

## THE GREATEST ENGINEERING ACHIEVEMENTS OF THE 20<sup>TH</sup> CENTURY

**1. Electrification.** The wide distribution of electrical power in the 20<sup>th</sup> century brought light to the world and power to almost every pursuit and enterprise in modern society. Consider its impact on everyday life—lighting, heating and air conditioning, refrigeration, computers, transportation, communications, medical technologies, food production—the list is endless. Several key engineering innovations made this possible, including the turbine generator, the use of alternating current (AC), techniques to obtain electrical power from various resources (fossil fuels, water, sunlight, nuclear), and the construction and refinement of massive transmission systems. Electrification is responsible for innumerable developments that have made life safer, healthier, and more convenient; so much so that it is hard to imagine our lives without it. It runs the smallest electric appliances in homes and offices, the mammoth computers that control power grids and telecommunications systems, and the machinery that produces consumer goods. Its impact is vast, and it has touched the majority of people on the planet.

**2. Automobile.** In 1900 the average person traveled about 1200 miles in an entire lifetime, mostly on foot, and mostly within his or her own village or town. Today the average American adult travels some 10,000 miles a year by automobile alone, and there are half a billion cars in the world. How the industry grew from a few thousand Tin Lizzies to the modern, aerodynamic, and multipurpose vehicles of today is a chronicle of engineering at its most resourceful—from innovations in materials and power sources to new techniques in design and mass production. Innovations were introduced throughout the century, including the electric starter, the synchronized transmission, heat and air conditioning, windshield wipers, interchangeable parts, independent front suspension, power steering, and of course, the famous model designs that became signatures of style and luxury. In one form or another, the automobile has become the major transporter of people and goods in the world, and the industry has become a major source of economic growth and stability.

**3. Airplane.** Today one can travel from Europe to America in four hours on the Concorde—the same trip that in 1900 took seven to ten days by boat. Air travel has revolutionized our world, and the extraordinary engineering developments that shaped the airplane's evolution weave one of the most dramatic stories of the 20<sup>th</sup> century. After the Wright Brothers achieved the first successful flight in 1903, the airplane developed rapidly, particularly in response to the needs of WWI, with advances in materials, wing design, and engines. In 1939 the gas turbine was introduced, signaling the beginning of jet transport, and during WWII, the airplane changed the character of national defense and how war is waged. By 1957 airplanes would surpass trains as the preferred mode of travel for Americans, and today air travel makes the whole world accessible, transporting goods and people around the globe, and facilitating personal, cultural, and commercial interaction on a grand scale.

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**4. Water Supply and Distribution.** At the outset of the 20<sup>th</sup> century, waterborne diseases like typhoid fever and cholera were scourges throughout the world. In the United States, typhoid alone killed more than 150 per 100,000 people annually, and dysentery and diarrhea—the most common waterborne diseases—were the third largest cause of death. Since then, effective water treatment systems have had a dramatic impact on reducing these illnesses, virtually eliminating them in developed nations by the 1940s. Water treatment techniques developed in this century include chlorination, chemical coagulation, sedimentation, filtration, carbon absorption, microorganism systems, and others. But just as important as treatment facilities are the elaborate supply and distribution systems engineered to bring clean water to our communities and farms. Water for drinking, irrigation, industry, fire control, and other uses is delivered over long distances to areas where it is needed—urban or rural. The success of these water systems has led to longer life expectancy, reduced infant mortality, vast increases in agricultural production, and improvements in the quality of life around the world.

**5. Electronics.** From vacuum tubes to transistors to microprocessors, electronic devices became smaller, more powerful, and more efficient throughout the 20<sup>th</sup> century, and provided the technological basis for countless innovations and products.. The vacuum tube led to the early designs of the radio, television, and computer. In the early 1950s the transistor had captured the world's imagination, first in the transistorized radio—the fastest selling retail object of all time. In 1955, an early high-speed commercial computer weighed three tons, consumed 50 kilowatts of power, and cost \$200,000. But it could perform 50 multiplications per second, a feat unmatched by either a human or the latest adding machine. In 1977, a handheld calculator weighed under a pound, consumed less than half a watt of power, could perform 250 multiplications per second, and cost \$300. Today, you can buy palm-sized organizers for \$250 that link to computers, transmit data, and store thousands of addresses, appointments, memos, lists, and e-mails. The key to this stunning revolution in personal power is the integrated circuit—the heart of the modern electronics systems that have swept the world in the last half of the 20<sup>th</sup> century. Brilliant engineering and innovation lie behind these unseen elements that operate wireless communications, satellite broadcasts, air traffic control systems, microwave ovens, video cameras, touch-tone phones, computers, and many other innovations that have improved the quality, safety, and convenience of modern life.

**6. Radio and Television.** The introduction of radio and television were major agents of social change in the 20<sup>th</sup> century, opening windows to other lives, to remote areas of the world, and to history in the making. Broadcasts of news, sports events, and live performances captivated audiences as they emanated from speakers or screens in living rooms. After Marconi's 1901 demonstration of the "wireless" telegraph and the practical use of signal transmission, technical developments were rapid. The diode enabled the detection of electric current by a receiver, and the vacuum tube provided signal amplification, making live voice broadcasting possible. The 1920s saw further technical innovation in the antenna, tuning circuits, capacitors, microphones, oscillators, and loudspeakers. By the mid-1930s almost every American household had a radio, and in the 1940s the television first reached the market. Each has engaged millions of people in the major historical events that have shaped our world.

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**7. Agricultural Mechanization.** At the beginning of the century in the United States, it took a large team of farmers and field hands weeks to plant and harvest one crop, and it took four farmers to feed 10 people. Today, the entire midwestern corn crop can be planted in 10 days and harvested in 20, and a single farmer can produce enough food to feed 97 Americans and 32 people in other countries. Twentieth century engineering has made the difference. The tractor, the reaper, the combine, and hundreds of other machines and devices gave farmers the mechanical advantage they had long needed to ease the burdens of their hard lives and to make their lands truly profitable. Mechanization enormously increased farm efficiency and productivity, and, when combined with other engineering developments such as refrigeration, processing equipment, and distribution systems, has provided Americans with one of the healthiest diets in the world at the lowest cost. And around the globe, the spread of advanced agricultural technology offers much promise in the battle against hunger and famine in the new millennium.

**8. Computers.** Perhaps no other engineered device has captured the attention of the average citizen as much as the computer. Within two decades, the computer went from large, cumbersome machines used to crunch numbers to portable, user-friendly tools that have become an integral part of every major industry—communications, manufacturing, research, medicine, education, government, entertainment, and a myriad of others. The rapid progress of computers came about because of innovations in stored data, the competitive race for superior materials that would make computers faster and more reliable, and engineers who saw that the computer was more than a calculator. Graphically driven software makes computers easy to use and has begun to open new worlds through the Internet. The average American now has access to unprecedented amounts of knowledge, and can communicate freely in a world forum. In this respect, the real computer revolution is not one of numbers and bytes, but one in which people, regardless of geography and politics, can share information and learn from each other. The computer, more than any other force in modern history, has advanced a global community.

**9. Telephone.** In the 20<sup>th</sup> century the telephone evolved from a fledgling tool with limited use to a host of advanced technologies that form a cornerstone of the modern lifestyle. Near instantaneous connections—between friends, families, businesses, and nations—enable the communications that enhance our lives, industries, and economies. Through a remarkable series of innovations, engineers transformed a system of copper wire, wooden poles, and primitive transmitters into a network of radio and microwave towers, fiber optics, and digital technology, bringing us from switchboards and party lines to cell phones and satellite-based systems that reach the most remote outposts of the planet. Along the way, several key developments have made this possible—high-quality wire and cabling, computer and electronics technologies, lasers, fiber optics, satellites, and others. From voice calls to the Internet, the telephone has brought the human family together.

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**10. Air Conditioning and Refrigeration.** Life changed immensely in the 20<sup>th</sup> century as air conditioning and refrigeration systems became more efficient, controllable, and even mobile. No longer dependent on the weather for work or play, humans truly made the environment adapt to their needs. Dozens of engineering innovations made this possible, from William Carrier's early work with cooling and humidity control, to later advances in cooling agents, materials, system designs, and energy efficiency. Climate control has become so reliable and inexpensive that it has grown from an invisible luxury to a common necessity. The ability to transport and store fresh foods and other perishables simplified shopping and widened our choices. By the end of the century, nearly 70 percent of U.S. households had air conditioning, and 99.5 percent had at least one refrigerator. And beyond the home, tight control of air temperature and quality provides the purified environments required for surgery, manufacturing computer chips, and performing many types of research.

**11. Highways.** Early in the 20<sup>th</sup> century, most of the streets and roads in the United States were made of dirt, brick, and cedar blocks. Built for the horse, carriage, and foot traffic, they were usually poorly cared for and too narrow to accommodate automobiles. Today we enjoy an extensive system of highways, bridges, and tunnels linking our towns, cities, and rural areas. The construction of this system was spurred by two wars and the growing availability of automobile transportation, and was made possible by the achievements of thousands of engineers. The interstate highway system traverses mountains, steep grades, wetlands, rivers, deserts, and plains, and navigates dense urban areas with innovative bypasses, interchanges, and overhead expressways. The traffic control systems, materials, and construction methods developed under the interstate program influenced construction around the world and were invaluable in improving the condition of urban streets and traffic patterns. Highways have opened our country, enabled goods and services to reach remote areas, encouraged the growth of suburbs, and provided people everywhere with greater options in terms of access to jobs, health care, services, education, and cultural resources. Above all, highways have provided America with one of our most cherished assets—the freedom of mobility.

**12. Spacecraft.** In 1957, Sputnik I pierced the atmosphere, shocked the world, and started a space race that launched the greatest engineering team effort in American history. The resulting space program had enormous impact on people throughout the world. First it re-ignited the pioneering spirit that had once driven humans to explore every corner of the Earth, setting a new course for discovery in a long-dreamed-of realm—outer space. Second, it expanded the world's knowledge base. In the process of making space travel a reality, engineers working on the space program spawned an incredible 60,000 products that have had a direct impact on the general public. Today we depend on satellites for video, voice, and data communications, defense, weather prediction, environmental monitoring, navigation, and more. The advent of human space flight brought increased demands for spacecraft performance, computing power, and physiological monitoring systems. These demands accelerated the development of the specialty materials, powerful and compact computers, and advanced medical sensors that we enjoy today. We are still developing our space technologies—the shuttle, the international space station, and the remote probes exploring our neighboring planets are all part of this learning process. The next century is sure to bring many more accomplishments and discoveries that will widen our perspectives and improve our lives.

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**13. Internet.** The Internet was conceived in the 1960s as a tool to link university and government research centers via a nationwide network that would allow a wide variety of computers to exchange information and share resources. The engineering challenges were manifold and complex, beginning with the design of a packet switching network—a system that could make computers communicate with each other without the need for a traditional central system. Other challenges included the design of the machines, data exchange protocols, and software to run it. What eventually grew out of this endeavor is a miraculous low-cost technology that is swiftly and dramatically changing the world. It is available to ordinary people at home, in grade and high schools, universities, public libraries, and “cyber” cafes. It is not owned or controlled by any corporation or nation. Today, the Internet has over 150 million users and 800 million web pages (and growing daily), and it connects people in 65 countries instantaneously through computers, fiber optics, satellites, and phone lines. It is changing cultural patterns, business practices, the consumer industry, and research and educational pursuits. The possibilities for its future use are only just beginning to be imagined.

**14. Imaging.** From the atom to vast galaxies in the far reaches of space, new classes of imaging technologies engineered in the 20<sup>th</sup> century have enabled humans to literally expand their vision to unprecedented levels of scrutiny and analysis. Probing inside the human body with X-rays, CAT scans, and MRIs—monitoring its life forces, identifying diseases and anomalies, and treating them—is just one of the many imaging activities that have been enabled through dramatic engineering advances. Examining individual atoms with electron microscopes, exploring for oil and gas deep within the Earth’s crust with seismic instruments, mapping ocean floors with sonar, tracking weather patterns from ground-based and orbiting optical and radar sensors, and studying the heavens with space- and Earth-based telescopes of increasing power and resolution—all are the result of engineering advances in a broad range of technical fields. Coupled with the power of the computer, our ability to not only acquire images but also to quickly analyze vast amounts of data for use in diagnosis and prediction has enabled imaging to provide us with incredible new views both within and beyond the human body and environment.

**15. Household Appliances.** Often overlooked as products of engineering, household appliances brought radical changes to 20<sup>th</sup> century lifestyles—especially for women—by eliminating much of the time-consuming and back-breaking labor of everyday tasks. In the first half of the century the introduction of electricity made this transformation possible, coupled with two basic engineering innovations—resistance heating and small, efficient motors. These technologies were incorporated into devices ranging from stoves, heaters, and fans to vacuum cleaners, dishwashers, and dryers. In the second half of the century technologies like the magnetron and microprocessor transformed the household environment yet again, spawning appliances such as the microwave oven and others that incorporated new sensors, timers, and programmable devices. The impact of household appliances is monumental. They enhance our personal and family lives by freeing our time and energy, enable more people to earn a living outside the home, and contribute significantly to the economy.

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**16. Health Technologies.** It is astounding to compare the medical technology of today with that of 1900. Then, doctors used the few instruments they had, but mostly their senses of touch and sight, to diagnose illness. Today people live nearly 30 years longer, on average, than their ancestors did at the beginning of the 20<sup>th</sup> century. Although many advances were underway early in the century, health technologies really began to blossom in the last half, when engineering and medicine became increasingly interdisciplinary, and the human body was more fully recognized as a complex system of electrical fields, fluids, biomechanics, chemistry, and motion—ideal for an engineering approach to many of its problems. Since then, engineers have worked with the medical profession to develop artificial organs, replacement joints, diagnostic and imaging technologies, and biomaterials that improve the quality of life for millions. The technologies for surgery, medical implants, bioimaging, intensive care monitors, and the mass production of antibiotics and other drugs are all vital parts of this story. The impact of engineering in the medical arena and the resulting benefits to the average person are incalculable. In no other field have engineers become so intimately wedded to life itself.

**17. Petroleum and Petrochemical Technologies.** Petroleum-based fuels transformed the world landscape as they increased agricultural productivity, provided the means for distributing industrial and farm products, and furnished the mobility that defines 20<sup>th</sup> century technology. Petrochemicals, equally, have had an enormous impact, providing everything from aspirin to zippers, including pharmaceuticals, medical devices, synthetic fabrics, fertilizers, pesticides, building materials, and cosmetics. The major refining engineering advances which have in part enabled this transformation began in 1913 with the introduction of thermal cracking to manipulate the molecules of the hydrocarbon raw material, continued with the introduction of catalytic cracking in 1936, and further advanced with the introduction of platinum as a catalyst in the refining process (“Platforming”) in 1947, and the increased use of hydrogen processing beginning in the 1950s. Parallel engineering advances in oil and natural gas exploration, drilling, and transportation technologies have enabled the growth in demand for petroleum and petroleum-based products to be met by increasing world crude oil production from 150 million barrels per year in 1900 to about 22 billion barrels per year in 2000. The impacts on the economies of the world's nations, and the related international political significance of oil, have had enormous impacts on the shape the societal landscape of the 20<sup>th</sup> century.

**18. Laser and Fiber Optics.** Depending on where in the world one lived, communication during the early part of the 20<sup>th</sup> century relied on mail, the telegraph, the telephone, or some combination of the three. Telephony, the most sophisticated long-distance communication method, was unimaginably slow and cumbersome by today's standards. It used signals transported through copper wires, and the lines were limited in both their capacity and geographic reach. In the 1940s and 1950s, physicists studying the properties of molecules stumbled on a new approach for investigating their properties, work that ultimately led to the development of the laser. The idea of using lasers as a communications channel soon captured the imagination of engineers. In the mid-1970s, the development of highly pure glass fibers provided the essential physical infrastructure for carrying information via pulses of light. Today, a single, amplified fiber-optic cable can transmit tens of millions of telephone conversations as well as large volumes of data and video images. The versatile laser is also used as a manufacturing tool to cut precision parts, in medical applications such as eye surgery, in satellites to transmit weather and climate information, in scanners to read bar codes at cash registers, and in devices to play music on compact discs.

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**19. Nuclear Technologies.** The harnessing of the atom in the 1940s changed the nature of war forever, offered a new source for electrical power generation, and improved medical diagnostic techniques. The awesome and compact power of nuclear arms has transformed the military arsenals, strategies, and psyches of nations around the world. It has also greatly improved the range and comfort of submarines, and had a significant impact on peacetime activities. Today nuclear power is meeting the annual electrical needs of more than a billion people, with 434 operating reactors worldwide, mostly in Europe, Sweden, and the United Kingdom. Approximately 20 percent of power production in the United States is from nuclear energy. Medical applications of nuclear materials are also important—the first radioisotopes for medical use were produced in 1946, and radioisotopes are now widely used in medical research and for internal imaging of patients. Nuclear technologies have stirred emotions and controversy, but the engineering achievements related to their development remain among the most important of the 20<sup>th</sup> century.

**20. High-performance materials.** The materials revolution that took hold in 1900 began with the heavy building blocks of iron and steel. As we enter the 21<sup>st</sup> century, the realm of new materials is limited only by imagination. Throughout the 20<sup>th</sup> century engineers learned new methods to analyze, process, refine, model, and manufacture materials in ways that maximized their properties and enhanced their performance. Engineers reshaped skylines with the sleek architecture of steel and glass, forged great sheets of metal for airplane wings and car bodies, fabricated plastics into heart valves and construction materials, created synthetics to replace organic fibers, and developed new composites for spacecraft. Much as earlier eras were characterized as the ages of stone, iron, and copper, it may be that the term that best characterizes the 20<sup>th</sup> century is "the age of engineered materials."