Edison, Tesla and Westinghouse

> "It is a matter of fact that any system employing high pressure, i.e., 500 to 2,000 units [volts], jeopardizes life:"
> "Direct current is like a river flowing peacefully to sea, while alternating current is like a torrent rushing violently over a precipice:"
> Thomas A. Edison, *A Warning*, pamphlet publicizing the dangers of alternating current, 1888

With a lifetime total of 1,093 U.S. patents to his name, covering such items as electric lighting, electric power generation, the phonograph, the first truly practical telephone transmitter and receiver, the basic technology of moviemaking, and even a process for the manufacture of artificial cement, Thomas Alva Edison must surely be counted as one of the principal creators of modern civilization. In his own long lifetime he was called the "Wizard of Menlo Park" (after the New Jersey location of his most famous laboratory-workshop) and the "modern Prometheus." It seems almost too obvious to describe him as visionary, an inventor capable of transforming the future into the present, a nearly godlike creator.

Or so it seems. There is no denying the impact of Edison on what students of civilization call our "built environment," yet the closer we look at the achievement of the modern Prometheus, the less visionary and godlike he seems.

Almost all of Edison's vast warehouse of patents were for improvements on earlier inventions--his own as well as others. They were, that is, for innovation rather than invention. The phonograph, for instance, was a development of various recording telegraph devices that Edison--and many others--were already working on or had even marketed. The technology of motion pictures, Edison's kinetoscope (a movie viewer) and his kinetograph (a movie camera), were improvements on existing devices invented by others. Even his most iconic invention, the incandescent electric lamp, was a development of an emerging electric lighting technology that had its origin in the years before Edison was born. That technology had yet to be made commercially viable, and by developing a practical incandescent lamp, Edison also created the need (and market) for an entire electric power industry, the components of which he created right along with the lamp itself. Yet even in building this industry, he turned to existing technology. Generators already existed, though Edison had to improve them. The idea of distributing and retailing energy to households and businesses also existed. Gas companies had been piping their product into homes and factories for years, for billing purposes measuring individual consumption with meters. Edison proposed changing the pipes to wires, the gaslight mantles to electric lamp fixtures (which he invented), and the gas meters to recording electric meters (which he also invented).

The source of Thomas Edison's creative impact on our world is at once less mystical and more complex than visionary wizardry. His ability to create the future was firmly based on the present. His boldest inventions were almost always analogies to existing technologies. Even his most transformative set of inventions--the electric light and the electric power systems that accompanied it--were vivid analogies to existing gas heating and lighting systems.

Creation by analogy may be less impressive than invention out of thin air, but Edison's achievements are not to be denigrated. His effect on modern life remains monumental. Nevertheless, Edison's habit of analogy--his tenacious refusal to let go of existing technologies even as he radically innovated upon them--sometimes led even the Wizard of Menlo Park into folly. When that happened, it was instructive.

Edison made all of his breakthroughs in the field of electricity with simple direct current (DC), the continuous flow of electricity in a single direction. His major patents were based on DC, and when he designed his power generating and distributing systems, he considered only this type of current. It made for a straightforward system, in which generating plants fed lines, which customers tapped to power their lights and motors. The Edison system operated at a uniform voltage level throughout. Generators would supply 110 volts, which would drop to about 100 volts at the customer's site, because of the resistance of the distributing lines. The 100-volt level worked well with Edison's incandescent

lamps and was relatively safe. Contact with a live wire would produce quite a jolt, but it would seldom result in injury or death. The biggest drawback of Edison's DC system was that generating plants had to be located not more than a mile or so from all customers, so that the voltage drop-off caused by the length of the conducting wires would not be so great as to be insufficient to power lights and motors. Substantially raising the voltage level at the generators was not a practical option because Edison was unable to devise an efficient and relatively low-cost technology to allow reduction of high transmission voltage to a lower voltage for customer use.

Direct current was an inherently limited technology, but, fortunately, there was an alternative. In 1882, Nikola Tesla, a Croatian-born Serb who had graduated from the Austrian Polytechnic School in Graz, Austria, and did advanced electrical engineering work in Prague, joined Edison's French firm, Compagnie Continentale Edison, in Paris. While he was still a student, Tesla had become aware of the limitations of DC generating systems and began searching for an alternative. By the time he joined Compagnie Continentale Edison, he had already worked out the basis of an alternating current (AC) generator. Tesla invented a dynamo armature that alternated the direction of current as it revolved. This alternating current had the advantage of dramatically decreasing voltage drop-off over long transmission distances. Whereas Edison's l l0-volt DC system was practically limited to about one mile, Tesla's AC system could reliably transmit power hundreds of miles, especially after he introduced the concept or polyphase current-current generated at very high voltages, which allowed for more efficient transmission over long distances, then was stepped down at various points along the system, ultimately reaching individual customers at 110-volts.

In June 1884, Tesla left Paris for New York, armed with a letter of recommendation to Thomas Edison from Edison's most trusted assistant and co-researcher, Charles Batchelor. "I know two great men and you are one of them," Batchelor wrote. "The other is this young man." On the strength of this recommendation, Edison hired Tesla for his Edison Machine Works, ultimately assigning him the massive job of redesigning all of his company's direct current generators and motors. Tesla did as he was told, all the time also trying to interest his employer in abandoning direct current and embracing the virtues of alternating current. Edison hardly listened, dismissing Tesla's ideas out of hand as "magnificent but utterly impractical."

Edison's biographers have struggled to account for the total blindness of the modern Prometheus where AC was concerned. Many have pointed out that Edison was above all else an empirical experimenter who worked largely through dint of relentless trial and error. His most famous pronouncement on the process of invention--"Genius is 1 percent inspiration and 99 percent perspiration"--bears this out. Moreover, the largely self-educated Edison had no formal background in mathematics and physics, and engineering alternating current requires precisely such grounding in theory. It was a grounding Tesla possessed in abundance, whereas Edison did not. On a more pragmatic level, all of Edison's electrical patents up to this point were based on DC technology, and he was loath to compete against and devalue his own work by supplanting direct current devices with those suitable to alternating current. All of these were rational reasons for shunning AC. But there was more. At the bottom of it all was the fact that, to Edison, direct current was highly familiar, whereas alternating current was strange. No question that Thomas Edison was an innovator, and no question that many of his innovations radically reshaped civilization itself. Yet Edison nevertheless repeatedly gravitated toward what was familiar to him. Intellectually, economically, and even emotionally, he could not bring himself to see beyond DC technology, and he became increasingly determined to defend it, tooth and nail, against the assault by AC.

At length fed up with Edison's intransigence on the subject of AC and locked in a dispute over payment for his work on upgrading Edison's DC devices, Tesla left the Edison company to eke out a living as a manual laborer (he even dug ditches-for one of Edison's power companies!) as he continued to develop his AC polyphase systems. In 1886, Tesla found backers who financed the Tesla Electric Light & Manufacturing, but his investors almost immediately forced him out of his own company.

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Once again, he supported himself as a common laborer until 1888, when he managed to interest George Westinghouse in AC polyphase technology. The railroad and electric power entrepreneur backed the creation of Tesla's revolutionary system.

Thomas Edison fought back. He could neither argue nor demonstrate that DC technology was superior to AC for the simple reason that it was not. Instead, he authorized a relentless public relations campaign to disseminate the popular image of AC as too dangerous to be used by and among human beings. True, there were accidents involving high-voltage AC currents, and Edison's people made as much of them as possible, planting news stories and lobbying states for legislation to bar the technology altogether. Edison even ordered two of his Employees, Arthur E. Kennelly and Harold P. Brown, to demonstrate the lethality of alternating current by using it to publicly “execute stray cats and doge, as well as cattle and horses that had outlived their usefulness. The most spectacularly grotesque demonstration came on January 4, 1903, at Luna Park, Coney Island, when Topsy, an elephant owned by the Forepaugh Circus, was put to death by alternating current. The pachyderm was condemned because she had, over a period of three years, killed three men. The Society for the Prevention of Cruelty to Animals agreed that the "rogue" animal should be put down, but the organization vetoed the proposed method of hanging as inhumane. Seizing the opportunity, Thomas Edison proposed passing 6,600 volts of AC through her. (To ensure a fatal result, however, the elephant was fed cyanide-laced carrots just before the switch was thrown.) Some 1,500 people witnessed the electrocution live, and Edison made certain that many thousands more would see it by using one of his motion picture cameras to capture the event. Shortly after the demise of Topsy, the Edison Company released the brief documentary *Electrocuting an Elephant*.

Cats, dogs, cattle, and Topsy were not the only members of the animal kingdom to be "Westinghoused"--the Edison party's freshly coined synonym for suffering electrocution. By the time of the elephant's demise, the electric chair had been humming in some prison systems for thirteen years.

Personally Thomas Edison was an opponent of capital punishment, but in the late 1880s, he commissioned Harold P. Brown to build the first "electric chair" for the state of New York. It would, of course, be energized by alternating current. Brown presented his design to a state committee, which approved it in 1889, but then Brown found that he could not build the chair because Westinghouse refused to sell him an AC generator to power it. Backed by Edison, Brown was able to acquire the generator by purchasing it through a South American university, which, in turn, transshipped it to New York.

On August 6, 1890, William Kemmler was seated in the chair at New York's Auburn Prison. A high-voltage alternating current was passed through his body for seventeen seconds, but failed to kill him. A second attempt at higher power-2,000 volts-was applied. The effect was horrific. Kemmler caught fire, even as superficial blood vessels ruptured. It took him eight minutes to die.

Edison tried, but killing an elephant and condemned criminals failed to kill AC. In the 1890s, the Niagara Falls Commission sought proposals for harnessing the force of the falls as a source of energy to generate electricity. Edison's General Electric proposed a DC system, whereas Tesla and Westinghouse presented a design for an AC system. The commission did not hesitate to award the contract to alternating current. Construction of the facility began in 1893, and on November 16, 1896, power was transmitted for the first time from Niagara Falls to industrial customers in Buffalo.

The balance was tipped. Within a very few years, AC was replacing DC on virtually all central station power generation and distribution networks. Once alternating current became a technological fact--a feature of America's technological landscape--even Edison's companies began a costly and belated conversion from DC to AC. By this time, however, Westinghouse and others had stolen the march on Edison, who was obliged to relinquish into many other hands an enormous share of the profits from his civilization-transforming inventions. He was and would remain a rich man, but Thomas Edison never enjoyed the magnitude of wealth realized by Westinghouse and other industrialists who were far less inventive than the modern Prometheus but who were also far less deeply invested in

familiar yet limited technologies.