The Spark of Genius
Thomas Edison created the first light bulb 125 years ago. But he was not only America's greatest inventor. He was also a master entrepreneur

By Harold Evans

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It sits in isolation on a slope in the middle of a cow pasture, a two-story white clapboard house surrounded by a picket fence. Approached from the front, it looks like an ordinary home, with high sash windows, a gracefully arched porch ascended by sagging wooden steps, and a little balustraded balcony above. The first surprise is how far back the house extends. From the modest 30-foot façade, it runs at least 100 feet to the fringe of a virgin forest.

It is late on a winter's night in 1876. There is snow on the ground, and wood smoke curls from two brick chimneys. Inside, up the dark, uncarpeted stairs, a big bare-boarded room lit by gas jets and kerosene lamps stretches the building's full 100 feet. Its ceiling is laced with wire and piping, its walls lined floor to roof with jars of liquids and bottles of powder of every color. A rack in the center of the room is stacked with galvanic batteries, and every other nook and surface is covered with bits of copper, brass, lead, and tinfoil; crucibles, phials, and small darkened panes of glass; microscopes, spectrometers, telegraph keys, and galvanometers; rubber tubing and wax and small disks of some obscure material. At scattered workbenches and heaped-up tables there are a dozen young men engrossed in what they are doing: A bearded pair observe a spark jumping from an electromagnet to a metal lever; another boils a smelly chemical; another has his ear to some kind of telephone receiver; another, chewing tobacco, bends his head to frown at the needle on an instrument. In the far corner, stretched out on the floor amid a score of open books, is a pale young man with a mop of brown hair and stains on his hands, entirely lost to this world because he is concentrating on making a new one.

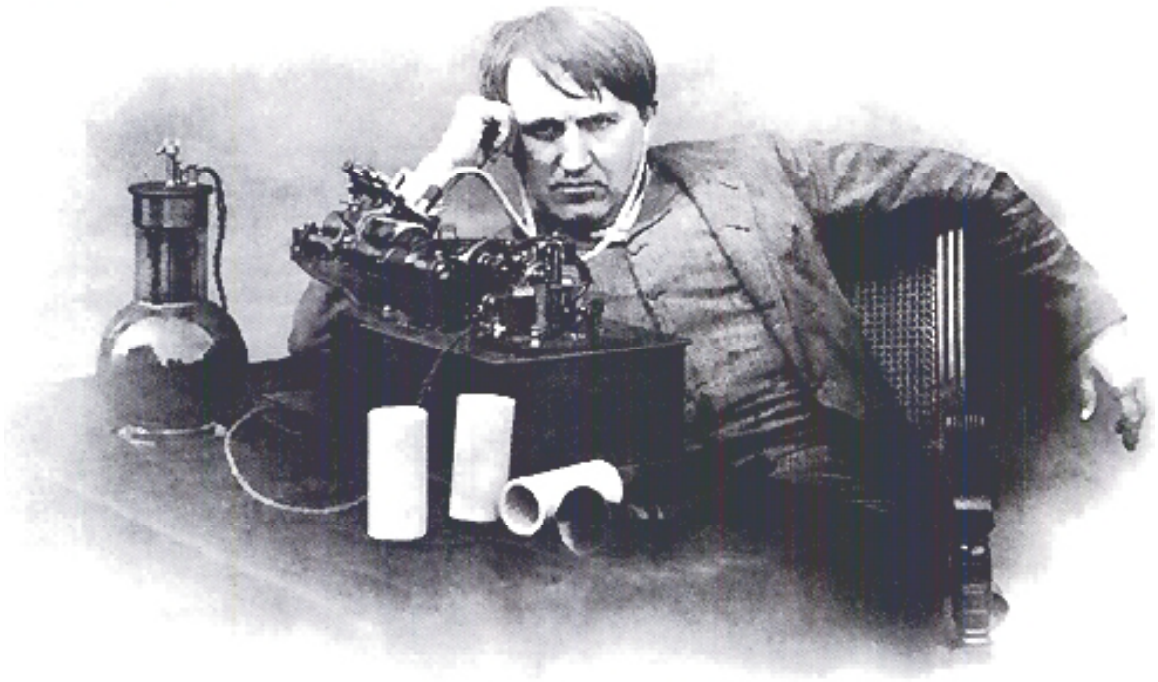
This is Thomas Alva Edison at 31. If we stay long enough, we will see him uncoil his shabby 5 feet, 8 inches and, stooping slightly, move slowly among the workbenches, cupping an ear to listen to observations on the night's work, reaching over to tweak an instrument, breaking out in laughter as one of the fellows makes a joke at his expense. His black frock coat and waistcoat are dusty, and a white silk handkerchief around his neck is tied in a careless knot over the stiff bosom of a white shirt rather the worse for wear, but what stands out is the extreme brightness of his eyes.

Around midnight he and his comrades in discovery will settle in front of a blazing fire for pie, ham, crackers, smoked herring, and beer. There is as likely to be a competition in mocking doggerel or crude cartoons as a debate on the proper expression of Newton's law

of gravitation. Someone, maybe Edison himself if he has had a good day, will blast out a melody on a huge pipe organ at the end of the big room and they will raise the rafters singing sentimental (and censorable) ditties. Then they will all go back to their benches and books until the early hours while down the hill in Edison's farmhouse home, Mary Edison, his wife and the mother of two of his children, will have given up and gone to sleep with a revolver under her pillow. One late night soon a disheveled Edison will forget his keys, climb onto the roof, and let himself in through an open bedroom window. Mary, ever fearful of intruders, will nearly shoot him with her .38 Smith & Wesson. In the words of his journal, he will again "resolve to work daytimes and stay home nights," but he cannot keep a promise to himself when his head is filled working out the complexities standing between a panoramic vision and the steps to its realization

Thomas Edison was America's most productive inventor in the 19th century and remains so into the 21st. His 1,093 patents are by no means the proper measure of the man. To Edison, the patents were the easy part, before "the long, laborious trouble of working them out and producing apparatus which is commercial" --and then fighting off the pirates. Edison's greatness lies not in any single invention, not even in the whole panoply, but in what he did with his own and other men's cleverness.

The invention for which he is most remembered, the incandescent bulb, is emblematic. The technology was a marked advance over the work of other inventors, but the piercing vision--and it was Edison's alone--was how he would bring light and power to millions of homes and offices. The historian Ruth Cowan writes that Edison from the beginning wanted to build a technological system and a series of businesses to manage that system. By the time he applied for any patent, Edison had already envisaged how he could translate the invention into a tangible, commercial product; indeed, he would not begin the research otherwise. Still, he was a classic innovator. "Only Leonardo da Vinci evokes the inventive spirit as impressively," writes the historian Thomas Hughes, "but, unlike Edison, Leonardo actually constructed only a few of his brilliant conceptions." Purists might respond that Leonardo was on his own whereas Edison had clever men at his beck and call--but what a sensible notion that was! One man could hardly hope to keep up with the efflorescence of knowledge in the sciences and the profusion of new techniques and new materials. In the decades after 1870, when industrialization in manufacturing superseded the machine-shop culture, it was quite brilliant to finance and focus multidisciplinary research in an organized manner with the deliberate intention of manufacturing the results. The momentum by which the United States surpassed Britain as the greatest industrial power near the turn of the century was in significant part due to the culture of research and development. In the year Edison was born, 1847, only 495 inventors won patents; in the year of his 40th birthday, he had more than 20,000 lesser mortals for company.



Little Al, as he was called then, did not do well at school. At the age of 8, in 1855, Edison was described by a teacher as "a little addled." Edison himself recalled, "I was always at the foot of the class. I used to feel that the teachers did not sympathize with me." Part of the trouble was that he missed years of lessons because of a series of infections, one of which seriously damaged his hearing. He was also ill-suited to rote learning; he could reach understanding only by doing and making.

His father, Sam, was a handsome jack-of-all-trades of Dutch extraction who became a lighthouse keeper on moving his family to Port Huron, Mich., in 1854. He had endless schemes for getting rich that never quite came off, but the little family was comfortable by the standards of the day, if erratically in debt. But it was Al's very protective mother, Nancy, a devout Presbyterian (who always dressed in black in memory of three children dead in infancy), who would be the boy's salvation. She divined that Al had a visual imagination and unusual powers of reasoning, and made it her business to take him out of the school that found him defective. She read him classics like Gibbon's Decline and Fall of the Roman Empire and Sear's History of the World, and when he kept asking questions she could not answer (What is electricity? What is pitch made of?) she put into his hands, at the age of 9, R. G. Parker's A School Compendium of Natural and Experimental Philosophy . It illustrated simple home experiments in chemistry and electricity, and Al attempted every one of them. When he left school for good at 13, a boy with a large head and jutting jaw, Alva was "dead set on being an engineer of a locomotive."

His first job was to climb aboard a train at Port Huron at 7 a.m. with copies of the Detroit Free Press to sell to passengers on the three-hour journey to Detroit and back. The budding entrepreneur persuaded the conductor to let him store berries, fruit, and vegetables, as well as sandwiches and peanuts, and deputized two other boys to sell the

food for him. He also made a cheeky habit of walking into the composing room of the Free Press to find out what the next day's headlines would be, and a year into the Civil War, on April 6, 1862, he scored a coup. A proof of next day's sensational front page reported that as many as 60,000 might be dead in a battle at Shiloh (actual deaths were 24,000). He had enough money to buy only 300 papers but talked his way into the sanctum of the fierce managing editor, Wilbur F. Storey, and got 1,000 copies on credit. Edison had already bribed officials at the railroad office to telegraph the fact that there had been a battle to every train station on the way back to Port Huron. He was mobbed at the first stop, raised prices at every station thereafter, and ended with a sell-out auction--and the princely sum of around $150. "I determined at once to be a telegrapher," he recalled later.

His luck was in. Late that summer, he plucked a 3-year-old boy from the path of a boxcar, and the grateful father--the railroad's stationmaster--offered telegraph lessons as a reward. Five months later, Al--now to be called Tom--began wandering Middle America as one of the hundreds of young "tramp" telegraph operators. In demand because so many telegraphers had been called into the armies on both sides, the tramps were fond of gambling, cursing, drinking, smoking, playing jokes, and carousing with women. Edison chewed tobacco ceaselessly, gambled a little, and played practical jokes, but he spent most of his spare time reading in lonely boardinghouse rooms and fiddling with telegraph equipment in railway stations on his preferred night shifts.

By the time he arrived in Boston in 1868, after jobs with Western Union and the military, Edison was a haunted man. The little sleep he had was populated by polarized magnets, springs, cylinders, rotating gears, armatures, batteries, and rheostats, all dancing intricate patterns with labyrinthine strands of wire to make the most marvelous advances in telegraphy, and all vanishing as soon as he awoke. He rented a corner of Charles Williams Jr.'s instrument workshop (the same workshop where Alexander Graham Bell encountered his collaborator Thomas A. Watson). Here Edison improved on the standard stock telegraph tape printer and went into business with other telegraphers to sell his machine and a stock-and-gold quotation service.

But there was not enough money for all his ideas in Boston, so Edison decamped for New York. Soon after his arrival in Manhattan in June 1869, at the age of 22, he was in the office of Dr. Sam Laws's Gold Indicator's wire service as a piecework assistant when its machine broke down. Hundreds of brokers' messengers fought at the door for the information while Wall Street came to a stop and the experts responsible for transmission worked themselves into impotent rage.

Edison fixed the machine.

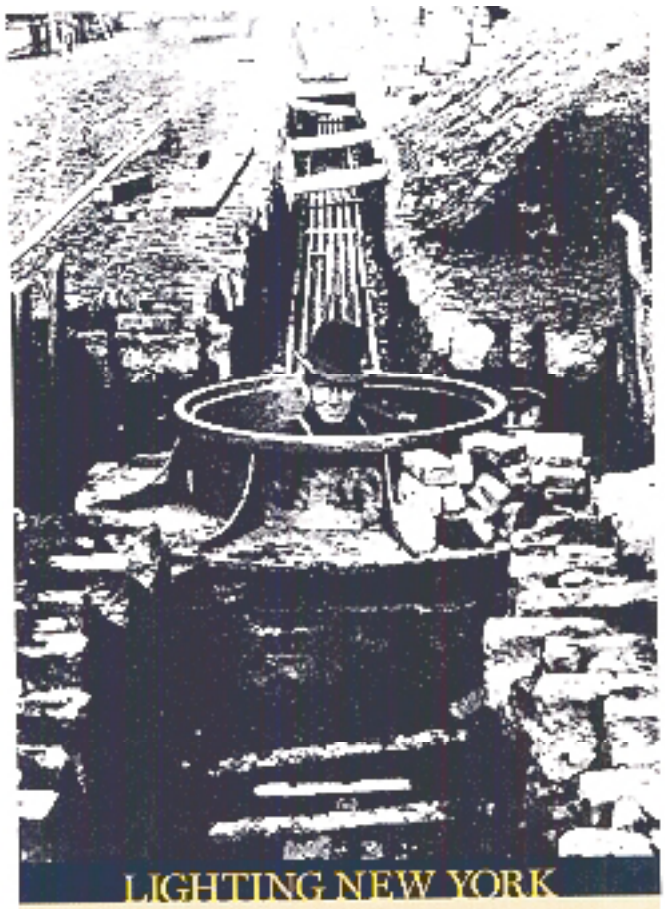
He was now the golden boy in the dizzily evolving telegraph world. When he went before the directors of a Western Union subsidiary to present a device that aligned stock tickers in outside offices with the central station, they offered an astounding $30,000. His confidence, already sublime, came to border on the reckless.

He boldly contracted to deliver private telegraph machines and electrical equipment as well as 1,200 sped-up stock tickers for Western Union, manufacturing them with a machinist in Newark. By working 16 hours at a stretch, living on coffee, apple pie, and cigars, he delivered all the machines, though his bookkeeping mixed up the accounts of rival companies. Then he bought out his machinist partner. He was now his own man. He acted as foreman of 50 or more pieceworkers in the Newark factory, but this was a secondary preoccupation. He set up a laboratory equipped with the latest scientific equipment. One of his associates described seeing him go through a 5-foot-high pile of journals from Europe, eating and sleeping in his chair over six weeks, and conducting hundreds of experiments.

Most important, in the early 1870s, he recruited three men who would be crucial: Charles Batchelor, an English textile machinist; John Kruesi, a Swiss clockmaker; and Edward Johnson, a voluble railroad and telegraph engineer. Batchelor would render a rough Edison sketch into a precise drawing, Kruesi would make a model that could be entered into an application for a patent, and Johnson would organize patent applications, contracts, and payroll. Edison had an instinct for the kind of people he needed to stimulate and service his fertile imagination, and the right people were drawn like moths to his creative flame. His journal of February 1872 had more than 100 sketches; with the help of Batchelor and Krusei, he won 34 patents in that single year.

In 1875 Edison gave his 71-year-old father an assignment. Sam had an eye for property, and it was he who found the pasture in New Jersey and oversaw the building of the curiously shaped house where Edison set up his laboratory in March 1876. Thomas Hughes describes Menlo Park as a cross between Camelot and a monastic cloister. Every downstairs room in the lab had a needling quotation from the English painter Joshua Reynolds: "There is no expedient to which a man will not resort to avoid the real labor of

thinking." Every clock had its spring removed to show that the place would not be a slave to time as measured by a machine; the length of the days would be fixed by Edison, who would often work for 24 hours, with tiny naps stretched out on floor or bench, and then sleep for 18.



LIGHTING NEW YORK

Above, one of Edison's workers lays cable under the streets of Manhattan in 1882; below, the industrialist himself, with Henry Ford (left) and Harvey Firestone (right).

His happy band of brothers knew something big was brewing at the end of August 1878 when a well-tanned Edison bounced into the lab wearing a big black sombrero. His exuberance was so different from July when, sick and exhausted, he had gone off by himself to the Rockies for a vacation, watching the total eclipse of the sun with a group of scientists. One of the scientists, George Barker of the University of Pennsylvania, had enthused about a system of lights the inventor Moses Farmer had installed at an Ansonia, Conn., foundry. They were arc lights, so called because the light was an arch of elongated sparks reaching between two carbon electrodes. Bright as searchlights, they had been familiar since the '60s in British and American lighthouses and a few places of public assembly but were too blinding (and hazardous) for domestic use.

Epiphanies. When he took the train to Ansonia with Barker and Batchelor on Sunday, September 8, it was not so much the eight big arc lamps at the foundry that excited Edison as the system he examined that morning: electric light generated not by batteries but by a primitive little dynamo, the current wired a quarter mile to the foundry. It was a double epiphany. Edison was seeing for the first time practical proof that electric power could be sent a distance--and subdivided between lamps. His next question: Could it be done at a profit?

A reporter for Charles Dana's New York Sun , who had come along, captured the moment of realization: "Edison was enraptured. . . . He ran from the instrument to the lights and from the lights back to the instrument. He sprawled over a table with the simplicity of a child, and made all kinds of calculations. He estimated the power of the instrument and of the lights, the probable loss of power in transmission, the amount of coal the instrument would save in a day, a week, a month, a year, and the result of such saving on manufacturing."

Edison's intuition was to think small. Instead of sending current to create a leap of light between the electrodes of big arc lamps, useless for domestic lighting, why not send it along the wire and into a filament in a small incandescent lamp? Back at Menlo Park he worked euphorically through two nights. "I discovered the necessary secret, so simple that a bootblack might understand it," he wrote. Edison went public only a week after his visit to Ansonia. His spicy quotes got full play in the newspapers: He had not only found the way to create an incandescent bulb but would be able to light the "entire lower part of New York" with one engine and 15 or 20 dynamos: "I have it now! With a process I have just discovered, I can produce a thousand--aye, ten thousand (lamps) from one machine. Indeed, the number may be said to be infinite. . . . with the same power you can run an elevator, a sewing machine, or any other mechanical contrivance, and by means of the heat you may cook your food."

It was hot air. The "secret" was something he had visualized but not realized, a thermal regulator to cut off current to the filament before it melted or burned out. The Edison scholars Robert Friedel and Paul Israel underline his audacity: "For Edison, the search for a practical incandescent light was a bold, even foolhardy, plunge into the unknown guided at first more by overconfidence and a few half-baked ideas than by science. To suggest otherwise is to rob the inventive act of its human dimension and thus to miss an understanding of the act itself."

Other experimenters in both arc and incandescent lighting had pushed a great deal of current along a thick wire to a low-resistance filament. The real secret, Edison found, arguing it out with Charles Batchelor, was to raise the voltage to push a small amount of current through a thin wire to a high-resistance filament. It was an application of the law propounded in 1827 by the German physicist George Ohm, but it was still imperfectly understood. Edison himself said later, "At the time I experimented I did not understand Ohm's law. Moreover, I do not want to understand Ohm's law. It would stop me experimenting." This is Edison in his folksy genius mode. Understanding the relationship linking voltage, current, and resistance was crucial to the development of the incandescent lamp, and he understood it intuitively even if he did not express it in a mathematical formula.

Scientists in America and England who were still thinking of low resistance and thicker and thicker wires (at great cost) dismissed Edison's project to light New York as both scientifically stupid and economically hopeless. But he had to find a filament of high resistance--and heat it up to incandescence in a bulb as close to airless as he could get to hinder oxidization. Edison was not even close to resolving these dilemmas in the early fall of 1878 when his friend and lawyer Grosvenor Lowrey (who had encouraged Edison to fly his colorful kite in the press) moved on his behalf in New York's banking parlors. Lowrey swiftly raised $300,000 to form the Edison Electric Light Co. The filament proved more elusive than Edison had hoped. He had discarded carbon because it burned up so readily. Platinum wire offered only low resistance but did not oxidize and therefore seemed to offer the best prospect. They worked on making long spirals of thin platinum, to increase the resistance, but it was delicate and dangerous work. In mid-April, Lowrey led a group of investors into the darkened lab where Edison had installed 12 lamps with a platinum filament linked in series. Edison told John Kruesi to turn on the current slowly. Francis Jehl, an assistant, recalls: "I can see those lamps rising to a cherry red and hear Mr. Edison saying, 'A little more juice,' and the lamps began to glow. A little more . . . and then one emits a light like a star after which there is an eruption and a puff, and the machine shop is in total darkness." Batchelor replaced the dud lamp; the same thing happened a few minutes later. Only Lowrey's eloquence and the steadfastness of 42-year-old John Pierpont Morgan held the group together.

The other challenge was the vacuum; nobody had been able to get enough air out of the bulb. Edison did a simple thing. He had put a classified advertisement in the New York Herald for a glass blower, which netted an 18-year-old in a little red German student cap. The mechanics were amused by the dainty Ludwig Boehm and his pince-nez, but he blew a better bulb to Edison's design and he helped work out a new way of evacuating a bulb

by infusions of mercury. It was laborious, frustrating work, but in September, after weeks of effort, Edison and his team achieved a vacuum of one hundredth of an atmosphere. Edison discovered that at this level they had so reduced the oxygen in the bulb that a carbon stick did not burn up quickly and it gave a better light than platinum ever had. That was the good news; the less good was that resistance to this particular piece of carbon was only around 2 ohms (which would mean more current, more copper). Resistance could be raised by shaping a tiny filament in a small spiral, but the filament would have to be no thicker than 15 thousandths of an inch. Edison set everyone in a frenzy trying to roll carbon into reeds no thicker than thread. Day after day, night after night, the spiral reeds kept breaking.

Success. After two sleepless weeks, Edison relieved the carbon rollers. His new idea was to bake the carbon into a length of plain cotton thread. On the eighth attempt, on October 21, the dexterous Batchelor held his breath carrying a tiny thread bent into the shape of a horseshoe to Boehm's house for insertion in a bulb. "Just as we reached the glass blower's house, the wretched carbon broke," Edison recalled. "We turned back to the main laboratory and set to work again. It was late in the afternoon before we produced another carbon, which was broken by a jeweler's screwdriver falling against it. But we turned back again and before nightfall the carbon was completed and inserted in the lamp. The bulb was exhausted of air and sealed, the current turned on, and the sight we had so long desired to see met our eyes."

Thread No. 9, lit at 1:30 a.m., lasted until 3 p.m.--13 1/2 hours, whereupon Edison added a stronger battery to boost the light to 30 candles, or three times gaslight. They watched the tiny filament struggle with the intense heat. The light continued for 60 minutes. It was a crack in the glass that turned the room back into darkness--amid the cheers of exhausted men. They had proved that a carbon filament in a vacuum would work.

After examining the charred filament under a microscope, Edison launched another search for an organic fibrous material, some form of cellulose that might yield even more resistance than cotton. By November 16, they settled on a piece of common cardboard. Edison records: "None of us could go to bed, and there was no sleep for any of us for 40 hours. We sat and watched it with anxiety growing into elation. The lamp lasted about 45 hours, and I realized that the practical incandescent lamp had been born."

Already, Edison was preparing to establish electric beach-heads in New York, Paris, and London. The lab staff worked frantically making bulbs by hand, one by one, so that on New Year's Eve, when Edison opened Menlo Park to a public exhibition, he had around 300 bulbs. Some 3,000 people came to gaze and put questions to the great man. Still, the experts in America and England refused to be dazzled. Henry Morton of the Stevens Institute, who had been on the Rockies expedition, charged that Edison was perpetrating "a fraud upon the public," provoking Edison to make another promise: He would erect a statue of Morton at Menlo Park and shine an eternal electric light on his gloomy countenance.

What Edison attempted next can be characterized only as awesome, as if having climbed Everest he sprouted wings and flew from the top. "There is a wide difference," he said, "between completing an invention and putting the manufactured article on the market," but marketing an electric light bulb was the least of it. He had to invent the electrical industry. He had to conceive a system down to its very last detail--and then manufacture everything in it. He had to build a central power station; design and manufacture his own dynamos to convert steam power into electrical energy; ensure an even flow of current; connect a 14-mile network of underground wiring; insulate the wiring against moisture and the accidental discharge of electrical charges; install safety devices against fire; design commercially efficient motors to use electricity in daylight hours for elevators, printing presses, lathes, fans, and the like; design and install meters to measure individual consumption of power; and invent and manufacture a plethora of switches, sockets, fuses, distributing boxes, and lamp holders.

Luckily, Edison was worth around half a million dollars by then; Western Union had made big payments for his telegraph and telephone patents. Shuttling between Menlo Park and his grand new headquarters in a double brownstone mansion at 65 Fifth Avenue, Edison the industrialist organized a group of companies from 1880 to 1881, the progenitors of the modern Con Edison and General Electric. For his power station, Edison bought a couple of dilapidated warehouses at 25-257 Pearl Street within sight of the high towers of the unfinished Brooklyn Bridge. In December 1881, he began to dig up cobblestones for conduits radiating symmetrically outward from Pearl Street. He was often down in the trenches in the raw early hours checking the connections made by the wiring runners. It took six months to do the work.

Lights on. Sunday was normally the one day of the week reserved for his neglected wife, Mary, and their two children, but Sunday, Sept. 3, 1882, was different. All day and into the night Edison was on Pearl Street rehearsing every part of the operation for the system's debut due on Monday afternoon. So much might go wrong when he gave the orders for the steam to flow. "The gas companies were our bitter enemies, ready to pounce upon us at the slightest failure," he recalled later. When the chief electrician pulled the switch at 3 p.m., only one of the six dynamo sets worked and the steam engine was wobbly. But Edison, over at the offices of Drexel, Morgan & Co., ready for the big moment when he would ceremonially connect the 106 lamps there, was not disappointed. They all came on! They came on, too, at the offices of the New York Times, "in fairy tale style," said the paper, 52 filaments appearing to glow stronger as the night drew in.

Edison's success was at once a vindication and an incitement. His patent was swiftly challenged, his ideas stolen. But Edison would not sue; he would out-invent and undersell them all. When Pearl Street went on line in 1882, no fewer than 200 companies across America had already signed up with the Edison Company for Isolated Lighting, using 45,000 lamps a day: companies like Marshall Field's dry goods store in Chicago, George Eastman's Photographic company in Rochester, N.Y., the Stetson Hat Co. in Philadelphia, and Dillard's Oregon Railway and Navigation Co. The electrical evangelists Edison had sent overseas had done their work well. A London newspaper summed up the acclaim: "There is but one Edison."