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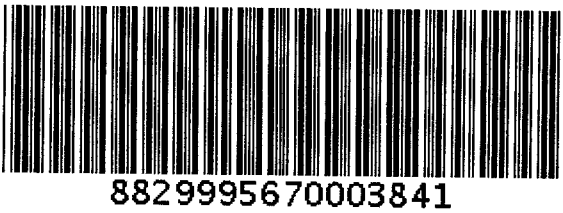

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The Rise of the Second Industrial Age

The First industrial Age was powered by coal and steam, the Second by oil and electricity.

Electricity came first. Its applications had been studied since the late eighteenth century by such scientists as Benjamin Franklin, Alessandro Volta, André-Marie Ampère, and Michael Faraday. But it was not until the 1860s that a practical dynamo—an electricity-generating machine—was developed. This was seized upon by Thomas Alva Edison, who had already gained fame for his invention of the phonograph, the "talking machine," in 1877. Within two years, the Wizard of Menlo Park, New Jersey, became equally renowned as the inventor of the incandescent lightbulb. But his contribution was broader than that. He invented a whole system of lighting centered around an improved generator of his own design whose energy could be transmitted via wires to multiple locations. Edison set up his first electrical system in lower Manhattan in 1882. He was not only a brilliant inventor but also a shrewd businessman. He launched a variety of businesses that merged to form Edison General Electric Company, later simply General Electric.

Within a few years, electricity was not only replacing gas lights and candles for illumination, it was also running factories, elevators, and light rail systems, making possible the rapid growth of urban areas with high-rise buildings. Within a few decades, electricity was running an increasing number of new appliances that were developed to take advantage of its ready availability and that transformed the way people lived. Washing machines, dishwashers, and vacuum cleaners liberated women from a good deal of household drudgery and made domestic servants expendable; air conditioners opened up the southern United States and other torrid climes for faster economic development and population growth; refrigeration dramatically reduced food spoilage and made possible richer, healthier diets.

Important as electricity generation was, it was not a primary source of energy; a dynamo requires an outside energy source—coal, water, wind, natural gas, oil, or, later, nuclear fission—to work. The same is true of the internal-combustion engine, which uses the explosive combustion of fuel to push pistons within a cylinder. The first practical model was created in 1859 by Jean-Joseph Étienne Lenoir, a Belgian working in Paris, and perfected in 1876 by Nicolaus August Otto, a German traveling salesman with no formal technical education. By 1886 engines had been installed on four-wheeled carriages by two competing German engineers, Gottlieb Daimler (a former employee of Otto's) and Karl Benz, giving birth to the automobile. In the next few years, a variety of other important inventions—the carburetor, radiator, steering wheel, crank-starter, pedal-brake control, pneumatic tire—were added by various mechanics.

It was not immediately apparent what type of engine would be best for "horseless carriages." Many early models ran on electricity or steam. Both had their advantages, but by the early 1900s the gasoline motor had triumphed decisively. It may have been noisy and noxious, but it was also small, cheap, and efficient. Best of all, it ran on a new and seemingly inexhaustible source of energy.

In 1901 the first major oilfield was discovered in Texas, and a great boom was on. Previously the oil industry, which had been centered in Pennsylvania, had primarily sold kerosene for lamps. With the spread of electricity, that market was going dark. But a vast new demand was growing as gasoline was used to power automobiles and fuel oil was used to run boilers in ships, factories, and trains. The growing value of petroleum would transform modern life. Men would kill each other in the future for control of this vital resource. In 1933, Interior Secretary Harold Ickes declared, without exaggeration, "There is no doubt about our absolute and complete dependence on oil. We have passed from the stone age, to bronze, to iron, to the industrial age, and now to an age of oil. Without oil, American civilization as we know it could not exist."

Luckily for the United States, it had ample supplies of this precious fuel; it produced two-thirds of the world's petroleum in 1941. It needed all that fuel because its motorization was more advanced than in other countries. European firms, such as Peugeot, Benz, Fiat, and Morris, had taken the early lead in automobile production, but by the early 1900s the Americans were catching up fast, led by a restless engineer named Henry Ford, who tinkered with engines in his spare time while working for the Edison Electrical Company in Detroit. In 1903, after several false starts, he founded the Ford Motor Company. Five years later, he launched what would become the most popular car of its era—the Model T. Simple, inexpensive, and reliable,

the hand-cranked "Tin Lizzie" was an instant hit. But Ford's most significant contribution was not what he produced but how he produced it.

Ford took several innovations pioneered by others, notably interchangeable parts (used by the Springfield Armory) and a moving production line (used by Chicago slaughterhouses), and combined them to create the most efficient factory in the world. In 1913 his Highland Park, Michigan, facility introduced a moving, electric-powered assembly line. Previously, gangs of workers had moved from one car to another. Now the cars came to them. Workers stood in one spot, endlessly repeating the same simple motion, whether adding a tire or tightening a bolt. The amount of time needed to assemble a car fell by 88 percent and the price of a finished Model T by more than 70 percent. The only problem was that workers hated this soul-deadening system that turned them, almost literally, into cogs in a machine. To attract and keep laborers, Ford doubled wages, to $5 a day. This not only made it easy for him to staff the assembly line but also, as an added benefit, made his workers well-paid enough to buy the very products they were producing.

Ford's techniques were widely copied in other industries, and, along with the expansion of advertising, they helped to usher in a new era of mass production and mass consumption. The American auto industry led the way. By the mid-1930s, the U.S. and Canada accounted for nearly 90 percent of the world output of trucks, cars, and tractors, and over half of all American families owned a car. This was impressive enough, considering that only a few years before, the horse had been the primary means of personal transportation. Even more amazing was that by the 1930s numerous people were soaring through the clouds.

The age-old dream of flight had first been achieved by the Montgolfier brothers in a hot-air balloon in 1783. Throughout the nineteenth century various inventors tried to create a reliable heavier-than-air flying machine, but none succeeded until 1903, when Orville and Wilbur Wright took their famous flight at Kitty Hawk, North Carolina. The internal combustion engine was as important for the Wrights' rickety Flyer as it was for the Model T; without it, they would not have had a compact power source for their propeller.

Although automobiles were utilized in World War I, starting with the use of Paris taxicabs to ferry French soldiers to the Battle of the Marne in 1914, the war did not play a major role in their development. (The war did lead to the invention of the tank, a close relative of the tractor, which will be examined later.) But, for the airplane, the Great War was crucial. In August 1914, Britain, France, the U.S., Russia, and Germany had all of 774 aircraft among them.

During the next four years, the belligerents produced more than two hundred thousand aircraft. Each new design had the longevity of a monarch butterfly: the average fighter plane went from introduction to combat to obsolescence in less than a year. This made for rapid improvements. In 1914 the typical airplane was a biplane or triplane made of wood, cloth, and wire. By the war's end in 1918 all-metal monoplanes were being produced that were recognizably modern in their design. The top speed of airplanes increased from 126 miles per hour in 1913 to 171 mph in 1920. (By 1939 the record was up to 469 mph.)

Surplus warplanes were put to good use after the Armistice. By 1919 regularly scheduled air service had begun between Paris, Brussels, and London, and the foundations had been laid for Lufthansa, British Airways, Air France, and the other great European state-owned airlines. The U.S., by contrast, developed its aviation industry through a mixture of public and private initiatives. The original impetus came from the U.S. Post Office, which paid private operators to carry airmail. To supplement their income, these new companies ferried passengers as well. By the early 1930s, a number of major airlines—Pan Am, Eastern, American, TWA, and United—had emerged. They were supplied with equipment by a growing manufacturing sector led by Boeing, Curtiss, Douglas, Pratt & Whitney, and Lockheed. Ford even got into the business in the 1920s with its popular Tri-Motor airplane. The 1930s introduced most of the features associated with modern air travel: everything from stewardesses and meals served on trays to cabin pressurization and in-flight movies.

The airline industry became, as it has remained, a ready reserve of pilots and aircraft that could be called upon in wartime. The link between civil and military aviation was especially close in Germany, Italy, Japan, and the Soviet Union, which were all heavily militarized, but it was also notable even in the least militarized major nation, the United States. The ubiquitous Douglas DC-3, a workhorse that carried fourteen passengers, doubled as the C-47, a U.S. military transport. The Boeing 307 Stratoliner, another popular aircraft that cut the time of a journey across the U.S. to a mere fourteen hours, was based on the B-17 bomber.

By the mid-1930s, American airlines were the world's biggest, but aircraft production in the U.S. lagged far behind that of the other Great Powers, whose output was mainly designated for military needs.

The airline industry, along with many others, benefited from great leaps in electronic communications. By the 1930s passengers were routinely inquiring about and booking flights using the telephone, a device which, since its invention by Alexander Graham Bell in 1876, had become ubiquitous in North American and western European offices and households.

The European states brought their telephone networks under government ownership. The U.S. preferred to have a state-regulated but privately owned monopoly.

By 1939, the Bell system, with assets worth an estimated $5 billion, had become the wealthiest corporation in the world. It was at the forefront of a development that had been gathering momentum since the nineteenth century: the split between ownership and management. In 1929, American Telephone & Telegraph, the Bell parent company, had half a million stockholders, none of whom owned more than 1 percent. This left its executives pretty much free to conduct its affairs as they liked. Business schools were springing up to train this new managerial elite, and consultants and gurus—the most famous was Frederick Winslow Taylor, the "Father of Scientific Management"—were coming along to advise them. Bureaucratization and professionalization, which had begun in the armed forces centuries earlier, had now spread to the business world. Many of the management techniques refined in the private sector would then be imported into the military by admirals and generals eager to make their forces as efficient as AT&T, Sears Roebuck, or General Motors—or later IBM, Wal-Mart, or Microsoft.

Coming along just after the telephone, another major technology that transformed communications was the radio. In 1896 Guglielmo Marconi, a wealthy twenty-two-year-old Anglo-Italian inventor, patented a "wireless telegraph" for transmitting dots and dashes through the ether. Before long, his invention gained the capacity to transmit voices and music too. Marconi's Wireless Telegraph Company took an early lead in harnessing this technology, but by the early 1920s it had been overtaken by Germany's Telefunken, France's Compagnie Générale de Télégraphie Sans Fil, and the Radio Corporation of America, all formed to free their nations of dependence on British communications networks. Britain, which had dominated cable telegraphy and pioneered wireless telegraphy, became an also-ran in the radio age. Not even Marconi's discovery in 1924 of a method for bouncing shortwaves off the ionosphere—which allowed radio signals to be sent across the globe simply and cheaply—could resurrect Britain's once-dominant position.

The world's first commercial radio station was opened in 1920 (KDKA in Pittsburgh), and before long radio had transformed the culture by transmitting everything from political addresses and sporting events to comedies like *Amos 'n' Andy*. A medium invented by Edison, motion pictures, completed the transformation of popular entertainment, particularly after the addition of sound in the mid-1920s. Both radio and film would become invaluable propaganda tools in wartime, motivating the masses to keep fighting and keep making sacrifices.

While broadcasting was the most popular radio application for the masses, point-to-point communications proved more important for military

and civil transportation. Two-way radios allowed ships and airplanes to update their coordinates and send distress signals if the need arose. Indeed, the radio first gained worldwide fame when it was used to transmit news of the *Titanic*'s sinking in 1912. In the 1920s, radio signals came to be used as aviation navigational aids. By listening to a series of beeps in their earphones, pilots could tell whether they were on course. It became possible to fly by instruments alone at night or in foul weather. Air-traffic control systems created in the 1930s using radios and other navigational aids dramatically reduced the incidence of airplane crashes.

As radio signals proliferated, many people began to notice that passing ships or airplanes would temporarily interfere with transmissions. The Scottish scientist Robert Watson Watt took advantage of this phenomenon to lay out a method of (to quote the title of his groundbreaking 1935 memorandum) "Detection of Aircraft by Radio Methods." The method was simplicity itself: use a directed antenna to transmit a radio pulse into the ether and time how long it took for it to bounce back. Since a radio wave moves at a constant speed (186,281 miles per second), the range of whatever object had caused it to bounce back could easily be computed. The location of the airplane could then be displayed as a blip on a screen using a cathode ray tube, which had been refined for a new medium called television. The entire system came to be known as radar (short for radio detecting and ranging), and it would prove to be of great benefit not only for guiding friendly airplanes but also for shooting down hostile ones. A similar system for using sound waves to detect objects in the water was also developed: sonar (sound navigation ranging).

Electrical generators, internal combustion engines, motor vehicles, airplanes, radios, telephones, radar: All of these technologies that contributed to the growth of the world economy between 1919 and 1939 (most of that growth occurring before the Great Depression started in 1929) would help to devastate a large portion of the world in the six years that followed. While the U.S. was a leader in exploiting these innovations in peacetime, it had not done nearly enough to apply them to the demands of warfare. It spent a mere 1.5 percent of its GDP on defense in 1937. Britain and France spent more—5.7 percent and 9.1 percent, respectively—but their economies were increasingly second-rate. Britain, which had accounted for 22.9 percent of world manufacturing output in 1880, was down to just 10.7 percent in 1938. The U.S. was the undisputed leader in manufacturing in 1938, with 31.4 percent of the global total. The Soviet Union was in second place with 17.6 percent. Ominously, Germany was the No. 3 industrial power, almost as big as Britain and France combined, with 13.2 percent of world output. Japan lagged farther behind, with 3.8 percent of world output, but its technology in

key military areas was as advanced as any in the world. The one bright spot for the Western democracies was the parlous economic condition of Italy, the least fearsome of the predatory states, which had a mere 2.9 percent of world output.

But while Mussolini was not a formidable adversary, Hitler and Tojo most definitely were. Their countries had spent a decade building the most advanced armed forces in the world, utilizing the full fruits of the Second Industrial Revolution to realize their mad dreams of conquest. The Western democracies were hard-pressed to match them. While Americans tooled around in Packards and flew on DC-3s, the Germans and Japanese were building tanks and dive bombers. The latent potential of the U.S. and the USSR was almost limitless, and in any prolonged war their greater resources would be likely—though far from certain—to prevail against smaller nations like Germany and Japan. But that was scant comfort to the Allied servicemen who, in the early years of World War II, would have to face the onslaught of well-oiled military machines that had revolutionized the art of war as thoroughly as Henry Ford had revolutionized individual transportation.

WAR MADE NEW

TECHNOLOGY, WARFARE, AND THE COURSE OF HISTORY, 1500 TO TODAY

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