaining distant electric vision . . . ," and extends with this further statement: "Possibly no photoelectric phenomenon at present known will provide what is required in this respect, but should something suitable be discovered, distant electric vision will, I think, come within the region of possibility."

28:*True to the*: Abramson (1987), 38–40, 1911, Swinton presented details of his television system (only an idea in 1908), "for the first time a description of a camera tube which not only used cathode ray scanning but also depended on the storage principle," also a photo of him with this caption: "A. A. Campbell Swinton, whose proposed system of electric television would be the inspiration for most of the related inventions of the 1920s and 1930s."

As was the case with the other aristocratic inventor in these pages with four names, William Kennedy Laurie Dickson, sometimes the last two names are hyphenated and used as a single name. Abramson (1987) omits the hyphen but treats the name as if there was one. I follow the English practice of using just the final name. See, for example, *English & Wales, National Probate Calendar (Index of Wills and Administrations), 1858–1966*, Ancestry.com, image online, "Swinton Alan Archibald Campbell of 40 Chester-square Westminster Middlesex died 19 February 1930 Probate London 25 March to . . . . Effects £99785 8s. 2d." Swinton himself signed his name "A. A. C. Swinton" on his London Freedom of the City admission paper, June 3, 1920, and on his membership papers in the Institution of Mechanical Engineers, Aug. 25, 1910 [images of both on Ancestry.com]. (£99,785 in 1930 was about $474,976 in 1930, or about $7,124,659 today.)

His set of names carried the history of his line, just as did Dickson's. His father was Archibald Campbell Swinton, who wrote a genealogy of his ancient Scottish family, *The Swintons of That Ilk and Their Cadets* (Edinburgh: 1883), especially "III. Campbell Swintons of Kimmerghame," beginning on p. 105, honoring the intermarriage of the Campbells with the Swintons. This book traces the old Saxon family back to intermarriage with the royal Stuarts and earlier, to the time of Macbeth and Malcolm of Canmore (about 1040). The name Alan was first used by Sir Alan of Swinton who died in 1200, and whose name was borrowed by Sir Walter Scott for one of his stories. As with W.K.L. Dickson, all four names of A.A.C. Swinton matter to members of that old family.

Alan Archibald Campbell Swinton was born Oct. 18, 1863, Edinburgh, Scotland, father Archibald Campbell Swinton, mother Georgiana Caroline Sitwell [*Scotland, Select Births and Baptisms, 1564–1950*, Ancestry.com]. His father was a notable described in the Swinton section of the *Dictionary of National Biography* (British).

Abramson (1987), 43, 1915, Swinton published a complete plan for his system in *Electrical Experimenter*.

Abramson (1987), 53, 1921, Swinton's system is published for the fourth time, "which makes it difficult for any inventor from 1921 on to claim he was not aware of its existence."

Abramson (1987), 67–68, 1924, Swinton again described his television system, still just an idea: "Campbell Swinton's paper had an enormous effect on the history of television as it stimulated a great amount of effort on behalf of the large electrical companies as well as many independent inventors."

Abramson (1987), 118, 1928, Swinton published an article, "Television by Cathode Rays." He incorrectly claimed that Zworykin's patent was dated (its "convention date") was July 13, 1923. The correct date was July 13, 1925. He claimed that CRT transmitters had not been exhibited or even claimed. "At this time, Campbell Swinton was unaware that the only cathode ray transmitters in the world were being built and operated in San Francisco by Philo T. Farnsworth." The July 13, 1925, patent by Zworykin was for a color television scheme that was based on his still-pending 1923 patent. Unlike the 1923 patent, with all its many problems, this 1925 patent went through the patent system relatively easily and was granted in the U.S. in 1928 [Abramson (1987), 78–79]. If you find that confusing, welcome to the esoteric world of patent law!

Abramson (1987), 148, Feb. 19, 1930, Swinton died. "He was never to know that at this time camera tubes very similar to the ones he described in 1911 were being built in the RCA Laboratories by V. K. Zworykin in Camden, N.J."

29:*And Swinton cheered*: Fisher and Fisher (1996), 60, reports his conversion, but 79–80, his redemption, which the *Times* refused to print in its entirety.

31:*The completely one-dimensional*: This example shows as clearly as possible what a scanline sample is. The problem with it is that the "A" is sharp-edged. In frequencyspeak, it has very high frequencies—too high. The Sampling Theorem couldn't reconstruct the missing information between just the four scanline samples shown. For the Sampling Theorem to work, the "A" would have to be defocused slightly to get rid of the sharp edges, and the number of scanline samples would have to be increased to sample often enough to make the image reconstructible (at twice the highest frequency remaining in the defocused "A"). These limitations are well within the capability of ordinary analog displays.

31:*A TV set*: In television we don't have to introduce the awkward notions of outside the pupil and inside the pupil. A TV set always reconstructs visual flow outside the pupil.

32:*Dick Shoup's SuperPaint*: Frampton did try to bridge the gap late in his life, working with the very crude personal computers available in the late 1970s and early 1980s. He said in 1980, "I'm sick and tired of the 'two cultures' of that gulf between what is called science on the one hand, and what is called art on the other. Artists who think there is some great and fundamental gulf between science and art think in terms of a repulsive little cartoon in which the sciences are cold and unfeeling and the arts are warm and emotional. Of course, I get to be typed as an icicle, Frosty the Snowman with his cinematic calculus, which mightily annoys me and hurts my feelings. On the other hand, scientists think of the sciences as straightforward and arts as abounding in mystery. And none of these things is true. In the sciences in particular, and in the queen of the sciences—mathematics—and, indeed, in the almost celestial, clumsily named intellectual entity computer science, which has already made mathematics a kind of subset of its interests, nothing is quite as rampant as a sort of undefined gut aestheticization." Quoted on <hollisframpton.org.uk/bio.htm>, accessed June 29, 2016.

The detailed history of color pixels is reserved for a later chapter (the Shade chapter). There had been several other early uses of color at more than one bit per pixel—for example, three bits per pixel for eight colors—but Shoup's system was the among the first, if not the first, with eight bits per pixel. SuperPaint was a fully functioning production system with video in and video out.

33:*What his tangled*: [Math] Neither Newton's calculus nor Zeno's paradox applies to film or video. The calculus only seems to sample a continuum. Its "samples"—the so-called infinitesimals—are taken infinitely close together in a very particular way. There are therefore an analog infinity of such "samples" or infinitesimals. They are not the discretely spaced samples used by the Sampling Theorem. Zeno's paradox is a famous thought problem that probes the nature of a continuum. It resembles the argument we used in the Kotelnikov chapter to show that digital infinity (used in Kotelnikov's sampling) is less than analog infinity (used in Newton's calculus). Zeno doesn't apply to the obviously discrete frames of film and video.

33:*As a result*: The NTSC introduced first was monochrome ("black and white"). Color was added to it later and became popular in the 1950s. An alternative unkind reading of NTSC was "Never The Same Color."

33:*The American system*: The English system is called PAL (Phase Alternate Line), and the French SECAM (Sequential Couleur Avec Mémoire). They both use 625 interlaced scanlines per frame and refresh at 25 frames per second (50 fields per second), consistent with European 50 cycles per second electrical current. But each handles color in an entirely different way.

34:*The naïve idea*: Abramson (1987), 85, Mar. 2, 1926, patent application by Frank Gray of Bell Labs, interlace described for the first time; Abramson (1987), 137, June 27, 1929, T. A. Smith of RCA applied for a patent on interlace.

35:*The picture isn't*: Another problem with the picture on the right: The television display spreads the scanlines vertically, with its spreader, so they aren't sharp-edged as the illustration indicates.

[Math] Psychophysical experiments have established that interlaced scanning at *m* scanlines per frame (so .5*m* scanlines per field, 60 fields per second) is perceptually equivalent to progressive scanning at .6*m* scanlines per frame, 60 frames per second. In other words, two interlaced fields don't double the resolution. They increase it by only 20%. For example, two 540-scanline fields in an interlaced system are perceptually equivalent to 648 scanlines per frame in a progressive system (120% of 540 is 648). Or, equivalently, 1080i is perceptually equivalent to 648p (60% of 1080 is 648).

Abramson (1987), 222, Aug. 1935, "all of the even-line interlaced systems seemed to have a very pronounced 'interline' flicker."

35:*Interlace is a*: Interline flicker is obvious on a television whose native technology is 1080i. A system that is natively 1080p can easily simulate a 1080i signal. It simply copies the missing scanline in each field from an adjacent scanline. So if information was missing because of interlace then it is still missing when simulated by a progressive system. That is, if a signal originates as 1080i then it has interline flicker even if presented on a 1080p system. The converse is not true: An intrinsically interlaced system cannot accurately simulate a progressive system. It has to "invent" the missing scanline information. It's easy to lower resolution, but not to raise it.

36:*The Sampling Theorem*: If half-resolution images were deemed good enough then the Sampling Theorem could be applied for each field. 240 scanlines could be reconstructed into an image as accurately as the Sampling Theorem allows. But, of course, fields are not intended to deliver half-resolution images, but an approximation to full 480-line resolution.

36:*A proper sample*: The horizontal scan rate of U.S. analog television is officially 15,750 cycles per second. So each line takes .000064 seconds (64 microseconds) to scan. There are 525 lines (counting the invisible ones) so one complete frame takes about .033 seconds—one-thirtieth second—about 33 milliseconds. In more detail, the odd lines take about half that time, and the even lines the other half, or one-sixtieth (.0167) second for each field. So the time *skew* along each line is 64 microseconds. That is, the right end is scanned 64 microseconds after the left end. And the bottom right of each field is scanned about 17 milliseconds after the top left.

Fourier theory *was* applied to the strange television signal, however, in very clever ways. Abramson (1987), 208, an important article was published in July 1934 by Bell Labs that "by the use of two-dimensional Fourier analysis, a theory of television scanning had been developed. . . . this important article indicated that as a result, much more information could be fitted into the television signal with no visible effects on the received picture." And in the 1940s Fourier theory was used to ingeniously "fit" color information into the NTSC signal that was designed initially for just grayscale, or "black-and-white," television.

37:*For years there*: Historian Abramson, in Abramson (1987), sorted through all the numerous patent subtleties of the television industry for us. It is a major achievement and should be applauded.

Abramson (1987), 63–64, Dec. 29, 1923, Zworykin at Westinghouse applied for a patent for an all-electric television. "This included several new concepts, with the camera tube of primary importance in this application, and as a result was the subject of many patent interferences (eleven) and many delays in going through the United States Patent Office."

Abramson (1987), 78–79, Oct. 2, 1925, Zworykin tried to amend his 1923 patent application. "This amendment was to slow down the patent application for the next 13 years and cause Dr. Zworykin many problems."

Schwartz (2002), 233–235, shows that the patent actually was never issued in the well-accepted way by U.S. Patent Office decision. The RCA legal team found a way around that process using a Delaware court, with no scientific or technical knowledge, to declare the patent was valid and force the Patent Office to issue it. It's hard to believe this worked but apparently it did. The powerful effect it had was to give RCA an additional 8 years of patent coverage (of some sort) after Farnsworth's ended.

37:*Zworykin evidently built*: Abramson (1987), 79–81, note 17 on 286. At about this time (but the time is disputed) he also gave a demonstration to Westinghouse executives. "Zworykin himself described the demonstration as being very poor," with a "'picture' merely an X-mark." And "At no time did Dr. Zworykin ever claim that this demonstration was a success." He was told to work on something else. Then comes this curious claim by Abramson: "The camera tube used in this demonstration has survived to this day. . . . for all intents and purposes it was the first electric camera tube ever built and operated."

Abramson (1987), 105, Sept. 7, 1927, "It is claimed . . . he [Farnsworth] was able to transmit an 'image' from one of his early camera tubes. It was no more than a moving blob of light that was reproduced on a receiving tube, but it proved that the new system would work. | At this time Farnsworth had the only working camera tubes in the world." Presumably, Zworykin's tube no longer worked (see paragraph above) to avoid contradiction here.

38:*In 1928 Farnsworth*: Farnsworth's own definition of television required the image to move. In a note Feb. 13, 1927, to an investor, he talked of showing a line picture, then transmitting a photograph, and "Television will then be the next step" [Fisher and Fisher (1996), 148].

Internally, Farnsworth recorded in his lab notes of Sept. 7, 1927, "The Received line picture was evident this time. Lines of various widths could be transmitted and any movement at right angles to the line was easily recognized." The image was of straight lines, and it was moved relative the camera as indicated.

Abramson (1987), 125, Aug. 24, 1928, Farnsworth of the Crocker-Bishop Research Laboratory, San Francisco, demonstrated the Farnsworth television system to Pacific Telephone. "They were impressed by the photoelectric transmitter tube (the dissector) and that all scanning was done electrically."

On Sept. 2, 1928, Farnsworth demonstrated to the press, reported in the *San Francisco Chronicl*e the following day, the transmission of an image 1.25 inches square of "a queer-looking little image in bluish light, one that frequently smudges and blurs," of 8,000 elements at 20 frames per second. That computes to 400 elements per frame, or say 20 elements per each of 20 scanlines [Fisher and Fisher (1996), 164].

Abramson (1987), 128, Nov. 28, 1928, Farnsworth applied for a patent, "the first one to show the standard form of dissector that was to be used for the next several years."

38:*But less than*: *Electronic* implies the use of vacuum tubes (and later transistors) for all things electrical—no moving, or mechanical, parts (at the macroscopic level).

Abramson (1987), 131, Jan. 1929, Farnsworth got nationwide publicity. On Feb. 15, 1929, he hired Harry Lubcke from UC Berkeley to build a completely electric scanning generator. They had it by July 1929. "This gave Philo Farnsworth the first all-electric television system in the world. He now had in his laboratory an all-electric camera device (the dissector tube), a magnetically focused high vacuum cathode ray viewing tube, and a vacuum tube scanning and pulse generator. There were absolutely no moving parts in the system." Fisher and Fisher (1996), 187, gives the date as Aug. 1, 1929, citing Farnsworth's lab notes of Aug. 17, 1929.

Abramson (1987), 145, Dec. 1929, magazine *Radio* published a photo of a Farnsworth television image. "This appears to be the first photograph published of an image produced by an all-electric television system with no moving parts." Takayanagi had published a picture from television earlier, but his system still contained mechanical parts. And, of course, so had Baird in 1926, but with mechanical pre-television.

38:*To show off*: Schwartz (2002), 151, "He was transmitting visual signals a mile away by radio to an office called the Hobart Building. He secured a copy of the first talking cartoon, Walt Disney's *Steamboat Willie* . . . and he was able to show these entertaining snippets on his reception tube."

The keyword in the Pem's face claim is *broadcast*. Otherwise there is a conflict with the claim of Baird's 1926 photograph of his partner, Hutchinson.

39:*Farnsworth was building*: Abramson (1987), 115, 118, May 22, 1928, Roy Bishop, one of Farnsworth's investors, wrote GE offering the patents. "It is known that Farnsworth's financial backers had decided quite early that his television project be turned over to one of the large electric companies in anticipation of the enormous development costs involved."

39:The Kinescope changed: Abramson (1987), 145, "Zworykin's tube was the most important single technical advancement ever made in the history of television." But it did not in itself constitute television as we mean it.

40:*Zworykin made an*: Abramson (1987), 122, 1928, Zworykin met Gregory Ogloblinsky, Fernand Holweck, and Pierre Chevallier at Etablissements Belin, under Marcel Belin. He was shown a working electrostatically controlled tube by Holweck and Chevallier; also, p. 123, Sept. 1928, he returned to Westinghouse with one of these tubes and with Ogloblinsky, who was "soon to become a most valuable addition to Dr. Zworykin's staff."

40:*About a year*: Abramson (1987), 123, Zworykin's big move, with a practical TV picture tube. "As is true of many great inventions, while all of these elements were in existence, it took Dr. Zworykin's genius to put them together properly. This was Dr. Zworykin's greatest triumph." But he couldn't get Westinghouse to proceed with the new tube.

Abramson (1987), 141, Nov. 16, 1929, Zworykin at Westinghouse patented Kinescope.

Abramson (1987), 143–145, Nov. 18, 1929, Zworykin delivered a paper to the IRE, Rochester, N.Y., on Kinescope. Despite reports, he did not show Kinescope at this meeting. There were seven receivers including one in Zworykin's home (60 scanlines, 12 frames per second). "This appears to be the first reception of television by radio to an all-electric receiver, with absolutely no moving parts." "There were absolutely no public demonstrations of this device until May 1932." (But Abramson (1987), 149, Apr. 2, 1930, demonstration of Zworykin's tube. "This seems to be the first report on the new Zworykin Kinescope.")

Zworykin used a Mickey Mouse film for a 60-scanline transmission test of Kinescope, but we don't know which one [Olessi (1971), 86]. This must have occurred at about the right time for the film to have been *Steamboat Willie*, *Plane Crazy*, or *The Gallopin' Gaucho*, all 1928 productions.

40:*While this was*: Abramson (1995), 81, late June 1929, the RCA television station W2XBS transmitted many images of a Felix the Cat doll standing on a rotating turntable. "Radio News reported not only that ‘conservative’ RCA was broadcasting on a regular schedule but that there were rumors of ‘impending RCA television receivers as well.’” N.B., Abramson (1987), 112, Apr. 1928, W2XBS “appears to be the first permit ever issued in the United States for a television station.” Notice the curved scanlines of the Felix the Cat picture, a sure sign of a mechanical spinning disk.

Fisher and Fisher (1996), caption of Felix photo in the photo insert following p. 236: “A plastic model of Felix the Cat provided a willing test model for RCA’s experimental transmissions in 1929 and 1930. Felix stood atop a phonograph turntable in front of a Nipkow-disk camera . . . The result was a 60-[scan]line picture on Zworykin’s Kinescope receiver.”

41:*The state of*: Abramson (1987), 146, end of 1929, “In the United States, the important work on cathode ray transmitters was being done by Dr. Zworykin at Westinghouse in Pittsburgh and Philo Farnsworth in San Francisco. The only *other* work on cathode ray receivers was that of Frank Gray of the Bell Telephone Labs and Kenjiro Takayanagi in Japan.”

41:*Kenjiro Takayanagi of*: Abramson (1987), 94, 113, 146. In Dec. 1926, Takayanagi claimed to have transmitted his first (still) picture onto a CRT display. In May 1928, he gave a demonstration of his 40-scanline CRT television system, “His article describing this system showed the first published pictures from the screen of a cathode ray tube.” By the end of 1928, “Clearly he had the most advanced cathode ray system in the world at the time.” But it was short-lived because of the subsequent more extensive developments by Farnsworth and Zworykin in 1929 and 1930.

Takayanagi died at age 91 in 1990.

41:*In 1929 Takayanagi*: Abramson (1987), 119, June 11, 1928, Kolomon Tihany (Hungarian), applied for a patent for a complete CRT-based television system. “Tihany described at least four varieties of photoelectric camera plates, each of which was quite novel and important. . . . The last two variations were quite important as they showed *means to store and intensify a charge* [emphasis added]." He showed all the elements necessary to produce a practical storage-type camera tube, but apparently never built one successfully.

Abramson (1987), 160, Dec. 27, 1930, Takayanagi applied for a patent on a charge-storage television camera. "By this time, the idea of a charge storage device was quite common. The problem was how actually to make such a device. That Zworykin had already reduced this principle to practice at this time was not to be known for several more years. In fact it wasn't too long before the problems of such a camera tube were thought by certain authorities to be insolvable."

42:*Takayanagi's next major*: Abramson (1987), 210, 222, "This 1934 trip by Kenjiro Takayanagi was the start of an organized effort by the Japanese government to devise and develop television systems of their own design." "Takayanagi had created the core of the future Japanese television industry with his vision and ingenuity."

Actually, the giant company Toshiba is widely considered to be the GE of Japan today.

42:*We pay particular*: "High definition" was generally used in early television to mean "higher than it used to be." And interlace vs progressive systems have to be compared carefully. A nominal 1,000-scanline interlaced system (500 scanlines per field) is perceptually equivalent to about a 600-scanline progressive system.

The US digital standard, called ATSC (became HDTV), was adopted in the US, Canada, Mexico. Similar standards have been adopted in most other parts of the world, or are scheduled for the first two or three decades of the millennium. For example, a digital standard called DVB has been adopted by Europe, Russia and most of the former Soviet republics, Australia, India, Malaysia, and much of Africa. The International Telecommunications Union is working on standards to assist in the coordination of the various standards.

43:*Zworykin must have*: Abramson (1987), 152, 166. Curiously, and disappointingly, Abramson's later biography of Zworykin substantially softens the impact of Image Dissector at RCA after this visit [Abramson (1996), 90–91]. I have great respect for Abramson (1987), the history of early television with its difficult and careful patent work, but I've lost a certain amount of respect for Abramson (1996), his Zworykin biography, because of such obvious omission of earlier established fact, established by himself.

43:*RCA passed on*: Abramson (1987), 151, Zworykin's report on his trip to Farnsworth's lab is not available reportedly. RCA's Ernst Alexanderson's full statement in turning down Farnsworth's patents: "I think that Farnsworth can do greater service as a competitor to the Radio Corporation group by settling this provided he has financial backing. If he should be right, the Radio Corporation can afford to pay more for his patent than we can justify now." However, Alexanderson was not in favor of CRT systems at all, not even Zworykin's. He supported mechanical systems.

44:*The industrial espionage*: Abramson (1987), 173–175, Oct. 23, 1931, the tube was named Iconoscope, apparently first built and successfully tested Nov. 9, 1931. Zworykin applied for the patent Nov. 13, 1931. "We must give Dr. Zworykin and his research team at Camden the credit they so richly deserved."

45:*This famous meeting*: Abramson (1987), 123; Fisher and Fisher (1996), 141–144. $100,000 in 1930 is about $1,500,000 today. $25,000 in 1926 is about $338,000 today. Farnsworth was also given, in addition to the $25,000, access to lab space at 202 Green St., San Francisco.

Fisher and Fisher (1996), 174, states that the meeting between Sarnoff and Zworykin occurred "On that January day in 1929." Bilby (1986), 121, says only, "In 1929." But it's Abramson (1987), 123, who states, "This famous meeting (of which the exact date is impossible to document, but which has been narrowed down to sometime late in December 1928 or at the latest, January 1929) took place."

46:*But two years*: Abramson (1987), 192, 1932, Philco transmitted 240-scanline pictures, it was claimed, in collaboration with Farnsworth. "It is known that neither Philco nor Farnsworth was happy with the arrangement and it was about to be terminated."

Elma Farnsworth (1990), 143–144, Philco also barred Farnsworth from taking time off at the death of his baby son to accompany his wife Pem and the baby's body to Utah for burial. She went alone.

47:*During these years*: Fisher and Fisher (1996), 48–49, "In actuality, the hundreds of viewers who came [to Selfridge's] to see 'television' looked through a narrow tube and 'were able to see outlines of shapes transmitted only a few yards by a crude wireless transmitter.'"

Abramson (1987), 105, "Baird had now settled into a pattern of producing many variations of his basic television system in order to keep his financial backers happy. (This practice was to have severe repercussions during the next few years.)"

Abramson (1987), 110, Mar. 7, 1928, it was claimed that a television signal was received on board the liner *Berengaria* while a thousand miles at sea. "This was in keeping with the Baird policy of exploring every facet of the new field of television (and getting much-needed publicity) to keep the public's curiosity alive." Also, June 1928, "the Baird system is hopeless" quotation.

47:*Nevertheless, Baird continued*: Abramson (1987), 140, Sept. 30, 1930, the first experimental broadcast took place from the Baird studio (30 scanlines, 12.5 frames per second). "This was quite a victory for the Baird Television Company." Westinghouse was broadcasting Felix the Cat in 1929.

47:*The only thing*: Abramson (1987), 176, Oct. 25, 1931, Baird's "no hope" quotation. "Baird's short-sightedness . . . was to cause him much grief in the future."

Abramson (1987), 178, Jan. 1932, Baird Television Ltd. was sold to the president of Gaumont-British Films. "This purchase saved Baird Television from complete financial collapse."

47:*The crucial battle*: Abramson (1987), 194. The RCA basis of EMI is explained in Fisher and Fisher (1996), 178–179.

48:The British Post: Abramson (1987), 18–19, 195, Apr. 1933, EMI "transmissions and equipment were far superior to those of Baird," and "The result of these demonstrations was a major change in policy of Baird Television in regard to cathode ray television."

48:*He did it*: Abramson (1987), 195, 202. The Crystal Palace was located at the time in Sydenham Hill, in the south part of London.

49:*Baird needed an*: Abramson (1987), 209, 213, Nov. 6, 1934, as a result of the collaboration of Baird and Farnsworth, Fernseh A.G. in Germany started to build Image Dissector tubes. The EMI version of Iconoscope was called Emitron.

49:*The Selsdon Committee*: Abramson (1987), 214, Jan. 14, 1935. This was perhaps the first use of the term "high definition," which would lie dormant for years then be resurrected for the High Definition Television (HDTV) digital standard at the millennium.

49:*Baird held with*: The rule of thumb (per note 35:*The picture isn't*) for comparing an interlaced system to a progressive system is multiply by 60%. The EMI system with 405 interlaced scanlines was thus perceptually equivalent to a progressive system with 243 scanlines (60% of 405 scanlines). In other words, the perceived resolution of the two systems was essentially the same. The Baird system must have flickered badly, however, with an update rate of only 25 frames per second. That the 405 number was larger then 240 surely made the EMI system seem better than the Baird in resolution too, but it was the lack of flicker that was the true improvement.

50:*Baird demonstrated its:* Abramson (1987), 224–225, "The details [EMI] revealed a very advanced, highly sophisticated set of specifications, one that turned out to be the standard for Great Britain for almost 50 years with few modifications.

50:*The penultimate face-off*: Abramson (1987), 232. Schwartz (2002), 227–232, recounts the close call that Farnsworth and his wife, Pem, had with the Nazis in a 1937 visit to Germany. The purpose of the visit was to collect fees from Fernseh for use of the Farnsworth technology. They were lucky to escape with their lives, and no money.

50:*In November 1936*: Abramson (1987), 234–235. "It was reported that John Logie Baird was present but was not invited to take part in the ceremonies."

Baird Television, Crystal Palace Television Studios, the South Tower was used for experimental transmission by the Baird Company. "In July 1933 his [Baird's] company moved to the Crystal Palace, occupying 40,000 sq. ft. of space under the south transept and adjoining the tunnel which connected the two distinctive towers."

Abramson (1987), 230, Apr.–May 1936, "For reasons which have never been explained, it [the Farnsworth camera] never could produce reasonable pictures for Baird in England."

51:*One of the*: Abramson (1987), 248, "This broadcast appears to have been the first actual broadcast by television of a major news event as it was actually happening," and 252, "Television in the United States made its formal debut on Sunday, April 30, 1939."

51:*The Great Depression*: Abramson (1987), 251–252, "For David Sarnoff, this was the realization of some eleven years of planning. His original idea, late in 1928, to have a television system operating in the United States by 1932 had long been delayed. A five-year plan had turned into an eleven-year reality. Very few people in 1928 had foreseen the depression or how long it would last. In fact, in 1939 the world was still suffering from its effects."

52:*The Patent Office*: Abramson (1987), 178–179; Fisher and Fisher (1996), 235–236. This was a different result than the 1932 victory by Farnsworth over the claim that Zworykin's 1923 patent covered Image Dissector.

53:*In July the*: Abramson (1987), 262, 268–269. On Jan. 27, 1941, the NTSC announced its first standards recommendations—441 scanlines, interlaced, 30 frames per second (60 fields per second), 4:3 aspect ratio (ratio of width to height of 1.333), bandwidth of each channel set at 6 megacycles per second. On Mar. 30, 1941, they upped it to 525 scanlines, everything else the same. The FCC adopted the NTSC standard on May 2, 1941, and declared July 1, 1941, as the start of commercial television in the U.S.

54:*For example, we*: Louis Lumière (!) was a charter member of the French Television Society, formed May 30, 1929. Marcel Belin was its first president. Belin was head of the important French lab that Zworykin visited in 1928 where he met Ogloblinsky and received key insights that led to Kinescope [Abramson (1987), 122, 135].

54:*There have been:* Abramson (1987), 200, "What about the prior efforts of Philo Farnsworth? He certainly had had an all-electric television system in his laboratory since July 1929. But he lacked a bright, large cathode ray display tube, and his efforts were soon overshadowed by the disclosure of the storage-type camera tube, the Iconoscope. . . . But one thing must be made clear: the early Iconoscope was never as sensitive as it was claimed to be; nor, conversely, was the Image Dissector as insensitive as RCA and others claimed it to be."

55:*In other words:* As an example of one of the many non-glamourous patents that it took for the full realization of television, consider this one by Dietrich Prinz, the same man mentioned briefly in the Dawn of Digital Light chapter as the earliest computer chess person: Abramson (1987), 149, Prinz, of Berlin, applied in 1930 for a patent for a means of synchronizing the horizontal and vertical scanning frequencies of a TV system. "As far as can be determined, this is the first patent covering this important feature." It was assigned to Telefunken, but therefore became part of the RCA patent suite because of a relationship between Telefunken and RCA.

Abramson (1987), 169, July 14, 1931, Farnsworth applied for a patent for a scanning and synchronizing system. "It is the process which is used in most modern day receivers."

56:*But he suffered:* Fisher and Fisher (1996), 273, 293, 334. Farnsworth spent much of his late career pursuing nuclear fusion. ITT Corporation, the company that bought Farnsworth's television company, finally defunded this research, another disappointment.

57:*Kenjiro Takayanagi became:* Obituary, Kenjiro Takayanagi, Electrical Engineer, 91, *The New York Times*, July 25, 1990, Tokyo, "Takayanagi was honored by the Japanese Government with the Order of Culture in 1981, the Grand Cordon of the Order of the Sacred Treasure in 1989."

58:*David Sarnoff became*: Bilby (1986), 150–152, 163–166. In 1940 Sarnoff had the first recording system installed in the Oval Office as a gift to FDR, who finally approved his first star in 1944. He very actively campaigned for a second star, but didn't get it.

Fisher and Fisher (1996), chapter 17, "The Color Wars." The NTSC color solution was a nifty one, utilizing properties of the human visual system in clever ways. But it has very little to do with the color of Digital Light.

Fisher and Fisher (1996), 309; Bilby (1986), 143–151. Sarnoff received the honorary rank after the war for having helped Eisenhower. "From that moment on all but his closest friends would address him as General Sarnoff."

Re aggrandizement: Bilby (1986), 5, "As his [Sarnoff's] successes mounted, he reached insatiably for publicity, for honorary degrees and parchment scrolls and medals. His psyche seemed to require certification of his greatness, an almost narcissistic need. In his waning years, he was on the glory road to a degree that discomfited some of his intimates. His associate and old friend . . . found him more publicity-avid than anyone he had known."

58:*Video didn't become:* Abramson (1987), 53–54, 128, June 27, 1922, "This was the first patent [Rtcheouloff's] covering the recording and playback (by magnetic means) of a television signal," Hammond applied Dec. 6, 1928, for the American patent.

59:*The Ampex Corporation:* Abramson (2003), the second volume of his television history, covers the details of videotape invention as thoroughly as his first volume covers the details of the invention of television.

61:*The International Video*: Abramson (2003), 149, "shown in May [1973] for the first time was the new IVC 9000. This revolutionary machine . . ." *IVC VTR Equipment Catalog*, "The IVC 9000 is considered by many to be the best analog VTR [video tape recorder] ever built." And, "It has been said of the IVC 9000 that you could go down 29 generations and still produce broadcast spec. Even if this is just half true, the machine's performance is on a par with today's digital VTRs."

The IVC engineers borrowed a vacuum column technique from computer engineers. Magtapes used for digital data storage with computers had the same problem of wear and tear on particle-covered tape as television engineers had.

62:*Many of the:* Strictly speaking, the color display signal was only *compatible* with the NTSC standard, but it still had to be put into strict NTSC form before the IVC could record it. Internal to NYIT, and to a typical TV studio, the electronic signal was divided into three signals, one each for the red, green, and blue parts of a full-color signal. And these were in progressive scan mode. A special hardware converter box did the job of combining the three signals into one and converting the progressive scan mode to interlaced scan mode. These boxes were standard gear in TV studios at the time.

Artist Ed Emshwiller worked with me, Lance Williams, and Garland Stern at NYIT to create the 1979 video art piece, *Sunstone*. It's now included in the Museum of Modern Art (New York City) and the Computer History Museum (Mountain View, Calif.) collections. It's available for viewing on *YouTube*, https://www.youtube.com/watch?v=8KU-g_zCfIM, accessed Mar. 22, 2022.

63:*We of the:* The eleventh-hour committee was formally called the Computer Industry Coalition on Advanced Television Service, or CICATS. Its member were: Apple, Compaq, Cray, Dell, Hewlett-Packard, Intel, Microsoft, Novell, Oracle, Silicon Graphics, and Tandem. This committee was formed during my years at Microsoft, so sometime in 1994–1999, probably after 1995 when the tentative ATSC standard was published, first alerting the computer industry to its flaws. And before publication of Brinkley (1997) which barely mentioned the computer industry's attack on the proposed standard.

The counterattack from the television industry—including the David Sarnoff Research Center—was to make it seem that "our" 720p was lower resolution than "their" 1080i because our prefix number was less than theirs. Recall that 1080i is equivalent to 60%, or about 648p, so had lower perceived resolution than 720p. In the long run it would make no difference because everyone was converging on higher resolutions progressively scanned, like 1080p (and even higher). But consumers meanwhile had to pay an unnecessary "tax" for the extra circuitry for interlace for many years and had to suffer the interline flicker in the interlaced formats.

63:*The committee so*: Another artifact in the HDTV standard is a 24 frames per second frame rate. It was added obviously to appeal to movie producers.

63:We can expect: In fact, by 2016 there already was a defined standard, called CCIR601 that specified 8K pixels per scanline, and 120 frames per second.

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Picture Credits

See the Bibliography for expansion of bibliographic references.

5b: Television

5b.1 Telephonoscope: *Punch's Almanack for 1879*, Dec. 5, 1878, from its reproduction in Spehr (2008), 79, which credits the Library of Congress.

5b.2 (left) https://commons.wikimedia.org/wiki/File:Farnsworth_ldac.jpg, downloaded Nov. 28, 2021. Description: "A statue of Philo T. Farnsworth located at the Letterman Digital Arts Center in San Francisco." Date: "3 May 2011." Author: "Photograph taken by me [*sic*, author not named], statue located on public grounds." Licensing: "© The copyright holder of this work allows anyone to use it for any purpose including unrestricted redistribution, commercial use, and modification."

(right) Zworykin statue: photo courtesy of George Dyson.

Composite by Alvy Ray Smith, using Microsoft PhotoDraw, 2016.

5b.3 (top left) https://commons.wikimedia.org/wiki/File:Farnsworth_cvc_500h_1.jpg, downloaded Nov. 28, 2021. Description: "Bronze statue by James R. Avati of Philo T. Farnsworth in the National Statuary Hall Collection, Washington, D.C." Source: [cropped from] https://www.aoc.gov/explore-capitol-campus/art/philo-t-farnsworth, downloaded Nov. 28, 2021. Author: "The Architect of the Capitol." Licensing: "This image is a work of an employee of the Architect of the Capitol, taken or made as part of that person's official duties. As a work of the U.S. federal government, all images created or made by the Architect of the Capitol are in the public domain in the United States."

(top right) Zworykin statue, at Murom: http://russia-ic.com/news/sho%20,w/16847#.VjGOtberRhF, downloaded Oct. 28, 2015, but with different content when accessed on Nov. 28, 2021. However, http://russia-ic.com/news/show/16847#.YWdMrhopBng, accessed Nov. 28, 2021, had the original textual content, but not the photograph: "Student Vladimir Zworykin Monument Set Up in Murom," photo credit to L. Kuznetsova (kp.ru). Source cited: https://www.vladimir.kp.ru/daily/26114/3008963/, dated Aug. 1, 2013, accessed Nov. 28, 2021, did contain the photograph, in color.

(mid right) *Philo Taylor Farnsworth: Mathematician, Inventor, Father of Electronic Television,* http://www.byhigh.org/History/Farnsworth/PhiloT1924.html, accessed Nov. 28, 2021.

(bottom right) http://www.delcampe.net/page/item/id,212015957,var,Macedonia-Science-Inventors-Russian-American-sciencist-Vladimir-Kosmich-Zworykin,language.html, downloaded Oct. 28, 2015, but no longer existed on Nov. 28, 2021. But https://www.pinterest.co.uk/pin/835136324626237664/, accessed Nov. 28, 2021, did contain the image.

Composite by Alvy Ray Smith, using Microsoft PhotoDraw, 2016.

5b.4 (left) created by Alvy Ray Smith, using Adobe Illustrator, 2016.

(right) https://en.wikipedia.org/wiki/File:John_Logie_Baird,_1st_Image.jpg, accessed Nov. 28, 2021. Description: "Low resolution, fair use image of an historic photograph. Photographer unknown, circa 1926," with this caption: "The first known photograph of a moving image produced by Baird's 'televisor,' circa 1926 (The subject is Baird's business partner Oliver Hutchinson, according to Wikipedia's page for John Logie Baird, accessed Nov. 28, 2021).” Licensing: “This image is a faithful digitisation of a unique historic image, and the copyright for it is most likely held by the person who created the image or the agency employing the person. It is believed that the use of this image may qualify as fair use under the Copyright law of the United States. Other use of this image, on Wikipedia or elsewhere, may be copyright infringement. See Wikipedia:Non-free content for more information.”

Composite by Alvy Ray Smith, using Microsoft PhotoDraw, 2016.

5b.5 (left) *Brigham Young High School: Philo Taylor Farnsworth: Mathematician, Inventor, Father of Electronic Television*, http://www.byhigh.org/History/Farnsworth/PhiloT1924.html, accessed Nov. 28, 2021.

(right) Abramson (1987), 96. I modified the patent image using Microsoft PhotoDraw to reverse it left to right to match the orientation of Farnsworth’s sketch, and then to reverse each of the labels left to right to make them readable.

Composite by Alvy Ray Smith, using Microsoft PhotoDraw, 2016.

5b.6 My modification of “Map Russia highlighting the Siberian Federal districts,” online at https://en.wikipedia.org/wiki/File:Map_of_Russia_-_Siberian_Federal_District.svg, accessed Nov. 28, 2021. Licensed under the Creative Commons Attribution-Share Alike 2.5 Generic license. I added, with Microsoft PhotoDraw, the 60N latitude, the Trans-Siberian Railway route (dashed), the title, all city names, the river names, the Siberia label, the bottom arrow indicating the relative size of the US, and the mileage table.

5b.7, 8, 9, 10 Created by Alvy Ray Smith, using Adobe Illustrator and Microsoft PhotoDraw, 2016.

5b.11 From the photo insert to Fisher and Fisher (1996), following p. 236, from the tenth page of the insert, credits the David Sarnoff Research Center.

5b.12, 13 *The Crystal Palace from the Air, Before and After the 1936 Fire*, https://w3.ric.edu/faculty/rpotter/beforeafter.html, accessed Nov. 28, 2021. RIC is Rhode Island College, Providence, RI.

Acknowledgments

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Endnotes

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