The Master of Lightning
A Sphex Club Presentation
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Nikola Tesla was born on July 9, 1856, in Smiljan, a rural village in the part of the Austro-Hungarian empire that now lies in Croatia. His father was a Serbian Orthodox priest who was vey well-educated, while his mother, though not educated, was highly intelligent and inventive. Tesla had an older brother, Dane, who died when Tesla was five, and three sisters.

As a child, he displayed both a fascination and an ability to imagine and understand mechanical devices. By the time he reached his full height of 6 ft, 6 in, he was fluent in six languages. Although he was a true prodigy in science, his family expected him to prepare for the priesthood or to join the military. He attended school in the nearby town of Gospic where he earned a reputation as a brilliant student before attending college in Carlstadt. While at Carlstadt he developed a lifetime fascination with electricity. Fortunately for the world, his path toward the priesthood was diverted when when a bout with cholera during his college days gave him the opportunity to convince his parents to allow him to pursue science. He was seriously ill for a year, and when upon his recovery, his father allowed him to return to school to pursue engineering.

Tesla entered the Polytechnic Institute in Graz, Austria in 1875 and began his formal study of electrical engineering. . Again, with obsessive effort that permitted only study, he excelled. He encountered a new type of generator that was able to generate direct current electricity using electromagnets to convert the naturally occurring AC from the generator into DC. The device could also be reversed to operate as an electricity-driven motor, as Maxwell had demonstrated a quarter century earlier. Tesla began to about the necessity of converting the AC to DC. Why not just create an AC motor? Batteries create direct current and all electrical devices at the time depended on battery power or direct current from generators. Tesla's thinking was revolutionary, but at this stage of his live, how to do it remained a problem in the back of his mind.

After a two years at Graz, Tesla continued to study electricity at the University of Prague. A year later, lack of money, possibly due to gambling, made it impossible for him to continue formal study, so he took a job with with the Hungarian Telegraph Office in Budapest. His innate ability, his insight into the nature of electricity and his ability to concentrate were soon evident and, in 1881, he became the manager. During his time, he produced a number of inventions and discoveries that improved the operation of the telephone. He continued to think about the AC motor to the point of a fixation—that led to a mental breakdown that was characterized by multiple symptoms --very sensitive to any intrusion on his senses. Physical stimuli such as sound, even vibrations, led to twitches, shivering, and even rapidly changing heart rates.. The symptoms were undiagnosed and continue for several months before subsiding and allowing him to return to productive work.

He continued to be obsessed with the idea of an AC motor. His biographers report that in the winter of 1881-82, he was walking on the beach at sunset, reciting a poem by Goethe when tie solution came to him. He stopped and explained to his companion precisely in full detail how an AC motor would work. Later in his life, Tesla described how he would conceptualize an idea in complete detail, a mental image with which he could return time after time to make changes, precisely as an engineer

would do with a set of engineering drawings. When the telephone company was sold, the owner suggested that he move to Paris, and in the spring of 1882, Tesla accepted a junior engineer position with the Compagnie Continental Edison. By this point in time, Edison was internationally known and heavily invested in DC power distribution. From his junior position, Tesla became one of the engineers who were designated to work on the Edison power installations that were distributed across the continent. He continued to think about and talk about AC motors, but in the DC environment, no one listened to him. Tesla became one of the traveling repairmen sent to work on installations throughout Europe. He continued to be a strange, phobic character and talk enthusiastically about his AC system. He received little attention from colleagues who were too busy expanding the DC system. Edison had scored a huge success by lighting the 1881 Paris Electrical Exhibition and was selling generators to light-restricted areas such as factories. However, the one-mile transmission range for DC transmission meant that generating stations would have to be built at approximately one mile intervals, a fact that limited sales to larger installations such as towns and cities.
When the city of Strasbourg purchased an Edison system, the initial lighting of the central area of the city caused an explosion.

Because Tesla was fluent in German, he was assigned to repair the system, a task that took nearly a year. As he waited for various bureaucratic decisions, he rented a machine shop and build the actual dynamo that he had created in his mind years before. It worked precisely as he had envisioned. He hoped to return to Paris where he would use the bonus he earned from the Strasbourg job for start up funds. Then he would search for investors to build his new AC generators and motors. When the bonus did not happen, the managers at Continental Edison advised him to move to America to realize his dreams.

Aside on DC vs AC

In order to transmit large amounts of electric power with direct current, large currents are required. Current heats the wire or cable that is carrying it, converting the power generated to heat and making it inaccessible to the device for which it is intended. The power loss due to heating is proportional to the square of the current, so as the transmitted current is increased the power lost to heating is increased enormously Alternating current does not bear the same cost, because transformers allow the AC current to be minimized for transmission resulting in significant power loss reductions. As noted earlier, the fact that the practical range for DC power transmission was about a mile at the time would require essentially local power production. Alternating current suffers no such limitation.

Edison immediately offered a job. He later described his first meeting with the renowned inventor as "a memorable event in my life." While working for Edison, Tesla immediately began to contribute many designs that improved both the control systems and the efficiency of Edison's DC systems. At one point Edison told Tesla he would pay $50,000 for an improved design for his DC dynamos. After months of experimentation, Tesla presented a solution and asked for the money. Edison demurred, saying, “Tesla, you don’t understand our American humor.” Tesla quit soon after.

But his reputation as an engineer was growing. When he found financial support to develop a series of AC motors and generators. He founded the Tesla Light and Manufacturing Company and began to build and supply AC driven lighting systems. He was now in direct competition with Edison

and his DC systems. As an aside, Edison's genius did not primarily reside in his inventions. The electric lamp would have been little more than a novelty, without a system to deliver electric energy to the point of use. The idea of a system is where the major profit would reside. Tesla certainly realized the same thing and his drive for AC was motivated by a vision of delivering electric energy more efficiently and less expensively.

He was successful in his initial projects, but soon had a disagreement with his backers, who essentially stole his money and patents, leaving him and his company bankrupt. He spent the winter of 1886 working as a ditch digger, but by the spring of 1887 the Tesla Electric Company was operating and he began to build complete electrical systems, generators to transformers to motors. Some of these components had previously existed only as visualizations in Tesla's mind. The patent office redirected his initial application for a patent into seven separate patents that cover the entire scope of what he had conceived in Budapest. The patents were granted in May of 1888.

Two weeks later, Tesla spoke before the American Institute of Electrical Engineers an indication of his growing reputation. He had been burned by his trust – in Edison and in those who backed his first company. Nonetheless, he remained naive and assumed that the money needed to finance development of his patents and others that remained virtual would appear. George Westinghouse, whose company made air brakes for the railroads, heard of his appearance to the AIEE and realized the possible financial implications. He offered Tesla a job, a million dollars for his patents and a royalty of one dollar per horsepower on all of the motors produced. Tesla did not particularly like working at the Westinghouse plant in Pittsburgh, where he was required to spent time. He especially did not like the friction that arose as his plans were converted to production, so he returned to New York when the AC motors went into actual production. During the next four years, Tesla received 45 U.S. patents.

This was a period in American history characterized by intense competition for financial backing and investors. While the use of electricity for lighting was growing, industrial use for electric motors was also expanding. Edison's DC system used incandescent lamps, while Tesla had perfected AC electric arc lamps, manufactured by Westinghouse. Edison merged with other competitors to form the General Electric Company. Newly acquired financial backers pressured Westinghouse to cancel his royalty contract with Tesla. Although he was reluctant to do so, he eventually agreed to ask Tesla to break his lucrative contract in order to save his company. In an extraordinary act of appreciation for Westinghouse's support, Tesla tore up the contract, an act that cost him millions of dollars and that would eventually cause him serious financial difficulties. This single act assured the success of the Westinghouse Electric and Manufacturing Company.

Tesla was still a young man, wealthy enough at the moment to continue to visualize and research. He began by studying electromagnetic radiation. As he strove to generate electromagnetic waves of ever increasing frequency, he was able to create an AC source operating at 10 kHz (the U.S. standard is 60 Hz.). Along the way, he invented invented the Tesla Coil, a form of transformer found in virtually every physics laboratory in the world. He created large Tesla coil transformers, filled with oill for cooling, that are still in use today. Speaking to the AIEE in 1891, he demonstrated an100kV spark discharge several inches in length, and a super bright high voltage electric lamp.

Newspapers reported such events and Tesla was growing more famous daily. He was driven to learn all that electricity had to offer and to share what he learned. He often entertained dinner guests

with laboratory shows full of electric arcs, sparks, glowing lights not connected to wires and even spinning metal eggs. He often used his own body, allowing current to pass through his body from head to toe, passing sparks from his fingertips. He demonstrated neon and phosphorescent lamps, electronic tubes for wireless signal reception, and coil tuning principles used in radios. He was 36 years old; during his eight years in the US, he had gone from ditch digger to international celebrity.

Tesla introduced his motors and electrical systems in a classic paper, “A New System of Alternating Current Motors and Transformers” which he delivered before the American Institute of Electrical Engineers in 1888. One of the most impressed listeners was the industrialist and inventor George Westinghouse. One day he visited Tesla’s laboratory and was amazed at what he saw. Tesla had constructed a model three-phase system consisting of an alternating current dynamo, step-up and step-down transformers and A.C. motor at the other end. The perfect partnership between Tesla and Westinghouse for the nationwide use of electricity in America had begun.

In February 1882, Tesla discovered the rotating magnetic field, a fundamental principle in physics and the basis of nearly all devices that use alternating current. He adapted the principle of rotating magnetic field for the construction of alternating current induction motor and the polyphase system for the generation, transmission, distribution and use of electrical power.

Edison had triumphed by lighting the Paris Exhibition of . But in May of 1893, Tesla and Westinghouse stunned the world when the Columbian Exhibition was lighted inside and out with AC power delivered across the fair by Tesla's inventions and Westinghouse manufacturing. It was a personal triumph for both men as it not only improved significantly on the Edison lighting but it also served as a powerful demonstration of the safety of AC power. Edison had done his best to convince the public that the opposite was true as he sought new contracts for DC lighting, especially the lucrative Niagara Falls Power project.

Since Tesla's first introduction of AC electricity, the "War of Electric Currents" had been waged, with Edison insisting on the safety of DC current over AC current. The Edison Company mounted what amounted to a propaganda campaign to discredit AC power and even employed men to demonstrate the dangers of AC by electrocuting animals. Edison himself invented the electric chair in an effort to discredit AC. Tesla disproved that claim by letting a charge of one million volts be passed through his body without harm. Westinghouse eventually won the Niagara contract and used the Tesla polyphase system to harness the power of Niagara Falls to produce 37 megawatts of electric power from ten generators and transmit it to Buffalo, 22 miles away. The system went online in August, 1895.
At one point Tesla built a large engine, a reciprocating engine whose back and forth motion could be driven by air or by steam. It caused the floor and walls to shake and he began to investigate the phenomena of resonance and vibrations of mechanical systems. By varying the frequency at which the machine vibrated, he learned that he could “tune” the vibrations to resonate with the natural vibration frequencies of the floor and walls. The situation was a direct analogue of varying the frequency of an electromagnetic wave to create resonance with a tuning circuit, or vice versa. Someone called the police fearing an earthquake and he was forced to discontinue the experiments

Three years after the Chicago success, he demonstrated a remotely controlled boat. It was controlled by radio signals that were received and could operate a servomechanism that translated the electromagnetic reception into movement of the rudder and control of the motor. He offered the patent, to the US government who laughed at the idea of a remotely controlled boat and refused his offer. The

Chief Examiner of the Patent Office traveled to New York to verify that the invention worked and Tesla was subsequently granted a patent. He continued to experiment with more and more powerful sources of electric power, but could not safely exceed 4 megavolts. Because he did not have the previously income from Westinghouse, he was once again nearly broke.
But once again his naive faith was rewarded with a promise of both laboratory space and financing in Colorado Springs, and moved his operation to that location in 1899. He built Tesla coils as large as 75 ft in diameter, the largest to date and very high frequencies creating artificial lightning bolts more than 100 feet long. The corresponding artificial thunder could be heard 15 miles away. His experiments occasionally exceeded the ability of the local electric power company to provide power, resulting in overloads and short circuits at the generating station. The ground was electrified near the transmitting tower to an extent that would be equivalent to hundreds of lightning bolts striking the ground simultaneously. These local disruptions and shortage of funds led to abandonment of the Colorado experiments and he returned to New York only a few months after moving there. We know neither the results he sought nor do we know details on the future he envisioned.

Bankrupt once more, Tesla returned to New York in the fall of 1899, satisfied that he had advanced his overriding and glorious goal of improving the condition of humanity by extending scientific knowledge. Through a friend, he published an article entitled "The Problem of Increasing Human Energy" which outlined his personal philosophy and his Colorado discoveries. Tesla believed that the type of energy available had been and would continue to be the controlling factor in the progress of the human condition, reducing such developments to a mechanical process. Thus, by discovering and improving electrical energy, he was playing his part in advancing humanity: a grandiose assertion.

J. P. Morgan was Tesla's next benefactor. He had underwritten the Niagara Falls power system and was aware of Tesla's genius and now supported his ideas on transmitting electric power through the earth and on worldwide wireless broadcasting. Morgan could imagine the commercial potential, which never occurred to Tesla, and the importance of controlling the release of the ideas' conclusions. Tesla now had a willing supporter and spoke of Morgan's "noble generosity."Again, in 1900, Tesla set out to build a new plant in Long Island, New York, intended as a source of a universal power supply and world-wide broadcasting. The enormous scope of his project never troubled Tesla; with Morgan's first donation, he confidently went forward. Stanford White agreed to design the centerpiece building of this new industrial city, a 154-foot-high tower to be the origin of the electrical power. Inevitably, delays crept into the project and bills went unpaid. The project ceased in 1905 and Tesla returned to New York City.

Tesla refused further lucrative offers which did not meet his idealistic purposes and took the consequences. He returned to the design of turbines and by 1910 had models available. However, his entry competed with machinery which had been developed in the interval since Niagara when Tesla was occupied with his Colorado and Long Island enterprises. Tesla's secretive nature and stubbornness caused problems and he met an audience which was not inclined to cooperate. The Tesla turbine, a machine of great ingenuity and promise, did not succeed.

In 1912, the Nobel Committee announced that Nikola Tesla and Thomas Edison were the recipients of the Physics Prize; instead, the prize went to Gustav Dalen. Details of the reversal are unclear but it is known that Tesla refused the prize (and the $20,000 that came with it). Tesla

differentiated between inspirational discoverers such as himself and methodical improvements such as Edison; he gave greater value to the former. Tesla was a pure scientist and Edison an applied scientist, and they should not be in combination. Tesla was persuaded to accept the 1917 Edison Medal from the American Institute of Electrical Engineers but made his disinterest noticeable.

Tesla continued his work on power generation, making occasional announcements of progress which reached the press. He mentioned many discoveries but supplied no experimental details. He had enough money to live and always remained optimistic. There was talk of Tesla having invented a "death ray beam"; he spoke of sending a beam from Earth to the dark side of the moon. The discovery of atomic physics sent Tesla's mind racing to cosmic possibilities as he celebrated what he saw as the reach of man nearing that of “the Creator”. He described himself as "merely an automaton endowed with power of movement, responding to the stimuli of the sense organs and thinking and acting accordingly”.

Tesla died of heart failure, a forgotten man, on January 7, 1943, the Orthodox Christmas Day of that year. Agents from the Federal Bureau of Investigation immediately removed the papers from Tesla's safe, citing wartime security concerns. His funeral was conducted in New York, and his body was created. The FBI confiscated everything that was in his hotel room when he died, but that's another story.

Tesla was a pioneer in many fields. The Tesla coil, which he invented in 1891, is widely used today in radio and television sets and other electronic equipment. That year also marked the date of Tesla's United States citizenship. His alternating current induction motor is considered one of the ten greatest discoveries of all time. Among his other discoveries are the fluorescent light, laser beam, wireless communications, wireless transmission of electrical energy, remote control, robotics, Tesla’s turbines and vertical take off aircraft. Tesla is the father of the radio and the modern electrical transmissions systems. He registered over 700 patents worldwide. His vision included exploration of solar energy and the power of the sea. He foresaw interplanetary communications and satellites. His inventions changed the world.