A Century of Innovation, by George Constable and Bob Somerville

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Greatest Engineering Achievements of the 20th Century

Timeline

1900	**Telephone transmission extends across and between major cities** As telephone transmission extends across and between major cities, "loading coils" or inductors are placed along the lines to reduce distortion and attenuation or the loss of a signal's power. Independently invented by the American Telephone and Telegraph Company's (AT&T) George Campbell and Michael Pupin of Columbia University, the loading coils are first used commercially in New York and Boston, nearly doubling the transmission distance of open lines. Pupin is awarded the patent for the device in 1904, and AT&T pays him for its use.
1900	**Kodak Brownie camera** Eastman introduces the Kodak Brownie camera. Named after popular children's book characters, it sells for $1 and uses film that sells for 15¢ a roll. For the first time, photography is inexpensive and accessible to anyone who wants to take "snapshots." In the first year 150,000 cameras are sold, and many of the first owners are children. In the course of its long production life, the Brownie has more than 175 models; the last one is marketed as late as 1980 in England.
1900	**Sanitary and Ship Canal opens in Chicago** In Chicago the Main Channel of the Sanitary and Ship Canal opens, reversing the flow of the Chicago River. The 28-mile, 24-foot-deep, 160-foot-wide drainage canal, built between Chicago and the town of Lockport, Illinois, is designed to bring in water from Lake Michigan to dilute sewage dumped into the river from houses, farms, stockyards, and other industries. Directed by Rudolph Hering, chief engineer of the Commission on Drainage and Water Supply, the project is the largest municipal earth-moving project of the time.
1900	**Tesla granted a U.S. patent** Nikola Tesla is granted a U.S. patent for a "system of transmitting electrical energy" and another patent for "an electrical transmitter"—both the products of his years of development in transmitting and receiving radio signals. These patents would be challenged and upheld (1903), reversed (1904), and finally restored (1943).

1901	**The telescope shock absorber developed** C. L. Horock designs the "telescope" shock absorber, using a piston and cylinder fitted inside a metal sleeve, with a one-way valve built into the piston. As air or oil moves through the valve into the cylinder, the piston moves freely in one direction but is resisted in the other direction by the air or oil. The result is a smoother ride and less lingering bounce. The telescope shock absorber is still used today.
1901	**North America's first oil gusher**

	North America's first oil gusher blows at the Spindletop field near Beaumont in southeastern Texas, spraying more than 800,000 barrels of crude into the air before it can be brought under control. The strike boosts the yearly oil output in the United States from 2,000 barrels in 1859 to more than 65 million barrels by 1901.
1901	**First successful flying model propelled by an internal combustion engine** Samuel Pierpont Langley builds a gasoline-powered version of his tandem-winged "Aerodromes." the first successful flying model to be propelled by an internal combustion engine. As early as 1896 he launches steam-propelled models with wingspans of up to 15 feet on flights of more than half a mile.
1901	**Olds automobile factory starts production** The Olds automobile factory starts production in Detroit. Ransom E. Olds contracts with outside companies for parts, thus helping to originate mass production techniques. Olds produces 425 cars in its first year of operation, introducing the three-horsepower "curved-dash" Oldsmobile at $650. The car is a success; Olds is selling 5,000 units a year by 1905.
1901	**Marconi picks up the first transatlantic radio signal** Guglielmo Marconi, waiting at a wireless receiver in St. John's, Newfoundland, picks up the first transatlantic radio signal, transmitted some 2,000 miles from a Marconi station in Cornwall, England. To send the signal—the three dots of the Morse letter "s"—Marconi's engineers send a copper wire aerial skyward by hoisting it with a kite. Marconi builds a booming business using radio as a new way to send Morse code.
1901	**Engine-powered vacuum cleaner** British civil engineer H. Cecil Booth patents a vacuum cleaner powered by an engine and mounted on a horse-drawn cart. Teams of operators would reel the hoses into buildings to be cleaned.

1902	**First office building with an air-conditioning system installed** The Armour Building in Kansas City, Missouri, becomes the first office building to install an air-conditioning system. Each room is individually controlled with a thermostat that operates dampers in the ductwork, making it also the first office building to incorporate individual "zone" control of separate rooms.
1902	**First U.S. factory for tractors driven by an internal combustion engine** Charles Hart and Charles Parr establish the first U.S. factory devoted to manufacturing a traction engine powered by an internal combustion engine. Smaller and lighter than its steam-driven predecessors, it runs all day on one tank of fuel. Hart and Parr are credited with coining the term "tractor" for the traction engine.
1902	**Standard drum brakes are invented** Standard drum brakes are invented by Louis Renault. His brakes work by using a cam to force apart two hinged shoes. Drum brakes are improved in many ways over the years, but the basic principle remains in cars for the entire 20th century; even with the advent of disk brakes in the 1970s, drum brakes remain the standard for rear wheels.
1902	**Comfort cooling system installed at the New York Stock Exchange** A 300-ton comfort cooling system designed by Alfred Wolff is installed at the New York Stock Exchange. Using free cooling provided by waste-steam-operated refrigeration systems, Wolff's system functions successfully for 20 years.

1903	**First electrocardiograph machine** Dutch physician and physiologist Willem Einthoven develops the first electrocardiograph machine, a simple, thin, lightweight quartz "string" galvanometer, suspended in a magnetic field and capable of measuring small changes in electrical potential as the heart contracts and relaxes. After attaching electrodes to both arms and the left leg of his patient, Einthoven is able to record the heart's wave patterns as the string deflects, obstructing a beam of light whose shadow is then recorded on a photographic plate or paper. In 1924 Einthoven is awarded the Nobel Prize in medicine for his discovery.
1903	**Lightweight electric iron introduced** Earl Richardson of Ontario, California, introduces the lightweight electric iron. After complaints from customers that it overheated in the center, Richardson makes an iron with more heat in the point, useful for pressing around buttonholes and ruffles. Soon his customers are clamoring for the "iron with the hot point"—and in 1905 Richardson's trademark iron is born.
1903	**First sustained flight with a powered, controlled airplane** Wilbur and Orville Wright of Dayton, Ohio, complete the first four sustained flights with a powered, controlled airplane at Kill Devil Hills, 4 miles south of Kitty Hawk, North Carolina. On their best flight of the day, Wilbur covers 852 feet over the ground in 59 seconds. In 1905 they introduce the Flyer, the world's first practical airplane.
1903	**Paper mathematically demonstrates liftoff with liquid fuels** Konstantin Tsiolkovsky publishes a paper in Russia that mathematically demonstrates how to achieve liftoff with liquid fuels. He also proposes using multistage rockets, which would be jettisoned as they spent their fuel, and guidance systems using gyroscopes and movable vanes positioned in the exhaust stream. His formulas for adjusting a spacecraft's direction and speed to place it in any given orbit are still in use today.
1903	**Steam Turbine Generator** The steam turbine generator invented by Charles G. Curtis and developed into a practical steam turbine by William Le Roy Emmet is a significant advance in the capacity of steam turbines. Requiring one-tenth the space and weighing one-eighth as much as reciprocating engines of comparable output, it generates 5,000 kilowatts and is the most powerful plant in the world.

1904	**Fleming invents the two-electrode radio rectifier, or vacuum diode** British engineer Sir John Ambrose Fleming invents the two-electrode radio rectifier, or vacuum diode, which he calls an oscillation valve. Based on Edison's lightbulbs, the valve reliably detects radio waves. Transcontinental telephone service becomes possible with Lee De Forest's 1907 patent of the triode, or three-element vacuum tube, which electronically amplifies signals.
1904	**First crawler tractor with tracks rather than wheels**

	Benjamin Holt, a California manufacturer of agricultural equipment, develops the first successful crawler tractor, equipped with a pair of tracks rather than wheels. Dubbed the “caterpillar” tread, the tracks help keep heavy tractors from sinking in soft soil and are the inspiration for the first military tanks. The 1904 version is powered by steam; a gasoline engine is incorporated in 1906. The Caterpillar Tractor Company is formed in 1925, in a merger of the Holt Manufacturing Company and its rival, the C. L. Best Gas Traction Company.
1904	**A self-contained mechanical refrigerator is displayed at the St. Louis World’s Fair** A self-contained mechanical refrigerator is displayed at the St. Louis World’s Fair by Brunswick Refrigerating Co., which specializes in designing small refrigerators for residences and butcher shops. The ammonia refrigerating system is mounted on the side of a wooden icebox-type refrigerator. Thousands of attendees at the World’s Fair also experience the public debut of air conditioning in the Missouri State Building. The system uses 35,000 cubic feet of air per minute to cool a 1,000- seat auditorium, the rotunda, and various other rooms
1904	**Concept of a fixed "boundary layer" described in paper by Ludwig Prandtl** German professor Ludwig Prandtl presents one of the most important papers in the history of aerodynamics, an eight-page document describing the concept of a fixed "boundary layer," the molecular layer of air on the surface of an aircraft wing. Over the next 20 years Prandtl and his graduate students pioneer theoretical aerodynamics.
1904	**Thermionic valve, or diode invented** Sir John Ambrose Fleming, a professor of electrical engineering and the first scientific adviser for the Marconi Company, invents the thermionic valve, or diode, a two-electrode rectifier. (A rectifier prevents the flow of current from reversing.) Building on the work of Thomas Edison, Fleming devises an “oscillation valve”—a filament and a small metal plate in a vacuum bulb. He discovers that an electric current passing through the vacuum is always unidirectional.
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1905	**Special theory of relativity** German-born physicist Albert Einstein introduces his special theory of relativity, which states that the laws of nature are the same for all observers and that the speed of light is not dependent on the motion of its source. The most celebrated result of his work is the mathematical formula $E=mc^2$, or energy equals mass multiplied by the speed of light squared, which demonstrates that mass can be converted into energy. Einstein wins the Nobel Prize in physics in 1921 for his work on the photoelectric effect
1905	**Electric filaments improved** Engineer Albert Marsh patents the nickel and chromium alloy nichrome, used to make electric filaments that can heat up quickly without burning out. The advent of nichrome paves the way, 4 years later, for the first electric toaster.

1905	**First agricultural engineering curriculum at Iowa State College** Jay Brownlee Davidson designs the first professional agricultural engineering curriculum at then-Iowa State College. Courses include agricultural machines; agricultural power sources, with an emphasis on design and operation of steam tractors; farm building design; rural road construction; and field drainage. Davidson also becomes the first president of the American Society of Agricultural Engineers in 1907, leading agricultural mechanization missions to the Soviet Union and China.
1905	**Office of Public Roads** The Office of Public Roads (OPR) is established, successor to the Office of Road Inquiry established in 1893. OPR's director, Logan Waller Page, who would serve until 1919, helps found the American Association of State Highway Officials and lobbies Congress to secure the Federal Aid Highway Program in 1916, giving states matching funds for highways

1906	**Audion** Expanding on Fleming's invention, American entrepreneur Lee De Forest puts a third wire, or grid, into a vacuum tube, creating a sensitive receiver. He calls his invention the "Audion." In later experiments he feeds the Audion output back into its grid and finds that this regenerative circuit can transmit signals.
1906	**Christmas Eve 1906 program** On Christmas Eve 1906 engineering professor Reginald Fessenden transmits a voice and music program in Massachusetts that is picked up as far away as Virginia.
1906	**First air-conditioned hospital** Boston Floating Hospital becomes the first air-conditioned hospital, using a system designed by Edward Williams to maintain the hospital wards at about 70°F with a relative humidity of 50 percent. The hospital's five wards are individually controlled by thermostats. Williams's system features "reheat" in which cooled air is heated slightly to lower its humidity.
1906	**Patent filed for "dew point control" system** Willis Carrier files for a patent on his "dew point control" system. Carrier has studied the science of humidity control after designing a rudimentary air-conditioning system for a Brooklyn printing plant in 1902. This and subsequent designs allow him to devise a precise method of controlling humidity using refrigerated water sprays, thereby allowing the manufacture of air-conditioning systems to be standardized.
1906	**First office building specifically designed for air conditioning.** In Buffalo, Frank Lloyd Wright's Larkin Administration Building is the first office building specifically designed for air conditioning. The system uses safe, nonflammable carbon dioxide as a refrigerant.

1907	**First practical domestic vacuum cleaner** James Spangler, a janitor at an Ohio department store who suffers from asthma, invents his "electric suction-sweeper," the first practical domestic vacuum cleaner. It employs an electric fan to generate suction, rotating brushes to loosen dirt, a pillowcase for a filter, and a broomstick for a handle. Unsuccessful with his heavy, clumsy invention,

	Spangler sells the rights the following year to a relative, William Hoover, whose redesign of the appliance coincides with the development of the small, high-speed universal motor, in which the same current (either AC or DC) passes through the appliance's rotor and stator. This gives the vacuum cleaner more horsepower, higher airflow and suction, better engine cooling, and more portability than was possible with the larger, heavier induction motor. And the rest, as they say, is history
1907	**Triode patented** Lee De Forest, an American inventor, files for a patent on a triode, a three-electrode device he calls an Audion. He improves on Fleming's diode by inserting a gridlike wire between the two elements in the vacuum tube, creating a sensitive receiver and amplifier of radio wave signals. The triode is used to improve sound in long-distance phone service, radios, televisions, sound on film, and eventually in modern applications such as computers and satellite transmitters
1907	**Bakelite created** Leo Baekeland, a Belgian immigrant to the United States, creates Bakelite, the first thermosetting plastic. An electrical insulator that is resistant to heat, water, and solvents, Bakelite is clear but can be dyed and machined.
1907	**Air-conditioning equipment installed in dining and meeting rooms at Congress Hotel in Chicago** Air-conditioning equipment designed by Frederick Wittenmeier is installed in dining and meeting rooms at Congress Hotel in Chicago. This is one of the first systems designed by Wittenmeier for hotels and movie theaters. His firm, Kroeschell Brothers Ice Machine Company, installs hundreds of cooling plants into the 1930s
1907	**Model T introduced** Henry Ford begins making the Model T. First-year production is 10,660 cars. Cadillac is awarded the Dewar Trophy by Britain's Royal Automobile Club for a demonstration of the precision and interchangeability of the parts from which the car is assembled. Mass production thus makes more headway in the industry

1908	**William Durant forms General Motors** William Durant forms General Motors. His combination of car producers and auto parts makers eventually becomes the largest corporation in the world.
1908	**First solar collector** William J. Bailley of the Carnegie Steel Company invents a solar collector with copper coils and an insulated box.

1909	**First commercially successful electric toaster** Frank Shailor of General Electric files a patent application for the D-12, the first commercially successful electric toaster. The D-12 has a single heating element and no exterior casing. It has no working parts, no controls, and no sensors; a slice of bread must be turned by hand to toast on both sides
1909	**Precipitation hardening discovered** Alfred Wilm, then leading the Metallurgical Department at the German Center for

	Scientific Research near Berlin, discovers "precipitation hardening," a phenomenon that is the basis for the creation of strong, lightweight aluminum alloys essential to aeronautics and other technologies in need of such materials. Many other materials are also strengthened by precipitation hardening.
1909	**First take off from a ship** Eugene Ely pilots a Curtiss biplane on the first flight to take off from a ship. In November he departs from the deck of a cruiser anchored in Hampton Roads, Virginia, and lands onshore. In January 1911 he takes off from shore and lands on a ship anchored off the coast of California. Hooks attached to the plane's landing gear, a primitive version of the system of arresting gear and safety barriers used on modern aircraft carriers.

1910	**First take off from a ship** Eugene Ely pilots a Curtiss biplane on the first flight to take off from a ship. In November he departs from the deck of a cruiser anchored in Hampton Roads, Virginia, and lands onshore. In January 1911 he takes off from shore and lands on a ship anchored off the coast of California. Hooks attached to the plane's landing gear, a primitive version of the system of arresting gear and safety barriers used on modern aircraft carriers.
1910	**Asphalt manufactured from oil-refining byproducts** Gulf Oil, Texas Refining, and Sun Oil introduce asphalt manufactured from byproducts of the oil-refining process. Suitable for road paving, it is less expensive than natural asphalt mined in and imported from Venezuela. The new asphalt serves a growing need for paved roads as the number of motor vehicles in the United States soars from 55,000 in 1904 to 470,000 in 1910 to about 10 million in 1922. Garrett Morgan, an inventor with a fifth-grade education and the first African-American in Cleveland to own a car, **invents the electric, automatic traffic light**.
1910	**Vacuum light bulbs** Irving Langmuir of General Electric experiments with gas-filled lamps, using nitrogen to reduce evaporation of the tungsten filament, thus raising the temperature of the filament and producing more light. To reduce conduction of heat by the gas, he makes the filament smaller by coiling the tungsten.

1911	**Electric starter introduced** Charles Kettering introduces the electric starter. Until this time engines had to be started by hand cranking. Critics believed no one could make an electric starter small enough to fit under a car's hood yet powerful enough to start the engine. His starters first saw service in 1912 Cadillacs.

1912	**Radio signal amplifier devised** Columbia University electrical engineering student Edwin Howard Armstrong devises a regenerative circuit for the triode that amplifies radio signals. By pushing the current

	to the highest level of amplification, he also discovers the key to continuous-wave transmission, which becomes the basis for amplitude modulation (AM) radio. In a long patent suit with Lee De Forest, whose three-element Audion was the basis for Armstrong's work, the courts eventually decide in favor of De Forest, but the scientific community credits Armstrong as the inventor of the regenerative circuit

1913	**High-pressure hydrogenation process developed** German organic chemist Friedrich Bergius develops a high-pressure hydrogenation process that transforms heavy oil and oil residues into lighter oils, boosting gasoline production. In 1926 IG Farben Industries, where Carl Bosch had been developing similar high-pressure processes, acquires the patent rights to the Bergius process. Bergius and Bosch share a Nobel Prize in 1931
1913	**Stainless steel is rediscovered** Although created earlier in the century by a Frenchman and a German, stainless steel is rediscovered by Harry Brearley in Sheffield, England, and he is credited with popularizing it. Made of iron with about 13 percent chromium and a small portion of carbon, stainless steel does not rust
1913	**Hot cathode x-ray tube invented** William David Coolidge invents the hot cathode x-ray tube, using a thermionic tube with a heated cathode electron emitter to replace the cold, or gas, tube. All modern x-ray tubes are of the thermionic type
1913	**New method of oil refining** Chemical engineers William Burton and Robert Humphreys of Standard Oil patent a method of oil refining that significantly increases gasoline yields. Known as thermal cracking, the chemists discover that by applying both heat and pressure during distillation, heavier petroleum molecules can be broken down, or cracked, into gasoline's lighter molecules. The discovery is a boon to the new auto industry, whose fuel of choice is gasoline
1913	**Activated sludge process** In Birmingham, England, chemists experiment with the bio-solids in sewage sludge by bubbling air through wastewater and then letting the mixture settle; once solids had settled out, the water was purified. Three years later, in 1916, this activated sludge process is put into operation in Worcester, England, and in 1923 construction begins on the world's first large-scale activated sludge plant, at Jones Island, on the shore of Lake Michigan.
1913	**Southern California Edison brings electricity to Los Angeles** Southern California Edison puts into service a 150,000-volt line to bring electricity to Los Angeles. Hydroelectric Power is generated along the 233-mile-long aqueduct that brings water from Owens Valley in the eastern Sierra
1913	**First highway paved with portland cement** The first highway paved with portland cement, or concrete, is built near Pine Bluff, Arkansas, 22 years after Bellefontaine, Ohio, first paved its Main Street with concrete. Invented in 1824 by British stone mason Joseph Aspdin from a mix of calcium, silicon, aluminum, and iron minerals, portland cement is so-named because of its similarity to the stone quarried on the Isle of Portland off the English coast

1913	**First electric dishwasher on the market** The Walker brothers of Philadelphia produce the first electric dishwasher to go on the market, with full-scale commercialization by Hotpoint and others in 1930.
1913	**First moving assembly line for automobiles developed** Ford Motor Company develops the first moving assembly line for automobiles. It brings the cars to the workers rather than having workers walk around factories gathering parts and tools and performing tasks. Under the Ford assembly line process, workers perform a single task rather than master whole portions of automobile assembly. The Highland Park, Michigan, plant produces 300,000 cars in 1914. Ford's process allows it to drop the price of its Model T continually over the next 14 years, transforming cars from unaffordable luxuries into transportation for the masses.
1913	**Los Angeles–Owens River Aqueduct** The Los Angeles–Owens River Aqueduct is completed, bringing water 238 miles from the Owens Valley of the Sierra Nevada Mountains into the Los Angeles basin. The project was proposed and designed by William Mulholland, an immigrant from Ireland who taught himself geology, hydraulics, and mathematics and worked his way up from a ditch tender on the Los Angeles River to become the superintendent of the Los Angeles Water Department. Mulholland devised a system to transport the water entirely by gravity flow and supervised 5,000 construction workers over 5 years to deliver the aqueduct within original time and cost estimates.
1913	**First refrigerator for home use** Fred W. Wolf of Fort Wayne, Indiana, invents the first refrigerator for home use, a small unit mounted on top of an old-fashioned icebox and requiring external plumbing connections. Only in 1925 would a hermetically sealed standalone home refrigerator of the modern type, based on pre-1900 work by Marcel Audiffren of France and by self-trained machinist Christian Steenstrup of Schenectady, New York, be commercially introduced. This and other early models use toxic gases such as methyl chloride and sulfur dioxide as refrigerants. On units not hermetically sealed, leaks—and resulting explosions and poisonings—are not uncommon, but the gas danger ends in 1929 with the advent of Freon-operated compressor refrigerators for home kitchens.
1913	**Mammography research** Albert Solomon, a pathologist in Berlin, uses a conventional x-ray machine to produce images of 3,000 gross anatomic mastectomy specimens, observing black spots at the centers of breast carcinomas. Mammography, the resulting imaging, has been used since 1927 as a diagnostic tool in the early detection of breast cancer.

1914	**First car body made entirely of steel** Dodge introduces the first car body made entirely of steel, fabricated by the Budd Company. The Dodge touring car is made in Hamtramck, Michigan, a suburb of Detroit.
1914	**Sewerage Practice, Volume I: Design of Sewers** Boston engineers Leonard Metcalf and Harrison P. Eddy publish *American Sewerage Practice*, Volume I: *Design of Sewers*, which declares that working for "the best interests of the public health" is the key professional obligation of sanitary engineers. The book becomes a standard reference in the field for decades.

1914	**Automatic gyrostabilizer demonstrated** Lawrence Sperry demonstrates an automatic gyrostabilizer at Lake Keuka, Hammondsport, New York. A gyroscope linked to sensors keeps the craft level and traveling in a straight line without aid from the human pilot. Two years later Sperry and his inventor father, Elmer, add a steering gyroscope to the stabilizer gyro and demonstrate the first "automatic pilot."
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1914	**Aircooled, electric, self-contained household refrigerating unit is marketed** Fred Wolf, Jr., markets an aircooled, electric, self-contained household refrigerating unit, the Domelre (Domestic Electric Refrigerator), in Chicago. The system is designed to be placed on top of any icebox, operating automatically using a thermostat. The first household refrigerating system to feature ice cubes, the Domelre uses air to cool the condenser, unlike other household refrigerators that need to be hooked up to water.
1914-1918	**Dramatic improvements in structures and control and propulsion systems** During World War I, the requirements of higher speed, higher altitude, and greater maneuverability drive dramatic improvements in aerodynamics, structures, and control and propulsion system design.

1915	**First transcontinental telephone call** Alexander Graham Bell makes the first transcontinental telephone call to Thomas Watson-from New York to San Francisco-after trials using De Forest's triodes successfully boost the long-distance signal. What is the world's longest telephone line consists of 2,500 tons of copper wire, 130,000 poles, three vacuum-tube repeaters, and countless numbers of loading coils.
1915	**Pyrex** Corning research physicist Jesse Littleton cuts the bottom from a glass battery jar produced by Corning, takes it home, and asks his wife to bake a cake in it. The glass withstands the heat during the baking process, leading to the development of borosilicate glasses for kitchenware and later to a wide range of glass products marketed as Pyrex.
1915	**National Advisory Committee for Aeronautics** Congress charters the National Advisory Committee for Aeronautics, a federal agency to spearhead advanced aeronautical research in the United States.
1915	**New Catskill Aqueduct is completed** In December the new Catskill Aqueduct is completed. The 92-mile-long aqueduct joins the Old Croton Aqueduct system and brings mountain water from west of the Hudson River to the water distribution system of Manhattan. Flowing at a speed of 4 feet per second, it delivers 500 million gallons of water daily.
1915	**Goddard establishes that it is possible to send a rocket to the Moon** Robert Goddard experiments with reaction propulsion in a vacuum and establishes that

	it is possible to send a rocket to the Moon. Eleven years later, in 1926, Goddard launches the first liquid-fuel rocket.
1915	**The hydrophone developed** French professor and physicist Paul Langevin, working with Swiss physicist and engineer Constantin Chilowsky, develops the hydrophone, a high-frequency, ultrasonic echo-sounding device. The pioneering underwater sound technique is improved by the U.S. Navy and used during World War I in antisubmarine warfare as well as in locating icebergs. The work forms the basis for research and development into pulse-echo sonar (sound navigation and ranging), used on naval ships as well as ocean liners.
1915	**Calrod developed** Charles C. Abbot of General Electric develops an electrically insulating, heat conducting ceramic "Calrod" that is still used in many electrical household appliances as well as in industry.

1916	**Flash-freezing system for preserving food products developed** Clarence Birdseye begins experiments in quick-freezing. Birdseye develops a flash-freezing system that moves food products through a refrigerating system on conveyor belts. This causes the food to be frozen very fast, minimizing ice crystals.

1917	**Theory of stimulated emission** Albert Einstein proposes the theory of stimulated emission—that is, if an atom in a high-energy state is stimulated by a photon of the right wavelength, another photon of the same wavelength and direction of travel will be created. Stimulated emission will form the basis for research into harnessing photons to amplify the energy of light.
1917	**Wisconsin adopts road numbering system** Wisconsin is the first state to adopt a numbering system as the network of roads increases. The idea gradually spreads across the country and replaces formerly named trails and highways.
1917	**Superheterodyne circuit** While serving in the U.S. Army Signal Corps during World War I, Edwin Howard Armstrong invents the superheterodyne circuit, an eight-tube receiver that dramatically improves the reception of radio signals by reducing static and increasing selectivity and amplification. He files for a patent the following year.
1917	**The Junkers J4, an all-metal airplane, introduced** Hugo Junkers, a German professor of mechanics introduces the Junkers J4, an all-metal airplane built largely of a relatively lightweight aluminum alloy called duralumin.
1917	**Fordson tractor sells for $395** Henry Ford & Son Corporation—a spinoff of the Ford Motor Company— begins production of the Fordson tractor. Originally called the "automobile plow" and designed to work 10- to 12-acre fields, it costs as little as $395 and soon accounts for 50 percent of the worldwide market for tractors.
1917	**First long-distance high-voltage transmission line** The first long-distance high-voltage transmission line is established by American Gas & Electric (AG&E), an investor-owned utility. The line originates from the first major

	steam plant to be built at the mouth of a coal mine, virtually eliminating fuel transportation costs.

1918	**Airmail service inaugurated** The U. S. Postal Service inaugurates airmail service from Polo Grounds in Washington, D.C., on May 15. Two years later, on February 22, 1920, the first transcontinental airmail service arrives in New York from San Francisco in 33 hours and 20 minutes, nearly 3 days faster than mail delivery by train.
1918	**American Harvestor manufactures the Ronning Harvestor** American Harvester Company of Minneapolis begins manufacturing the horse-drawn Ronning Harvester, a corn silage harvester patented in 1915 by Minnesota farmers Andrean and Adolph Ronning. The Ronning machine uses and improves a harvester developed three years earlier by South Dakotan Joseph Weigel. The first field corn silage harvester was patented in 1892 by Iowan Charles C. Fenno.

1919	**Formula for the chlorination of urban water** Civil engineer Abel Wolman and chemist Linn H. Enslow of the Maryland Department of Health in Baltimore develop a rigorous scientific formula for the chlorination of urban water supplies. (In 1908 Jersey City Water Works, New Jersey, became the first facility to chlorinate, using sodium hypochlorite, but there was uncertainty as to the amount of chlorine to add and no regulation of standards.) To determine the correct dose, Wolman and Enslow analyze the bacteria, acidity, and factors related to taste and purity. Wolman overcomes strong opposition to convince local governments that adding the correct amounts of otherwise poisonous chemicals to the water supply is beneficial—and crucial—to public health. By the 1930s chlorination and filtration of public water supplies eliminates waterborne diseases such as cholera, typhoid, hepatitis A, and dysentery. The formula is still used today by water treatment plants around the world.
1919	**MacDonald appointed head of federal Bureau of Public Roads** Thomas MacDonald is appointed to head the federal Bureau of Public Roads (BPR), successor to OPR. During his 34-year tenure he helps create the Advisory Board on Highway Research, which becomes the Highway Research Board in 1924 and the Transportation Research Board in 1974. Among other things, BPR operates an experimental farm in Arlington, Virginia, to test road surfaces.
1919	**U.S. Navy aviators make the first airplane crossing of the North Atlantic** U.S. Navy aviators in Curtiss NC-4 flying boats, led Lt. Cdr. Albert C. Read, make the first airplane crossing of the North Atlantic, flying from Newfoundland to London with stops in the Azores and Lisbon. A few months later British Capt. John Alcock and Lt. Albert Brown make the first nonstop transatlantic flight, from Newfoundland to Ireland.
1919	**First single foot pedal to operate coupled four-wheel brakes** The Hispano-Suiza H6B, a French luxury car, demonstrates the first single foot pedal to operate coupled four-wheel brakes. Previously drivers had to apply a hand brake and a foot brake simultaneously.

1919	**First automatic pop-up toaster** Charles Strite's first automatic pop-up toaster uses a clockwork mechanism to time the toasting process, shut off the heating element when the bread is done, and release the slice with a pop-up spring. The invention finally reaches the marketplace in 1926 under the name Toastmaster.
1919	**Passenger service across the English Channel introduced** Britain and France introduce passenger service across the English Channel, flying initially between London and Paris. 1919 the first nonstop transatlantic flight, from Newfoundland to Ireland.
1919	**Switching systems and rotary-dial telephones** Bell System companies begin installing switching systems and rotary-dial telephones, though dial phones have been around since just before the turn of the century. The dial makes it easier for customers to place calls without an operator. The finger wheel of the dial interrupts the current in the phone line, creating pulses that correspond to the digits of the number being called.

1920	**Frequency multiplexing concept** AT&T develops the frequency multiplexing concept, in which frequencies of speech are shifted electronically among various frequency bands to allow several telephone calls at the same time. Metal coaxial cable eventually is used to carry a wide range of frequencies.
1920	**First scheduled commercial radio programmer** Station KDKA in Pittsburgh becomes radio's first scheduled commercial programmer with its broadcast of the Harding-Cox presidential election returns, transmitted at 100 watts from a wooden shack atop the Westinghouse Company's East Pittsburgh plant. Throughout the broadcast KDKA intersperses the election returns and occasional music with a message: "Will anyone hearing this broadcast please communicate with us, as we are anxious to know how far the broadcast is reaching and how it is being received?"
1920	**Yellow traffic lights** William Potts, a Detroit police officer, refines Garrett Morgan's invention by adding the yellow light. Red and green traffic signals in some form have been in use since 1868, but the increase in automobile traffic requires the addition of a warning signal.
1920s	**Fischer-Tropsch method** By using fractional distillation, two German coal researchers create synthetic gasoline. Known as the Fischer-Tropsch method, the gasoline is produced by combining either coke and steam or crushed coal and heavy oil, then exposing the mixture to a catalyst to form synthetic gasoline. The process plays a critical role in helping to meet the increasing demand for gasoline as automobiles come into widespread use and later for easing gasoline shortages during World War II.
1920s	**Windmills used to drive generators** Windmills with modified airplane propellers marketed by Parris-Dunn and Jacobs Wind are used to drive 1- to 3- kilowatt DC generators on farms in the U.S. Plains states. At first these provide power for electric lights and power to charge batteries for crystal radio sets, but later they supply electricity for motor-driven washing machines,

	refrigerators, freezers and power tools.
1920s	**High-pressure steam power plants** Boston Edison's Edgar Station becomes a model for high-pressure steam power plants worldwide by producing electricity at the rate of 1 kilowatt-hour per pound of coal at a time when generators commonly use 5 to 10 pounds of coal to produce 1 kilowatt-hour. The key was operating a boiler and turbine unit at 1,200 pounds of steam pressure, a unique design developed under the supervision of Irving Moultrop.
1920s	**First Plant to Reheat Steam** In Philo, Ohio, AG&E introduces the first plant to reheat steam, thereby increasing the amount of electricity generated from a given amount of raw material. Soon new, more heat-resistant steel alloys are enabling turbines to generate even more power.
1920s-1940s	**Nylon, acrylics, and polyester are developed** An assortment of new compounds derived from byproducts of the oil-refining process enter the market. Three of the most promising new materials—synthesized from the hydrocarbon ethylene—are polystyrene, a brittle plastic known also as styrofoam; polyvinyl chloride, used in plumbing fixtures and weather-resistant home siding; and polyethylene, which is flexible inexpensive, and widely used in packaging. New synthetic fibers and resins are also introduced, including nylon, acrylics, and polyester, and are used to make everything from clothing and sports gear to industrial equipment, parachutes, and plexiglass.
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1921	**First major aerial dusting of crops** U.S. Army pilots and Ohio entomologists conduct the first major aerial dusting of crops, spraying arsenate of lead over 6 acres of catalpa trees in Troy to control the sphinx caterpillar. Stricter regulations on pesticides and herbicides go into effect in the 1960s.
1921	**Lead added to gasoline** Charles Kettering of General Motors and his assistants, organic chemists Thomas Midgley, Jr., and T. A. Boyd, discover that adding lead to gasoline eliminates engine knock. Until the 1970s, when environmental concerns forced its removal, tetraethyl lead was a standard ingredient in gasoline.

1922	**International Harvester introduces a power takeoff** International Harvester introduces a power takeoff feature, a device that allows power

	from a tractor engine to be transmitted to attached harvesting equipment. This innovation is part of the company's signature Farmall tractor in 1924. The Farmall features a tricycle design with a high-clearance rear axle and closely spaced front wheels that run between crop rows. The four-cylinder tractor can also be mounted with a cultivator guided by the steering wheel
1922	**First American car with four-wheel hydraulic brakes** The Duesenberg, made in Indianapolis, Indiana, is the first American car with four-wheel hydraulic brakes, replacing ones that relied on the pressure of the driver's foot alone. Hydraulic brakes use a master cylinder in a hydraulic system to keep pressure evenly applied to each wheel of the car as the driver presses on the brake pedal.

1923	**Electrically refrigerated ice cream dipping cabinet is marketed** An electrically refrigerated ice cream dipping cabinet is marketed by Nizer and shortly after by Frigidaire. These cabinets use a refrigeration system to chill alcohol-based antifreeze, which surrounds ice cream cans placed in wells in the cabinet. The alcohol is later replaced by salt brine
1923	**Uniform system of signs** State highway engineers across the country adopt a uniform system of signage based on shapes that include the octagonal stop sign.

1924	
1924	

1925	**18/8 austenitic grade steel adopted by chemical industry** A stainless steel containing 18 percent chromium, 8 percent nickel, and 0.2 percent carbon comes into use. Known as 18/8 austenitic grade, it is adopted by the chemical industry starting in 1929. By the late 1930s the material's usefulness at high temperatures is recognized and it is used in the production of jet engines during World War II.
1925	**Televisor** Scottish inventor John Logie Baird successfully transmits the first recognizable image—the head of a ventriloquist's dummy—at a London department store, using a device he calls a Televisor. A mechanical system based on the spinning disk scanner developed in the 1880s by German scientist Paul Nipkow, it requires synchronization of the transmitter and receiver disks. The Televisor images, composed of 30 lines flashing 10 times per second, are so hard to watch they give viewers a headache. Charles F. Jenkins pioneers his mechanical wireless television system, radiovision, with a public transmission sent from a navy radio station across the Anacostia River to his office in downtown Washington, D.C. Jenkins's radiovisor is a multitube radio set with a special scanning-drum attachment for receiving pictures—cloudy 40- to 48-line images projected on a six-inch-square mirror. Jenkins's system, like Baird's, broadcasts

	and receives sound and visual images separately. Three years later the Federal Radio Commission grants Charles Jenkins Laboratories the first license for an experimental television station.
1925	**Numbering system for interstate highways** BPR and state highway representatives create a numbering system for interstate highways. East-west routes are designated with even numbers, north-south routes with odd numbers. Three-digit route numbers are given to shorter highway sections, and alternate routes are assigned the number of the principal line of traffic preceded by a one.
1925-1926	**Introduction of lightweight, air-cooled radial engines** The introduction of a new generation of lightweight, air-cooled radial engines revolutionizes aeronautics, making bigger, faster planes possible.

1926	**First power steering system** Francis Wright Davis uses a Pierce-Arrow to introduce the first power steering system. It works by integrating the steering linkage with a hydraulics system.

1927	**First garbage disposal** John W. Hammes, a Racine, Wisconsin, architect, develops the first garbage disposal in his basement because he wants to make kitchen cleanup work easier for his wife. Nicknamed the "electric pig" when first introduced by the Emerson Electric Company, the appliance operates on the principle of centrifugal force to pulverize food waste against a stationary grind ring so it would easily flush down the drain.
1927	**First iron with an adjustable temperature control** The Silex Company introduces the first iron with an adjustable temperature control. The thermostat, devised by Joseph Myers, is made of pure silver.
1927	**First refrigerator to be mass produced with a completely sealed refrigerating system** General Electric introduces the first refrigerator to be mass produced with a completely sealed refrigerating system. Nicknamed "The Monitor Top" for its distinctive round refrigerating unit, resembling the gun turret of the Civil War ironclad ship Monitor, the refrigerator is produced over the next 10 years and is so reliable that thousands are still in use today.
1927	**First modern practical respirator** Harvard medical researcher Philip Drinker, assisted by Louis Agassiz Shaw, devises the first modern practical respirator using an iron box and two vacuum cleaners. Dubbed the iron lung, his finished product—nearly the length of a small car—encloses the entire bodies of its first users, polio sufferers with chest paralysis. Pumps raise and lower the pressure within the respirator's chamber, exerting a pull-push motion on the patients' chests. Only their heads protrude from the huge cylindrical steel drum.
1927	**Holland Tunnel** Completion of the Holland Tunnel beneath the Hudson River links New York City and Jersey City, New Jersey. It is named for engineer Clifford Holland, who solves the problem of venting the build-up of deadly car exhaust by installing 84 electric fans,

	each 80 feet in diameter.
1927	**Gas-fired household absorption refrigerators become popular** Gas-fired household absorption refrigerators that do not require electricity are marketed to rural areas in the United States. One, the Electrolux, marketed in Sweden since 1925, becomes very popular.
1927	**All-electronic television system** Using his all-electronic television system, 21-year-old Utah farm boy and electronic prodigy Philo T. Farnsworth transmits images of a piece of glass painted black, with a center line scratched into the paint. The glass is positioned between a blindingly bright carbon arc lamp and Farnsworth's "image dissector" cathode-ray camera tube. As viewers in the next room watch a cathode-ray tube receiver, someone turns the glass slide 90 degrees—and the line moves. The use of cathode-ray tubes to transmit and receive pictures—a concept first promoted by British lighting engineer A. Campbell Swinton—is the death knell for the mechanical rotating-disk scanner system.
1927	**First nonstop solo flight across the Atlantic** On May 21, Charles Lindbergh completes the first nonstop solo flight across the Atlantic, traveling 3,600 miles from New York to Paris in a Ryan monoplane named the *Spirit of St. Louis*. On June 29, Albert Hegenberger and Lester Maitland complete the first flight from Oakland, California, to Honolulu, Hawaii. At 2,400 miles it is the longest open-sea flight to date.

1928	**Chlorofluorocarbon (CFC) refrigerants are synthesized** Chlorofluorocarbon (CFC) refrigerants are synthesized for Frigidaire by the General Motors Research Lab team of Thomas Midgley, Albert Henne, and Robert McNary. Announced publicly in 1930 and trademarked as Freon, CFCs are the first nontoxic and nonflammable refrigerating fluids, making it possible for refrigerators and air conditioners to be used with complete safety.
1928	**First electromechanical flight simulator** Edwin A. Link introduces the Link Trainer, the first electromechanical flight simulator. Mounted on a base that allows the cockpit to pitch, roll, and yaw, these ground-based pilot trainers have closed hoods that force a pilot to rely on instruments. The flight simulator is used for virtually all U.S. pilot training during WWII.
1928	**Televisor system produces images in crude color** John Logie Baird demonstrates, with the aid of two ventriloquist's dummies, that his Televisor system can produce images in crude color by covering three sets of holes in his mechanical scanning disks with gels of the three primary colors. The results, as reported in 1929 following an experimental BBC broadcast, appear "as a soft-tone photograph illuminated by a reddish-orange light."
1928	**Portable offshore drilling** By mounting a derrick and drilling outfit onto a submersible barge, Texas oilman Louis Giliasso creates an efficient portable method of offshore drilling. The transportable barge allows a rig to be erected in as little as a day, which makes for easier exploration of the Texas and Louisiana coastal wetlands. More permanent offshore piers and platforms had been successfully operating since the late 1800s off the coast of

	California near Santa Barbara, where oil seepage in the Pacific had been reported by Spanish explorers as early as 1542.

1929	**First room cooler goes on the market** Frigidaire markets the first room cooler. The refrigeration unit, which uses sulfur dioxide refrigerant and has a capacity of one ton (12,000 BTUH), is designed to be located outside the house or in the basement.
1929	**Television camera and a cathode-ray tube receiver** Vladimir Zworykin, who came to the United States from Russia in 1919, demonstrates the newest version of his iconoscope, a cathode-ray-based television camera that scans images electronically, and a cathode-ray tube receiver called the kinescope. The iconoscope, first developed in 1923, is similar to Philo Farnsworth's "image dissector" camera tube invention, fueling the growing rivalry between the two inventors for the eventual title of "father of modern television."

1930	**Synthetic rubber developed** Wallace Carothers and a team at DuPont, building on work begun in Germany early in the century, make synthetic rubber. Called neoprene, the substance is more resistant than natural rubber to oil, gasoline, and ozone, and it becomes important as an adhesive and a sealant in industrial uses.
1930	**Hardy Cross method** Hardy Cross, civil and structural engineer and educator, develops a method for the analysis and design of water flow in simple pipe distribution systems, ensuring consistent water pressure. Cross employs the same principles for the water system problem that he devised for the "Hardy Cross method" of structural analysis, a technique that enables engineers—without benefit of computers—to make the thousands of mathematical calculations necessary to distribute loads and moments in building complex structures such as multi-bent highway bridges and multistory buildings.
1930	**Smaller air-conditioning units appear on trains** With the advent of the centrifugal chiller, smaller air-conditioning units become feasible for trains. In 1930 the Baltimore & Ohio Railroad tests a unit designed by Willis Carrier on the "Martha Washington" the dining car on the *Columbian*, running between Washington, D.C. and New York. To test the system, the car is heated to 93°F. The heat is then turned off and the air conditioner turned on. Within 20 minutes, the temperature in the dining car is a comfortable 73°F.
1930s	**New process increases octane rating gasoline** U.S. refineries take advantage of a new process of alkalinization and fine-powder fluid-bed production that increases the octane rating of aviation gasoline to 100. This becomes important in the success of the Royal Air Force and the U.S. Army Air Force in World War II.
1930s	**Glass fibers become commercially viable** Engineers at the Owens Illinois Glass Company and Corning Glass Works develop several means to make glass fibers commercially viable. Composed of ingredients that

	constitute regular glass, the glass fibers produced in the 1930s are made into strands, twirled on a bobbin, and then spun into yarn. Combined with plastics, the material is called fiberglass and is used in automobiles, boat bodies, and fishing rods, and is also made into material suitable for home insulation.
1930s	**Artificial pacemaker invented** Albert S. Hyman, a practitioner cardiologist in New York City, invents an artificial pacemaker to resuscitate patients whose hearts have stopped. Working with his brother Charles, he constructs a hand-cranked apparatus with a spring motor that turns a magnet to supply an electrical impulse. Hyman tests his device on several small laboratory animals, one large dog, and at least one human patient before receiving a patent, but his invention never receives acceptance from the medical community.
1930s (Late)	**Air-entrained concrete introduced** Air-entrained concrete, one of the greatest advancements in concrete technology, is introduced. The addition of tiny air bubbles in the concrete provides room for expansion when water freezes, thus making the concrete surface resistant to frost damage.
1930s (Mid)	**Washing machine to wash, rinse, and extract water from clothes** John W. Chamberlain of Bendix Corporation invents a device that enables a washing machine to wash, rinse, and extract water from clothes in a single operation. This eliminates the need for cumbersome and often dangerous powered wringer rolls atop the machine.

1931	**Caterpillar manufactures a crawler tractor with a diesel engine** Caterpillar manufactures a crawler tractor with a diesel engine, which offers more power, reliability, and fuel efficiency than those using low-octane gasoline. Four years later International Harvester introduces a diesel engine for wheeled tractors. Several decades later diesel fuel would still be used for agricultural machinery.
1931	**"Hot- Kold" year-round central air-conditioning system for homes on the market** Frigidaire markets the "Hot- Kold" year-round central air-conditioning system for homes. During the early 1930s, a number of manufacturers design central air conditioners for homes, a market that grows slowly until the 1960s, when lower costs make it affordable for many new homes.
1931	**First modern independent front suspension system** Mercedes-Benz introduces the first modern independent front suspension system, giving cars a smoother ride and better handling. By making each front wheel virtually independent of the other though attached to a single axle, independent front suspension minimizes the transfer of road shock from one wheel to the other.
1931	**A heat pump air-conditioning system in Los Angeles office building** Southern California Edison Company installs a heat pump air-conditioning system in its Los Angeles office building. Since a refrigeration system moves heat from one place to another, the same principle can be used to remove heat in summer or add heat in winter by engineering the system to be reversible.
1931	**Introduction of bulk-power, utility-scale wind energy conversion systems** The 100-kilowatt Balaclava wind generator on the shores of the Caspian Sea in Russia marks the introduction of bulk-power, utility-scale wind energy conversion systems.

	This machine operates for about 2 years, generating 200,000 kilowatt-hours of electricity. A few years later, other countries, including Great Britain, the United States, Denmark, Germany, and France, begin experimental large-scale wind plants.
1931-1933	**Electron microscope** Ernst Ruska, a German electrical engineer working with Max Kroll, constructs and builds an electron microscope, the first instrument to provide better definition than a light microscope. Electron microscopes can view objects as small as the diameter of an atom and can magnify objects one million times. (In 1986 Ruska is awarded half of the Nobel Prize in physics. The other half is divided between Heinrich Rohrer and Gerd Binnig for their work on the scanning tunneling microscope; see 1981.)

1932	**First pickup baler manufactured** The Ann Arbor Machine Company of Shelbyville, IIlinois, manufactures the first pickup baler, based on a 1929 design by Raymond McDonald. Six years later Edwin Nolt develops and markets a self-tying pickup baler. The baler, attached to a tractor, picks up cut hay in the field, shapes it into a 16-18-inch bale, and knots the twine that hold the bale secure. Self-propelled hay balers soon follow.
1932	**Rubber wheels result in a 25 percent improvement in fuel economy for tractors** An Allis-Chalmers Model U tractor belonging to Albert Schroeder of Waukesha, Wisconsin, is outfitted with a pair of Firestone 48°-12 airplane tires in place of lugged steel wheels. Tests by the University of Nebraska Tractor Test Laboratory find that rubber wheels result in a 25 percent improvement in fuel economy. Rubber wheels also mean smoother, faster driving with less wear and tear on tractor parts and the driver. Minneapolis Marine Power Implement Company even markets a "Comfort Tractor" with road speeds up to 40 mph, making it usable on public roads for hauling grain or transporting equipment.
1932	**First overnight train with air conditioning** Chesapeake & Ohio Railroad begins running the first overnight train with air conditioning, the *George Washington*, between New York and Washington. Four years later United Air Lines uses air conditioning in its "three miles a minute" passenger planes.
1932	**Neutron is discovered** English physicist and Nobel laureate James Chadwick exposes the metal beryllium to alpha particles and discovers the neutron, an uncharged particle. It is one of the three chief subatomic particles, along with the positively charged proton and the negatively charged electron. Alpha particles, consisting of two neutrons and two protons, are positively charged, and are given off by certain radioactive materials. His work follows the contributions of New Zealander Ernest Rutherford, who demonstrated in 1919 the existence of protons. Chadwick also studies deuterium, known as heavy hydrogen, an isotope of hydrogen used in nuclear reactors.
1932	**Autobahn opens** The opening of a 20-mile section of Germany’s fledgling autobahn, regarded as the world’s first superhighway, links Cologne and Bonn. By the end of the decade the autobahn measures 3,000 kilometers and inspires U.S. civil engineers contemplating a similar network. Today the autobahn covers more than 11,000 kilometers.

1932	**Cockcroft teams Walton to split the atom** British physicist John Cockcroft teams with Ernest Walton of Ireland to split the atom with protons accelerated to high speed. Their work wins them the Nobel Prize in physics in 1951.
1932	**Rubber wheels improve the tractor** An Allis-Chalmers Model U tractor belonging to Albert Schroeder of Waukesha, Wisconsin, is outfitted with a pair of Firestone 48X12 airplane tires in place of lugged steel wheels. Tests by the University of Nebraska Tractor Test Laboratory find that rubber wheels result in a 25 percent improvement in fuel economy. Rubber wheels also mean smoother, faster driving with less wear and tear on tractor parts and the driver. Minneapolis Marine Power Implement Company even markets a "Comfort Tractor" with road speeds up to 40 mph, making it usable on public roads or hauling grain or transporting equipment.

1933	**Tennessee Valley Authority** Congress passes legislation establishing the Tennessee Valley Authority (TVA). Today the TVA manages numerous dams, 11 steam turbine power plants, and two nuclear power plants. Altogether these produce 125 billion kilowatt-hours of electricity a year.
1933	**Douglas introduces the 12-passenger twin engine DC-1** In that summer Douglas introduces the 12-passenger twin-engine DC-1, designed by aeronautical engineer Arthur Raymond for a contract with TWA. A key requirement is that the plane can take off, fully loaded, if one engine goes out. In September the DC-1 joins the TWA fleet, followed 2 years later by the DC-3, the first passenger airliner capable of making a profit for its operator without a postal subsidy. The DC-3's range of nearly 1,500 miles is more than double that of the Boeing 247. As the C-47 it becomes the workhorse of WWII.
1933	**First modern commercial airliner** In February, Boeing introduces the 247, a twin-engine 10-passenger monoplane that is the first modern commercial airliner. With variable-pitch propellers, it has an economical cruising speed and excellent takeoff. Retractable landing gear reduces drag during flight.
1933	**Hydraulic draft control system developed** Irish mechanic Harry Ferguson develops a tractor that incorporates his innovative hydraulic draft control system, which raises and lowers attached implements—such as tillers, mowers, post-hole diggers, and plows—and automatically sets their needed depth. The David Brown Company in England is the first to build the tractor, but Ferguson also demonstrates it to Henry Ford in the United States. With a handshake agreement, Ford manufactures Ferguson's tractor and implements from 1939 to 1948. A few years later Ferguson's company merges with Canadian company Massey-Harris to form Massey-Ferguson.
1933	**FM radio** Edwin Howard Armstrong develops frequency modulation, or FM, radio as a solution to the static interference problem that plagues AM radio transmission, especially in summer when electrical storms are prevalent. Rather than increasing the strength or amplitude of his radio waves, Armstrong changes only the frequency on which they are

	transmitted. However, it will be several years before FM receivers come on the market.
1933	**Polyethylene discovered** Polyethylene, a useful insulator, is discovered by accident by J. C. Swallow, M.W. Perrin, and Reginald Gibson in Britain. First used for coating telegraph cables, polyethylene is then developed into packaging and liners. Processes developed later render it into linear low-density polyethylene and low-density polyethylene.
1933	**Kouwenhoven cardiovascular research** Working on rats and dogs at Johns Hopkins University, William B. Kouwenhoven and neurologist Orthello Langworthy discover that while a low-voltage shock can cause ventricular fibrillation, or arrhythmia, a second surge of electricity, or countershock, can restore the heart's normal rhythm and contraction. Kouwenhoven's research in electric shock and his study of the effects of electricity on the heart lead to the development of the closed-chest electric defibrillator and the technique of external cardiac massage today known as cardiopulmonary resuscitation, or CPR.

1934	**First successful mass-produced front-wheel-drive car** The French automobile Citroën Traction Avant is the first successful mass-produced front-wheel-drive car. Citroën also pioneers the all-steel unitized body-frame structure (chassis and body are welded together). Audi in Germany and Cord in the United States offer front-wheel drive.
1934	**Nylon** Experimenting over 4 years to craft an engineered substitute for silk, Wallace Carothers and his assistant Julian Hill at DuPont ultimately discover a successful process with polyamides. They also learn that their polymer increases in strength and silkiness as it is stretched, thus also discovering the benefits of cold drawing. The new material, called nylon, is put to use in fabrics, ropes, and sutures and eventually also in toothbrushes, sails, carpeting, and more.

1935	**First generator at Hoover Dam begins operation** The first generator at Hoover Dam along the Nevada-Arizona border begins commercial operation. More generators are added through the years, the 17th and last one in 1961.
1935	**Hoover Dam** In September, President Franklin D. Roosevelt speaks at the dedication of Hoover Dam, which sits astride the Colorado River in Black Canyon, Nevada. Five years in construction, the dam ends destructive flooding in the lower canyon; provides water for irrigation and municipal water supplies for Nevada, Arizona, and California; and generates electricity for Las Vegas and most of Southern California.
1935	**First research on conservation tillage** Agronomists Frank Duley and Jouette Russell at the University of Nebraska, along with other scientists with the U.S. Soil Conservation Service, begin the first research on conservation tillage. The practice involves various methods of tilling the soil, with

	stubble mulch and different types of plows and discs, to control wind erosion and manage crop residue. This technology is common on farms by the early 1960s.
1935	**First practical radar** British scientist Sir Robert Watson-Watt patents the first practical radar (for radio detection and ranging) system for meteorological applications. During World War II radar is successfully used in Great Britain to detect incoming aircraft and provide information to intercept bombers.
1935	**First transpacific mail service** Pan American inaugurates the first transpacific mail service, between San Francisco and Manila, on November 22, and the first transpacific passenger service in October the following year. Four years later, in 1939, Pan Am and Britain's Imperial Airways begin scheduled transatlantic passenger service.
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1935	**First clothes dryer** To spare his mother having to hang wet laundry outside in the brutal North Dakota winter, J. Ross Moore builds an oil-heated drum in a shed next to his house, thereby creating the first clothes dryer. Moore's first patented dryers run on either gas or electricity, but he is forced to sell the design to the Hamilton Manufacturing Company the following year because of financial difficulties.
1935	**Rural Electrification Administration bring electricity to many farmers** President Roosevelt issues an executive order to create the Rural Electrification Administration (REA), which forms cooperatives that bring electricity to millions of rural Americans. Within 6 years the REA has aided the formation of 800 rural electric cooperatives with 350,000 miles of power lines.
1935	**Flashing turn signals introduced** A Delaware company uses a thermal interrupter switch to create flashing turn signals. Electricity flowing through a wire expands it, completing a circuit and allowing current to reach the lightbulb. This short-circuits the wire, which then shrinks and terminates contact with the bulb but is then ready for another cycle. Transistor circuits begin taking over the task of thermal interrupters in the 1960s.
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1935	**"A Symbolic Analysis of Relay and Switching Circuits"** Electrical engineer and mathematician Claude Shannon, in his master's thesis, "A Symbolic Analysis of Relay and Switching Circuits," uses Boolean algebra to establish a working model for digital circuits. This paper, as well as later research by Shannon, lays the groundwork for the future telecommunications and computer industries.

1936	**Albert Henne synthesizes refrigerant R-134a** Albert Henne, coinventor of the CFC refrigerants, synthesizes refrigerant R-134a. In the 1980s this refrigerant is hailed as the best nonozone-depleting replacement for CFCs.
1936	**Clear, strong plastic** The Rohm and Haas Company of Philadelphia presses polymethyl acrylate between two pieces of glass, thereby making a clear plastic sheet of the material. It is the forerunner of what in the United States is called Plexiglass (polyvinyl methacrylate). Far tougher than glass, it is used as a substitute for glass in automobiles, airplanes, signs, and homes.
1936	**Catalytic cracking introduced** French scientist Eugene Houdry introduces catalytic cracking. By using silica and alumina-based catalysts, he demonstrates not only that more gasoline can be produced from oil without the use of high pressure but also that it has a higher octane rating and burns more efficiently.

1937	**Golden Gate Bridge** The Golden Gate Bridge opens and connects San Francisco with Marin County. To construct a suspension bridge in a region prone to earthquakes, engineer Joseph Strauss uses a million tons of concrete to hold the anchorages in place. Its two main towers each rise 746 feet above the water and are strung with 80,000 miles of cable.
1937	**Route 66 completed** The paving of Route 66 linking Chicago and Santa Monica, California, is complete. Stretching across eight states and three time zones, the 2,448-mile-long road is also known as "The Mother Road" and "The Main Street of America." For the next half-century it is the country's main thoroughfare, bringing farm workers from the Midwest to California during the Dust Bowl and contributing to California's post-World War II population growth. Officially decommissioned in 1985, the route has been replaced by sections of Interstate-55, I-44, I-40, I-15, and I-10.
1937	**Jet engines designed** Jet engines designed independently by Britain's Frank Whittle and Germany's Hans von Ohain make their first test runs. (Seven years earlier, Whittle, a young Royal Air Force officer, filed a patent for a gas turbine engine to power an aircraft, but the Royal Air Ministry was not interested in developing the idea at the time. Meanwhile, German doctoral student Von Ohain was developing his own design.) Two years later, on August 27, the first jet aircraft, the Heinkel HE 178, takes off, powered by von Ohain's HE S-3 engine.
1937	**Delaware Aqueduct System** Construction begins on the 115-mile-long Delaware Aqueduct System. Water for the system is impounded in three upstate reservoir systems, including 19 reservoirs and three controlled lakes with a total storage capacity of approximately 580 billion gallons. The deep, gravityflow construction of the aqueduct allows water to flow from Rondout Reservoir in Sullivan County into New York City's water system at Hillview

	Reservoir in Westchester County, supplying more than half the city's water. Approximately 95 percent of the total water supply is delivered by gravity with about 5 percent pumped to maintain the desired pressure. As a result, operating costs are relatively insensitive to fluctuations in the cost of power.
1937	**5-million-volt Van de Graaff generator built** The Westinghouse Corporation builds the 5-million-volt Van de Graaff generator. Named for its inventor, physicist Robert Van de Graaff, the generator gathers and stores electrostatic charges. Released in a single spark and accelerated by way of a magnetic field, the accumulated charge, equivalent to a bolt of lightning, can be used as a particle accelerator in atom smashing and other experiments.

1938	**First self-propelled combine** In Australia, Massey-Harris introduces the first self-propelled combine—a thresher and reaper in a single machine—not drawn by a tractor or horse. Welcomed because it replaces the labor-intensive binder, handshocking, and threshing, the new combine becomes increasingly popular. By the end of the century, single-driver combines feature air-conditioned cabins that are lightly pressurized to keep out dirt and debris.
1938	**DuPont discovers Teflon** Annoyed one day that a tank presumably full of tetrafluoroethylene gas is empty, DuPont scientist Roy Plunkett investigates and discovers that the gas had polymerized on the sides of the tank vessel. Waxy and slippery, the coating is also highly resistant to acids, bases, heat, and solvents. At first Teflon is used only in the war effort, but it later becomes a key ingredient in the manufacture of cookware, rocket nose cones, heart pacemakers, space suits, and artificial limbs and joints.
1938	**A window air conditioner using Freon is marketed** A window air conditioner using Freon is marketed by Philco-York. Featuring a beautiful wood front, the Philco air conditioner can simply be plugged into an electrical outlet.
1938-1957	**Colorado–Big Thompson Project** The Colorado–Big Thompson Project (C-BT), the first trans-mountain diversion of water in Colorado, is undertaken during a period of drought and economic depression. The C-BT brings water through the 13-mile Alva B. Adams Tunnel, under the Continental Divide, from a series of reservoirs on the Western Slope of the Rocky Mountains to the East Slope, delivering 230,000 acre-feet of water annually to help irrigate more than 600,000 acres of farmland in northeastern Colorado and to provide municipal water supplies and generate electricity for Colorado's Front Range.

1939	**Resonant-cavity magnetron developed** Henry Boot and John Randall, at the University of Birmingham in England, develop the resonant-cavity magnetron, which combines features of two devices, the magnetron and the klystron. The magnetron, capable of generating high-frequency radio pulses with large amounts of power, significantly advances radar technology and assists the Allies during World War II.
1939	**Atanasoff-Berry Computer, the first electronic computer**

	John Atanasoff and Clifford Berry at Iowa State College design the first electronic computer. The obscure project, called the Atanasoff-Berry Computer (ABC), incorporates binary arithmetic and electronic switching. Before the computer is perfected, Atanasoff is recruited by the Naval Ordnance Laboratory and never resumes its research and development. However, in the summer of 1941, at Atanasoff's invitation, computer pioneer John Mauchly of the University of Pennsylvania, visits Atanasoff in Iowa and sees the ABC demonstrated.
1939	**First binary digital computers are developed** The first binary digital computers are developed. Bell Labs's George Stibitz designs the Complex Number Calculator, which performs mathematical operations in binary form using on-off relays, and finds the quotient of two 8-digit numbers in 30 seconds. In Germany, Konrad Zuse develops the first programmable calculator, the Z2, using binary numbers and Boolean algebra—programmed with punched tape.
1939	**Air conditioning offered as an option in a Packard automobile** Packard Motor Car Company markets an automobile with air conditioning offered as an option for $274. The refrigeration compressor runs off the engine, and the system has no thermostat. It discharges the cooled air from the back of the car.
1939	**First practical singlerotor helicopters** Russian emigre Igor Sikorsky develops the VS-300 helicopter for the U.S. Army, one of the first practical singlerotor helicopters.
1939	**Uranium atoms are split** Physicists Otto Hahn and Fritz Strassmann of Germany, along with Lise Meitner of Austria and her nephew Otto Frisch, split uranium atoms in a process known as fission. The mass of some of the atoms converts into energy, thus proving Einstein's original theory.
1939	**First air conditioning system added to automobiles** The Nash Motor Company adds the first air conditioning system to cars.
1939-1945	**World war again spurs innovation** A world war again spurs innovation. The British develop airplane-detecting radar just in time for the Battle of Britain. At the same time the Germans develop radiowave navigation techniques. Then both sides develop airborne radar, useful for attacking aircraft at night. German engineers produce the first practical jet fighter, the twin-engine ME 262, which flies at 540 miles per hour, and the 600-mph, rocket-powered Messerschmitt 163 Komet. In the United States, the Boeing Company modifies its B-17 into the high-altitude Flying Fortress. Later it makes the 141-foot-wingspan long-range B-29 Superfortress. In Britain the Instrument Landing System (ILS) for landing in bad weather is put into use in 1944.
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1939-1945	**Manhattan Project** The U.S. Army's top-secret atomic energy program, known as the Manhattan Project, employs scientists in Los Alamos, New Mexico, under the direction of physicist J. Robert Oppenheimer, to develop the first transportable atomic bomb. Other Manhattan Project teams at Hanford, Washington, and Oak Ridge, Tennessee, produce the plutonium and uranium-235 necessary for nuclear fission.

1940	**Pennsylvania Turnpike** The Pennsylvania Turnpike opens as the country's first roadway with no cross streets, no railroad crossings, and no traffic lights. Built on an abandoned railroad right of way, it includes 7 miles of tunnels through the mountains, 11 interchanges, 300 bridges and culverts, and 10 service plazas. By the mid-1950s America's first superhighway extends westward to the Ohio border, north toward Scranton, and east to Philadelphia for a total of 470 route miles.
1940	**Jeep is designed** Karl Pabst designs the Jeep, workhorse of WWII. More than 360,000 are made for the Allied armed forces. Oldsmobile introduces the first mass-produced, fully automatic transmission.
1940	**Ohl discovers that impurities in semiconductor crystals create photoelectric properties** Russell Ohl, a researcher at Bell Labs, discovers that small amounts of impurities in semiconductor crystals create photoelectric and other potentially useful properties. When he shines a light on a silicon crystal with a crack running through it, a voltmeter attached to the crystal registers a half-volt jump. The crack, it turns out, is a natural P-N junction, with impurities on one side that create an excess of negative electrons (N) and impurities on the other side that create a deficit (P). Ohl's crystal is the precursor of modern-day solar cells, which convert sunlight into electricity. It also heralds the coming of transistors.
1940	**First mass-produced, fully automatic transmission** Oldsmobile introduces the first mass-produced, fully automatic transmission.
1940s	**Microwave radar systems** MIT's Radiation Laboratory begins investigating the development of microwave radar systems, physical electronics, microwave physics, electromagnetic properties of matter, and microwave communication principles.
1940s	**Ceramic magnets** Scientists in the Netherlands develop ceramic magnets, known as ferrites, that are complex multiple oxides of iron, nickel, and other metals. Such magnets quickly become vital in all high-frequency communications, including the sound recording industry. Nickel-zinc-based ceramic magnets eventually become important as computer memory cores and in televisions and telecommunications equipment.
1940s	**Nickel-based superalloys** Metallurgists develop nickel-based superalloys that are extremely resistant to high temperatures, pressure, centrifugal force, fatigue, and oxidation. The class of nickel-based superalloys with chromium, titanium, and aluminum makes the jet engine

	possible, and is eventually used in spacecraft as well as in ground-based power generators.

1941	
1941	

1942	**Successful launch of a V-2 rocket** Ten years after his first successful rocket launch, German ballistic missile technical director Wernher von Braun achieves the successful launch of a V-2 rocket. Thousands of V-2s are deployed during World War II, but the guidance system for these missiles is imperfect and many do not reach their targets. The later capture of V-2 rocket components gives American scientists an early opportunity to develop rocket research techniques. In 1949, for example, a V-2 mated to a smaller U.S. Army WAC Corporal second-stage rocket reaches an altitude of 244 miles and is used to obtain data on both high altitudes and the principles of two-stage rockets.
1942	**First catalytic cracking unit is put on-stream** The first catalytic cracking unit is put on-stream in Baton Rouge, Louisiana, by Standard Oil, New Jersey.
1942	**First controlled, self-sustaining nuclear chain reaction** Italian-born physicist and Nobel winner Enrico Fermi and his colleagues at the University of Chicago achieve the first controlled, self-sustaining nuclear chain reaction in which neutrons released during the splitting of the atom continue splitting atoms and releasing more neutrons. Fermi's team builds a low-powered reactor, insulated with blocks of graphite, beneath the stands at the university's stadium. In case of fire, teams of students stand by, equipped with buckets of water.
1942	**Grand Coulee Dam completed** Grand Coulee Dam on the Columbia River in Washington State is completed. With 24 turbines, the dam eventually brings electricity to 11 western states and irrigation to more than 500,000 acres of farmland in the Columbia Basin.

1943	**First commercially viable mechanical spindle cotton picker** International Harvester builds "Old Red," the first commercially viable mechanical spindle cotton picker, invented and tested by Texans John and Mack Rust beginning in 1927. The spindle picker features moistened rotating spindles that grab cotton fibers from open bolls while leaving the plant intact. The cotton fibers are then blown into waiting hoppers, free of debris.
1943	**Radar storm detection** The use of radar to detect storms begins. The U.S. Weather Radar Laboratory conducts research in the 1950s on Doppler radar, the change in frequency that occurs as a moving object nears or passes (an effect discovered for sound waves in 1842 by Austrian scientist Christian Doppler).
1943	**First vacuum-tube programmable logic calculator** Colossus, the world's first vacuum-tube programmable logic calculator, is built in

	Britain for the purpose of breaking Nazi codes. On average, Colossus deciphers a coded message in two hours.

1944	**Federal Aid Highway Act** The Federal Aid Highway Act authorizes the designation of 40,000 miles of interstate highways to connect principal cities and industrial centers.

1945	**Barium titanate developed** Scientists in Ohio, Russia, and Japan all develop barium titanate, a ceramic that develops an electrical charge when mechanically stressed (and vice versa). Such ceramics advance the technologies of sound recordings, sonar, and ultrasonics.
1945	**Specifications of a stored-program computer** Two mathematicians, Briton Alan Turing and Hungarian John von Neumann, work independently on the specifications of a stored-program computer. Von Neumann writes a document describing a computer on which data and programs can be stored. Turing publishes a paper on an Automatic Computing Engine, based on the principles of speed and memory.
1945	**Magnetron discovered to melt candy, pop corn, and cook an egg** Raytheon Corporation engineer Percy L. Spencer's realization that the vacuum tube, or magnetron, he is testing can melt candy, pop corn, and cook an egg leads to the first microwave oven. Raytheon's first model, in 1947, stands 5.5 feet tall, weighs more than 750 pounds, and sells for $5,000. It is quickly superseded by the equally gigantic but slightly less expensive Radarange; easily affordable countertop models are not marketed until 1967.
1945	**First kidney dialysis machine** Willem J. Kolff successfully treats a dying patient in his native Holland with an "artificial kidney," the first kidney dialysis machine. Kolff's creation is made of wooden drums, cellophane tubing, and laundry tubs and is able to draw the woman's blood, clean it of impurities, and pump it back into her body. Kolff's invention is the product of many years' work, and this patient is his first long-term success after 15 failures. In the course of his work with the artificial kidney, Kolff notices that blue, oxygen-poor blood passing through the artificial kidney becomes red, or oxygen-rich, leading to later work on the membrane oxygenator.
1945	**Hiroshima and Nagasaki** To force the Japanese to surrender and end World War II, the United States drops atomic bombs on Hiroshima, an important army depot and port of embarkation, and Nagasaki, a coastal city where the Mitsubishi torpedoes used in the attack on Pearl Harbor were made.

1946	**First nuclear-reactor-produced radioisotopes for peacetime civilian use** The U.S. Army's Oak Ridge facility in Tennessee ships the first nuclear-reactor-produced radioisotopes for peacetime civilian use to Brainard Cancer Hospital in St. Louis.

1946	**First electronic computer put into operation** The first electronic computer put into operation is developed late in World War II by John Mauchly and John Presper Eckert at the University of Pennsylvania's Moore School of Electrical Engineering. The Electronic Numerical Integrator and Computer (ENIAC), used for ballistics computations, weighs 30 tons and includes 18,000 vacuum tubes, 6,000 switches, and 1,500 relays.
1946	**Atomic Energy Commission** The U.S. Congress passes the Atomic Energy Act to establish the Atomic Energy Commission, which replaces the Manhattan Project. The commission is charged with overseeing the use of nuclear technology in the postwar era.
1946	**Tupperware** As a chemist at DuPont in the 1930s, Earl Tupper develops a sturdy but pliable synthetic polymer he calls Poly T. By 1947 Tupper forms his own corporation and makes nesting Tupperware bowls along with companion airtight lids. Virtually breakproof, Tupperware begins replacing ceramics in kitchens nationwide.
1946	**Nuclear-reactor radioisotopes for peacetime civilian use** The U. S. Army's Oak Ridge facility in Tennessee ships the first nuclear-reactor produced radioisotopes for peacetime civilian use to Brainard Cancer Hospital in St. Louis.
1946	**Radar-equipped air traffic control** The Civil Aviation Authority unveils an experimental radar-equipped tower for control of civil flights. Air traffic controllers soon are able to track positions of aircraft on video displays for air traffic control and ground controlled approach to airports.

1947	**First commercial oil well out of sight of land** A consortium of oil companies led by Kerr-McGee drills the world's first commercial oil well out of sight of land in the Gulf of Mexico, 10.5 miles offshore and 45 miles south of Morgan City, Louisiana. Eleven oil fields are mapped in the gulf by 1949, with 44 exploratory wells in operation.
1947	**Mass-produced, low-cost window air conditioners become possible** Mass-produced, low-cost window air conditioners become possible as a result of innovations by engineer Henry Galson, who sets up production lines for a number of manufacturers. In 1947, 43,000 window air conditioners are sold in the United States. For the first time, many homeowners can enjoy air conditioning without having to buy a new home or renovate their heating system.
1947	**First top-loading automatic washer** The Nineteen Hundred Corporation introduces the first top-loading automatic washer, which Sears markets under the Kenmore label. Billed as a "suds saver," the round appliance sells for $239.95.
1947	**Sound barrier broken** U.S. Air Force pilot Captain Charles "Chuck" Yeager becomes the fastest man alive when he pilots the Bell X-1 faster than sound for the first time on October 14 over the town of Victorville, California.
1947	**Platforming invented** German-born American chemical engineer Vladimir Haensel invents platforming, a

	process for producing cleaner-burning high-octane fuels using a platinum catalyst to speed up certain chemical reactions. Platforming eliminates the need to add lead to gasoline.
1947	**North American Numbering Plan** With the rapidly growing number of telephone customers, AT&T and Bell Labs develop the North American Numbering Plan, a system that assigns telephone numbers to customers in the United States and its territories as well as Canada and many Caribbean nations. The first three digits of a typical number identify the area being called; the next three, called the prefix, locate the closest central or switching office; and the last four digits represent the line number. Bell Labs conceives the idea of reusing radio frequencies among hexagonal "cells"—the beginning of the drive toward cellular communications. Mobile phones become an even more realistic dream with the invention of the transistor, which eventually makes them possible.
1947	**First point contact transistor** John Bardeen, Walter H. Brattain, and William B. Shockley of Bell Labs discover the transistor. Brattain and Bardeen build the first pointcontact transistor, made of two gold foil contacts sitting on a germanium crystal. When electric current is applied to one contact, the germanium boosts the strength of the current flowing through the other contact. Shockley improves on the idea by building the junction transistor—"sandwiches" of N- and P-type germanium. A weak voltage applied to the middle layer modifies a current traveling across the entire "sandwich." In November 1956 the three men are awarded the Nobel Prize in physics.
1947	**Transistor is invented** The future of radio and television is forever changed when John Bardeen, Walter Brattain, and William Shockley of Bell Laboratories co-invent the transistor.
1947	**Transistor is invented** John Bardeen, Walter H. Brattain, and William B. Shockley of Bell Telephone Laboratories invent the transistor.

1948	**Plastic contact lens developed** Kevin Touhy receives a patent for a plastic contact lens designed to cover only the eye's cornea, a major change from earlier designs. Two years later George Butterfield introduces a lens that is molded to fit the cornea's contours rather than lie flat atop it. As the industry evolves, the diameter of contact lenses gradually shrinks.
1948	**A Mathematical Theory of Communication** Bell Labs's Claude Shannon publishes the landmark paper "A Mathematical Theory of Communication," which provides mathematicians and engineers with the foundation of information theory. The paper seeks to answer questions about how quickly and reliably information can be transmitted.
1948	**Plans to commercialize nuclear power** The U.S. government's Argonne National Laboratory, operated in Illinois by the University of Chicago, and the Westinghouse Corporation's Bettis Atomic Power Laboratory in Pittsburgh, announce plans to commercialize nuclear power to produce electricity for consumer use.
1948	**Center pivot irrigation machine invented**

	Colorado farmer Frank Zybach invents the center pivot irrigation machine, which revolutionizes irrigation technology. The system consists of sprinklers attached to arms that radiate from a water-filled hub out to motorized wheeled towers in the field. Zybach is awarded a patent in 1952 for the "Self- Propelled Sprinkling Irrigating Apparatus."

1949	**First concrete pavement constructed using slipforms** The first concrete pavement constructed using slipforms is built in O'Brian and Cerro Counties, Iowa.
1949	**First jet-powered commercial aircraft** The prototype De Havilland Comet makes its first flight on July 27. Three years later the Comet starts regular passenger service as the first jet-powered commercial aircraft, flying between London and South Africa.
1949	**First phone to combine a ringer and handset** AT&T introduces the Model 500 telephone, the first that combines a ringer and handset. The classic black rotary phone, featuring an adjustable volume control for the bell and later a variety of colors, becomes a cultural icon.
1949	**First stored-program compute is built** The Electronic Delay Storage Automatic Calculator (EDSAC), the first stored-program computer, is built and programmed by British mathematical engineer Maurice Wilkes.

1950s	**Cathode-ray tube (CRT) for television monitors improved** Engineers improve the rectangular cathode-ray tube (CRT) for television monitors, eliminating the need for rectangular "masks" over the round picture tubes of earlier monitors. The average price of a television set drops from $500 to $200.
1950s	**Silicones** Silicones, a family of chemically related substances whose molecules are made up of silicon-oxygen cores with carbon groups attached, become important as waterproofing sealants, lubricants, and surgical implants.
1950s	**X-ray crystallography reveal helical structure of DNA** Rosalind Franklin uses x-ray crystallography to create crystal-clear x-ray photographs that reveal the basic helical structure of the DNA molecule.
1950s	**Cruise control is developed** Ralph Teeter, a blind man, senses by ear that cars on the Pennsylvania Turnpike travel at uneven speeds, which he believes leads to accidents. Through the 1940s he develops a cruise control mechanism that a driver can set to hold the car at a steady speed. Unpopular when generally introduced in the 1950s, cruise control is now standard on more than 70 percent of today's automobiles.
1950s	**X-ray crystallography helps solve mystery** British chemists Max Perutz and Sir John Kendrew use x-ray crystallography to solve the structure of the oxygen-carrying proteins myoglobin and hemoglobin. They win the Nobel Prize in chemistry in 1962.
1950s	**B-52 bomber** Boeing makes the B-52 bomber. It has eight turbojet engines, intercontinental range,

	and a capacity of 500,000 pounds.
1950s	**Medical fluoroscopy and night vision** Russell Morgan, a professor of radiological science at Johns Hopkins University, Edward Chamberlain, a radiologist at Temple University, and John W. Coltman, a physicist and associate director of the Westinghouse Research Laboratories, perfect a method of screen intensification that reduces radiation exposure and improves fluoroscopic vision. Their image intensifier in fluoroscopy is now universally used in medical fluoroscopy and in military applications, including night vision.
1950s (Late)	**First artificial hip replacement** English surgeon John Charnley applies engineering principles to orthopedics and develops the first artificial hip replacement procedure, or arthroplasty. In 1962 he devises a low-friction, high-density polythene suitable for artificial hip joints and pioneers the use of methyl methacrylate cement for holding the metal prosthesis, or implant, to the shaft of the femur. Charnley's principles are subsequently adopted for other joint replacements, including the knee and shoulder.

1951	**Experimental Breeder Reactor 1** Experimental Breeder Reactor 1 at the Idaho National Engineering and Environmental Laboratory (INEEL) produces the world's first usable amount of electricity from nuclear energy. When neutrons released in the fission process convert uranium into plutonium, they generate, or breed, more fissile material, thus producing new fuel as well as energy. No longer in operation, the reactor is now a registered national historic landmark and is open to the public for touring.
1951	**First hard rock tunnel-boring machine built** Mining engineer James S. Robbins builds the first hard rock tunnel-boring machine (TBM). Robbins discovers that if a sharp-edged metal wheel is pressed on a rock surface with the correct amount of pressure, the rock shatters. If the wheel, or an array of wheels, continually rolls around on the rock and the pressure is constant, the machine digs deeper with each turn. The engineering industry is at first reluctant to switch from the commonly used drill-and-blast method because Robbins's machine has a $10 million price tag. Today, TBMs are used to excavate circular cross-section tunnels through a wide variety of geology, from soils to hard rock.
1951	**Direct long distance calling first available** In a test in Englewood, New Jersey, customers are able to make long-distance calls within the United States directly, without the assistance of an operator. But it takes another decade for direct long-distance dialing to be available nationwide.
1951	**First computer designed for U.S. business** Eckert and Mauchly, now with their own company (later sold to Remington Rand), design UNIVAC (UNIVersal Automatic Computer)—the first computer for U.S. business. Its breakthrough feature: magnetic tape storage to replace punched cards. First developed for the Bureau of the Census to aid in census data collection, UNIVAC passes a highly public test by correctly predicting Dwight Eisenhower's victory over Adlai Stevenson in the 1952 presidential race. But months before UNIVAC is completed, the British firm J. Lyons & Company unveils the first computer for

	business use, the LEO (Lyons Electronic Office), which eventually calculated the company's weekly payroll.
1951	**Artificial heart valve developed** Charles Hufnagel, a professor of experimental surgery at Georgetown University, develops an artificial heart valve and performs the first artificial valve implantation surgery in a human patient the following year. The valve—a methacrylate ball in a methacrylate aortic—size tube-does not replace the leaky valve but acts as an auxiliary. The first replacement valve surgeries are performed in 1960 by two surgeons who develop their ball-in-cage designs independently. In Boston, Dwight Harken develops a double-cage design in which the outer cage separates the valve struts from the aortic wall. At the University of Oregon, Albert Starr, working with electrical engineer Lowell Edwards, designs a silicone ball inside a cage made of stellite-21, an alloy of cobalt, molybdenum, chromium, and nickel. The Starr-Edwards heart valve is born and is still in use today.

1952	**First computer compiler** Grace Murray Hopper, a senior mathematician at Eckert-Mauchly Computer Corporation and a programmer for Harvard's Mark I computer, develops the first computer compiler, a program that translates computer instructions from English into machine language. She later creates Flow-Matic, the first programming language to use English words and the key influence for COBOL (Common Business Oriented Language). Attaining the rank of rear admiral in a navy career that brackets her work at Harvard and Eckert-Mauchly, Hopper eventually becomes the driving force behind many advanced automated programming technologies.
1952	**Discovery of the area rule of aircraft design** Richard Whitcomb, an engineer at Langley Memorial Aeronautical Laboratory, discovers and experimentally verifies an aircraft design concept known as the area rule. A revolutionary method of designing aircraft to reduce drag and increase speed without additional power, the area rule is incorporated into the development of almost every American supersonic aircraft. He later invents winglets, which increase the lift-to-drag ratio of transport airplanes and other vehicles.
1952	**Glass into fine-grained ceramics** Corning research chemist S. Donald Stookey discovers a heat treatment process for transforming glass objects into fine-grained ceramics. Further development of this new Pyroceram composition leads to the introduction of CorningWare in 1957.
1952	**Chesapeake Bay Bridge** The Chesapeake Bay Bridge, the world's largest continuous over-water steel structure, opens, linking Maryland's eastern and western shores of the bay. Spanning 4.35 miles, the bridge has a vertical clearance of 186 feet to accommodate shipping traffic. In 1973 another span of the bridge opens to ease increasing traffic. By the end of the century, more than 23 million cars and trucks cross the bridge each year.
1952	**First commercial device to apply Shockley's junction transistor** Sonotone markets a $229.50 hearing aid that uses two vacuum tubes and one transistor—the first commercial device to apply Shockley's junction transistor. Replacement batteries for transistorized hearing aids cost only $10, not the nearly $100

	of batteries for earlier vacuum tube models.
1952	**Walk/Don't Walk signal** The first "Walk/Don't Walk" signal is installed in New York City.
1952	**First automatic coffeepot** Russell Hobbs invents the CP1, the first automatic coffeepot as well as the first of what would become a successful line of appliances. The percolator regulates the strength of the coffee according to taste and has a green warning light and bimetallic strip that automatically cuts out when the coffee is perked.
1952	**First successful cardiac pacemaker** Paul M. Zoll of Boston's Beth Israel Hospital, in conjunction with the Electrodyne Company, develops the first successful cardiac pacemaker. The bulky device, worn externally on the patient's belt, plugs into an electric wall socket and stimulates the heart through two metal electrodes placed on the patient's bare chest. Five years later doctors begin implanting electrodes into chests. Around the same time a battery-powered external machine is developed by Earl Bakken and C. Walton Lillehei.

1953	**Seven-state power grid** The American Electric Power Company (AEP) commissions a 345,000-volt system that interconnects the grids of seven states. The system reduces the cost of transmission by sending power where and when it is needed rather than allowing all plants to work at less than full capacity.
1953	**RCA's new system for commercial color adopted** RCA beats out rival CBS when the National Television System Committee adopts RCA's new system for commercial color TV broadcasting. CBS has pioneered color telecasting, but its system is incompatible with existing black-and-white TV monitors throughout the country.
1953	**Dacron** DuPont opens a U.S. manufacturing plant to produce Dacron, a synthetic material first developed in Britain in 1941 as polyethylene terephthalate. Because it has a higher melting temperature than other synthetic fibers, Dacron revolutionizes the textiles industry.
1953	**First of a series of Boiling Reactor Experiment reactors** BORAX-I, the first of a series of Boiling Reactor Experiment reactors, is built at INEEL. The series is designed to test the theory that the formation of steam bubbles in the reactor core does not cause an instability problem. BORAX-I proves that steam formation is, in fact, a rapid, reliable, and effective mechanism for limiting power, capable of protecting a properly designed reactor against "runaway" events.
1953	**First successful open-heart bypass surgery** Philadelphia physician John H. Gibbon performs the first successful open-heart bypass surgery on 18-year-old Cecelia Bavolek, whose heart and lung functions are supported by a heart-lung machine developed by Gibbon. The device is the culmination of two decades of research and experimentation and heralds a new era in surgery and medicine. Today coronary bypass surgery is one of the most common operations performed.

1953	**High-density polyethylene** Karl Zeigler develops a method for creating a high-density polyethylene molecule that can be manufactured at low temperatures and pressures but has a very high melting point. It is made into dishes, squeezable bottles, and soft plastic materials.

1954	**"Maser" developed** Charles Townes, James Gordon, and Herbert Zeiger at Columbia University develop a "maser" (for microwave amplification by stimulated emission of radiation), in which excited molecules of ammonia gas amplify and generate radio waves. The work caps 3 years of effort since Townes's idea in 1951 to take advantage of high-frequency molecular oscillation to generate short-wavelength radio waves.
1954	**First truly consistent mass-produced transistor is demonstrated** Gordon Teal, a physical chemist formerly with Bell Labs, shows colleagues at Texas Instruments that transistors can be made from pure silicon—demonstrating the first truly consistent mass-produced transistor. By the late 1950s silicon begins to replace germanium as the semiconductor material out of which almost all modern transistors are made.
1954	**Corn head attachments for combines are introduced** The John Deere and International Harvester companies introduce corn head attachments for their combines. This attachment rapidly replaces the self-propelled corn picker, which picked the corn and stripped off its husk. The corn head attachment also shells the ears in the field. The attachment allows a farmer to use just one combine, harvesting other grain crops in the summer and corn in the fall.
1954	**Synthetic diamonds** Working at General Electric's research laboratories, scientists use a high-pressure vessel to synthesize diamonds, converting a mixture of graphite and metal powder to minuscule diamonds. The process requires a temperature of 4,800°F and a pressure of 1.5 million pounds per square inch, but the tiny diamonds are invaluable as abrasives and cutting points.
1954	**First coast-to-coast color television transmission** The New Year's Day Tournament of Roses in Pasadena, California, becomes the first coast-to-coast color television transmission, or "colorcast." The parade is broadcast by RCA's NBC network to 21 specially equipped stations and is viewed on newly designed 12-inch RCA Victor receivers set up in selected public venues. Six weeks later NBC's *Camel News Caravan* transmits in color, and the following summer the network launches its first color sitcom, *The Marriage*, starring Hume Cronyn and Jessica Tandy.
1954	**Atomic Energy Act of 1954** The U.S. Congress passes the Atomic Energy Act of 1954, amending the 1946 act to allow the Atomic Energy Commission to license private companies to use nuclear materials and also to build and operate nuclear power plants. The act is designed to promote peaceful uses of nuclear energy through private enterprise, implementing President Dwight D. Eisenhower's Atoms for Peace Program.
1954	**Synthetic zeolites** Following work done in the late 1940s by Robert Milton and Donald Breck of the

	Linde Division of Union Carbide Corporation, the company markets two new families of synthetic zeolites (from the Greek for "boiling stone," referring to the visible loss of water that occurs when zeolites are heated) as a new class of industrial materials for separation and purification of organic liquids and gases. As the key materials for "cracking"—that is, separating and reducing the large molecules in crude oil—they revolutionize the petroleum and petrochemical industries. Synthetic zeolites are also put to use in soil improvement, water purification, and radioactive waste treatment, and as a more environmentally friendly replacement in detergents for phosphates.
1954	**First human kidney transplant** A team of doctors at Boston's Peter Bent Brigham Hospital successfully performs the first human kidney transplant. Led by Joseph E. Murray, the physicians remove a healthy kidney from the donor, Ronald Herrick, and implant it in his identical twin brother, Richard, who is dying of renal disease. Since the donor and recipient are perfectly matched, the operation proves that in the absence of the body's rejection response, which is stimulated by foreign tissue, human organ transplants can succeed.
1954	**First transistor radio** Texas Instruments introduces the first transistor radio, the Regency TR1, with radios by Regency Electronics and transistors by Texas Instruments. The transistor replaces De Forest's triode, which was the electrical component that amplified audio signals—making AM (amplitude modulation) radio possible. The door is now open to the transistorization of other mass production devices.
1954	**First all-transistor radio** Regency Electronics introduces the TR-1, the first all-transistor radio. It operates on a 22-volt battery and works as soon as it is switched on, unlike tube radios, which take several minutes to warm up. The TR-1 sells for $49.95; is available in six colors, including mandarin red, cloud gray and olive green; and is no larger than a package of cigarettes.

1955	**Nuclear power plant power entire town** On July 17, Arco, Idaho, becomes the first town to have all its electrical needs generated by a nuclear power plant. Arco is 20 miles from the Atomic Energy Commission's National Reactor Testing Station, where Argonne National Laboratory operates BORAX (Boiling Reactor Experiment) III, an experimental nuclear reactor.
1955	**First nuclear-powered submarine** The USS *Nautilus SSN 571*, the world's first nuclear-powered submarine, gets under way on sea trials. The result of the efforts of 300 engineers and technicians working under the direction of Admiral Hyman Rickover, "father of the nuclear navy," it is designed and built by the Electric Boat Company of Groton, Connecticut, and outfitted with a pressurized-water reactor built by the Westinghouse Corporation's Bettis Atomic Power Laboratory. In 1958 the *Nautilus* is the first ship to voyage under the North Pole.
1955	**BORAX-III provide an entire town with electricity** In July, BORAX-III becomes the first nuclear power plant in the world to provide an entire town with all of its electricity. When power from the reactor is cut in, utility lines supplying conventional power to the town of Arco, Idaho (population 1,200), are

	disconnected. The community depends solely on nuclear power for more than an hour.
1955	**New York draws power from nuclear power plant** That same year the Niagara-Mohawk Power Corporation grid in New York draws electricity from a nuclear generation plant, and 3 years later the first large-scale nuclear power plant in the United States comes on line in Shippingport, Pennsylvania. The work of Duquesne Light Company and the Westinghouse Bettis Atomic Power Laboratory, this pressurized-water reactor supplies power to Pittsburgh and much of western Pennsylvania.
1955	**Ductile cast-iron pipe becomes the industry standard** Ductile cast-iron pipe, developed in 1948, is used in water distribution systems. It becomes the industry standard for metal due to its superior strength, durability, and reliability over cast iron. The pipe is used to transport potable water, sewage, and fuel, and is also used in fire-fighting systems.
1955	**First jack-up oil-drilling rig** The first jack-up oil-drilling rig is designed for offshore exploration. The rig features long legs that can be lowered into the seabed to a depth of 500 feet, allowing the platform to be raised to various heights above the level of the water.
1955	**First disk drive for random-access storage of data** IBM engineers led by Reynold Johnson design the first disk drive for random-access storage of data, offering more surface area for magnetization and storage than earlier drums. In later drives a protective "boundary layer" of air between the heads and the disk surface would be provided by the spinning disk itself. The Model 305 Disk Storage unit, later called the Random Access Method of Accounting and Control, is released in 1956 with a stack of fifty 24-inch aluminum disks storing 5 million bytes of data.
1955	**High molecular weight polypropylene developed** Building on the work of Karl Ziegler, Giullo Natta in Italy develops a high molecular weight polypropylene that has high tensile strength and is resistant to heat, ushering in an age of "designer" polymers. Polypropylene is put to use in films, automobile parts, carpeting, and medical tools.
1955	**Silicon dioxide discovery** Carl Frosch and Link Derick at Bell Labs discover that silicon dioxide can act as a diffusion mask. That is, when a silicon wafer is heated to about 1200°C in an atmosphere of water vapor or oxygen, a thin skin of silicon dioxide forms on the surface. With selective etching of the oxide layer, they could diffuse impurities into the silicon to create P-N junctions. Bell Labs engineer John Moll then develops the all-diffused silicon transistor, in which impurities are diffused into the wafer while the active elements are protected by the oxide layer. Silicon begins to replace germanium as the preferred semiconductor for electronics.

1956	**First transatlantic telephone cable** The first transatlantic telephone cable—the TAT-1—is installed from Scotland to Nova Scotia, providing telephone service between North America and the United Kingdom. Additional circuitry through London links Western European countries such as

	Germany, France, and the Netherlands. A joint project of the United States, Canada, and Britain, the TAT-1 takes 3 years and $42 million to plan and install, using 1,500 nautical miles of specially insulated coaxial cable. It handles up to 36 simultaneous calls and supplements existing telegraph and radiophone links. The first TAT-1 call is placed on September 25 by the U.K. postmaster to the chairman of AT&T and the Canadian Minister of Transport.
1956	**Lake Pontchartrain Causeway opens** Lake Pontchartrain Causeway opens, connecting New Orleans with its north shore suburbs. At 24 miles it is the world's longest over-water highway bridge. Made up of two parallel bridges, the causeway is supported by 95,000 hollow concrete pilings sunk into the lakebed. It was originally designed to handle 3,000 vehicles per day but now carries that many cars and trucks in an hour.
1956	**New Federal Aid Highway Act** President Dwight D. Eisenhower signs a new Federal Aid Highway Act, committing $25 billion in federal funding. Missouri is the first state to award a highway construction contract with the new funding. The act incorporates existing toll roads, bridges, and tunnels into the system and also sets uniform interstate design standards.
1956	**The Gyral air seeder is patented** The Gyral air seeder, which plants seeds through a pneumatic delivery system, is patented in Australia. The technology eventually evolves into large multirow machines with a trailing seed tank and often a second tank holding fertilizers.

1957	**FORTRAN becomes commercially available** FORTRAN (for FORmula TRANslation), a high-level programming language developed by an IBM team led by John Backus, becomes commercially available. FORTRAN is a way to express scientific and mathematical computations with a programming language similar to mathematical formulas. Backus and his team claim that the FORTRAN compiler produces machine code as efficient as any produced directly by a human programmer. Other programming languages quickly follow, including ALGOL, intended as a universal computer language, in 1958 and COBOL in 1959. ALGOL has a profound impact on future languages such as Simula (the first object-oriented programming language), Pascal, and C/C++. FORTRAN becomes the standard language for scientific computer applications, and COBOL is developed by the U.S. government to standardize its commercial application programs. Both dominate the computer-language world for the next 2 decades.
1957	**International Atomic Energy Agency** The International Atomic Energy Agency is formed with 18 member countries to promote peaceful uses of nuclear energy. Today it has 130 members. The first U.S. large-scale nuclear power plant begins operation in Shippingport, Pennsylvania. Built by the federal government but operated by the Duquesne Light Company in conjunction with the Westinghouse Bettis Atomic Power Laboratory, the pressurized-water reactor supplies power to the city of Pittsburgh and much of western Pennsylvania. In 1977 the original reactor is replaced by a more efficient light-water breeder reactor.

1957	**Sputnik I** On October 4 the Soviet Union launches *Sputnik I* using a liquid-fueled rocket built by Sergei Korolev. About the size of a basketball, the first artificial Earth satellite weighs 184 pounds and takes about 98 minutes to complete one orbit. On November 3 the Soviets launch *Sputnik II*, carrying a much heavier payload that includes a passenger, a dog named Laika.

1958	**Integrated circuit** Jack S. Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor, working independently, create the integrated circuit, a composite semiconductor block in which transistor, resistor, condenser, and other electrical components are manufactured together as one unit. Initially, the revolutionary invention is seen primarily as an advancement for radio and television, which together were then the nation's largest electronics industry.
1958	**Integrated circuit invented** Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor independently invent the integrated circuit. (see *Electronics.*)
1958	**Imaging device to detect tumors** Hal Anger invents a medical imaging device that enables physicians to detect tumors and make diagnoses by imaging gamma rays emitted by radioactive isotopes. Now the most common nuclear medicine imaging instrument worldwide, the camera uses photoelectron multiplier tubes closely packed behind a large scintillation crystal plate. The center of the scintillation is determined electronically by what is known as Anger logic.
1958	**Concept of a laser introduce** Townes and physicist Arthur Schawlow publish a paper showing that masers could be made to operate in optical and infrared regions. The paper explains the concept of a laser (light amplification by stimulated emission of radiation)—that light reflected back and forth in an energized medium generates amplified light.
1958	**United States launches its first satellite** The United States launches its first satellite, the 30.8-pound *Explorer 1*. During this mission, *Explorer 1* carries an experiment designed by James A.Van Allen, a physicist at the University of Iowa, which documents the existence of radiation zones encircling Earth within the planet's magnetic field. The Van Allen Radiation Belt, as it comes to be called, partially dictates the electrical charges in the atmosphere and the solar radiation that reaches Earth. Later that year the U.S. Congress authorizes formation of the National Aeronautics and Space Administration (NASA).
1958-1959	**Integrated circuit invented** Jack Kilby, an electrical engineer at Texas Instruments and Robert Noyce of Fairchild Semiconductor independently invent the integrated circuit. In September 1958, Kilby builds an integrated circuit that includes multiple components connected with gold wires on a tiny silicon chip, creating a "solid circuit." (On February 6, 1959, a patent is issued to TI for "miniaturized electronic circuits.") In January 1959, Noyce develops his integrated circuit using the process of planar technology, developed by a colleague, Jean Hoerni. Instead of connecting individual circuits with gold wires, Noyce uses

	vapor-deposited metal connections, a method that allows for miniaturization and mass production. Noyce files a detailed patent on July 30, 1959.

1959	**Luna 3 probe flies past the Moon** The Soviet Union's *Luna 3* probe flies past the Moon and takes the first pictures of its far side. This satellite carries an automated film developing unit and then relays the pictures back to Earth via video camera.
1959	**First large geothermal electricity-generating plant** New Zealand opens the first large geothermal electricity-generating plant driven by steam heated by nonvolcanic hot rocks. The following year electricity is produced from a geothermal source in the United States at the Geysers, near San Francisco, California.
1959	**"Float" glass developed** British glassmakers Pilkington Brothers announce a revolutionary new process of glass manufacturing developed by engineer Alastair Pilkington. Called "float" glass, it combines the distortion-free qualities of ground and polished plate glass with the less expensive production method of sheet glass. Tough and shatter-resistant, float glass is used in windows for shops and skyscrapers, windshields for automobiles and jet aircraft, submarine periscopes, and eyeglass lenses.
1959	**Ultrasound** Ian Donald, a professor working at the University of Glasgow's Department of Midwifery, and his colleagues develop practical technology and applications for ultrasound as a diagnostic tool in obstetrics and gynecology. Ultrasound displays images on a screen of tissues or organs formed by the echoes of inaudible sound waves at high frequencies (20,000 or more vibrations per second) beamed into the body. The technique is used to look for tumors, analyze bone structure, or examine the health of an unborn baby.

1960	**Operable laser invented** Theodore Maiman, a physicist and electrical engineer at Hughes Research Laboratories, invents an operable laser using a synthetic pink ruby crystal as the medium. Encased in a "flash tube" and book ended by mirrors, the laser successfully produces a pulse of light. Prior to Maiman's working model, Columbia University doctoral student Gordon Gould also designs a laser, but his patent application is initially denied. Gould finally wins patent recognition nearly 30 years later.
1960	**First totally internal pacemaker** Buffalo, New York, electrical engineer Wilson Greatbatch develops the first totally internal pacemaker using two commercial silicon transistors. Surgeon William Chardack implants the device into 10 fatally ill patients. The first lives for 18 months, another for 30 years.
1960	**Radioisotopes for research, diagnosis, and treatment of disease** Powell Richards and Walter Tucker, and many colleagues at the Bureau of Engineering Research at the U.S. Department of Energy's Brookhaven National Laboratory, invent a short halflife radionuclide generator that produces technetium-99m for use in diagnostic imaging procedures in nuclear medicine—a branch of medicine that uses

	radioisotopes for research, diagnosis, and treatment of disease. (Technetium-99m was discovered in 1939 by Emilio Segrè and Glenn Seaborg.)
1960	**Continuously operating helium-neon gas laser invented** Bell Laboratories researcher and former Townes student Ali Javan and his colleagues William Bennett, Jr., and Donald Herriott invent a continuously operating helium-neon gas laser. The continuous beam of laser light is extracted by placing parallel mirrors on both ends of an apparatus delivering an electrical current through the helium and neon gases. On December 13, Javan experiments by holding the first telephone conversation ever delivered by a laser beam.
1960	**TIROS 1 launched** Weather satellite *TIROS 1* is launched to test experimental television techniques for a worldwide meteorological satellite information system. Weighing 270 pounds, the aluminum alloy and stainless steel spacecraft is 42 inches in diameter and 19 inches high and is covered by 9,200 solar cells, which serve to charge the onboard batteries. Magnetic tape recorders, one for each of two television cameras, store photographs while the satellite is out of range of the ground station network. Although it is operational for only 78 days, *TIROS 1* proves that a satellite can be a useful tool for surveying global weather conditions from space.
1960	**Digital Equipment Corporation introduces the "compact" PDP-1** Digital Equipment Corporation introduces the "compact" PDP-1 for the science and engineering market. Not including software or peripherals, the system costs $125,000, fits in a corner of a room, and doesn't require air conditioning. Operated by one person, it features a cathode-ray tube display and a light pen. In 1962 at MIT a PDP-1 becomes the first computer to run a video game when Steve Russell programs it to play "Spacewar." The PDP-8, released 5 years later, is the first computer to fully use integrated circuits.
1960s	**Kuwait begins using seawater desalination technology** Kuwait is the first state in the Middle East to begin using seawater desalination technology, providing the dual benefits of fresh water and electric power. Kuwait produces fresh water from seawater with the technology known as multistage flash (MSF) evaporation. The MSF process begins with heating saltwater, which occurs as a byproduct of producing steam for generating electricity, and ends with condensing potable water. Between the heater and condenser stages are multiple evaporator-heat exchanger subunits, with heat supplied from the power plant external heat source. During repeated distillation cycles cold seawater is used as a heat sink in the condenser.
1960s	**Optical lithography** Semiconductor manufacturing begins using optical lithography, an innovative technology using a highly specialized printing process that places intricate patterns onto silicon chips, or wafers. In the first stage an image containing the defining pattern is projected onto the silicon wafer, which is coated with a very thin layer of photosensitive material called "resist." The process is still used to manufacture integrated circuits and could continue to be used through the 100-nanometer generation of devices.
1960s	**Large single crystals of silicon grown** Engineers begin to grow large single crystals of silicon with nearly perfect purity and perfection. The crystals are then sliced into thin wafers, etched, and doped to become

	semiconductors, the basis for the electronics industry. Borosilicate glass is developed for encapsulating radioactive waste. Better but more expensive trapping materials are made from crystalline ceramic materials zirconolite and perovskite and from the most widespread material of all for containing radioactivity—carefully designed cements.
1960s	**Reflective paint for highway markings developed** Paint chemist and professor Elbert Dysart Botts develops a reflective paint for marking highway lanes. When rainwater obscures the paint's reflective quality, Botts develops a raised marker that protrudes above water level. Widely known as Botts' Dots, the raised markers were first installed in Solano County, California, along a section of I-80. They have the added benefit of making a drumming sound when driven over, warning drivers who veer from their lanes.
1960s	**Synthetic oils** Synthetic oils are in development to meet the special lubricating requirements of military jets. Mobil Oil and AMSOIL are leaders in this field; their synthetics contain such additives as polyalphaolefins, derived from olefin, one of the three primary petrochemical groups. Saturated with hydrogen, olefin-carbon molecules provide excellent thermal stability. Following on the success of synthetic oils in military applications, they are introduced into the commercial market in the 1970s for use in automobiles.
1960s	**Efforts begin to reduce harmful emissions** Automakers begin efforts to reduce harmful emissions, starting with the introduction of positive crankcase ventilation in 1963. PCV valves route gases back to the cylinders for further combustion. With the introduction of catalytic converters in the 1970s, hydrocarbon emissions are reduced 95 percent by the end of the century compared to emissions in 1967.
1960s and 1970s	**Space-based imaging begins** Space-based imaging gets under way throughout the 1960s as Earth-observing satellites begin to trace the planet's topography. In 1968 astronauts on *Apollo 7*, the first piloted Apollo mission, conduct two scientific photographic sessions and transmit television pictures to the American public from inside the space capsule. In 1973 astronauts aboard *Skylab*, the first U.S. space station, conduct high-resolution photography of Earth using photographic remote-sensing systems mounted on the spacecraft as well as a Hasselblad handheld camera. Landsat satellites launched by NASA between 1972 and 1978 produce the first composite multispectral mosaic images of the 48 contiguous states. Landsat imagery provides information for monitoring agricultural productivity, water resources, urban growth, deforestation, and natural change.

1961	**Alan B. Shepard, Jr. becomes the second human in space** On May 5 astronaut Alan B. Shepard, Jr., in *Freedom 7*, becomes the second human in space. Launched from Cape Canaveral by a Mercury-Redstone rocket, *Freedom 7*—the first piloted Mercury spacecraft—reaches an altitude of 115 nautical miles and a speed of 5,100 miles per hour before splashing down in the Atlantic Ocean. During his 15-minute suborbital flight, Shepard demonstrates that individuals can control a vehicle

	during weightlessness and high G stresses, supplying researchers on the ground with significant biomedical data.
1961	**France and England connect electrical grids** France and England connect their electrical grids with a cable submerged in the English Channel. It carries up to 160 megawatts of DC current, allowing the two countries to share power or support each other's system.
1961	**First medical use of the ruby laser** In the first medical use of the ruby laser, Charles Campbell of the Institute of Ophthalmology at Columbia- Presbyterian Medical Center and Charles Koester of the American Optical Corporation use a prototype ruby laser photocoagulator to destroy a human patient's retinal tumor.
1961	**Yuri Gagarin becomes the first human in space** On April 12, cosmonaut Yuri Gagarin, in *Vostok I*, becomes the first human in space. Launching from Baikonur Cosmodrome, he completes one orbit of Earth in a cabin that contains radios, instrumentation, life-support equipment, and an ejection seat. Three small portholes give him a view of space. At the end of his 108-minute ride, during which all flight controls are operated by ground crews, he parachutes to safety in Kazakhstan.
1961	**Glass fiber demonstration** Industry researchers Elias Snitzer and Will Hicks demonstrate a laser beam directed through a thin glass fiber. The fiber's core is small enough that the light follows a single path, but most scientists still consider fibers unsuitable for communications because of the high loss of light across long distances.

1962	**MOSFET is invented** The metal oxide semiconductor field effect transistor (MOSFET) is invented by engineers Steven Hofstein and Frederic Heiman at RCA's research laboratory in Princeton, New Jersey. Although slower than a bipolar junction transistor, a MOSFET is smaller and cheaper and uses less power, allowing greater numbers of transistors to be crammed together before a heat problem arises. Most microprocessors are made up of MOSFETs, which are also widely used in switching applications.
1962	**First PET transverse section instrument** Sy Rankowitz and James Robertson, working at Brookhaven National Laboratory, invent the first positron emission tomography (PET) transverse section instrument, using a ring of scintillation crystals surrounding the head. (The first application of positron imaging for medical diagnosis occurred in 1953, when Gordon Brownell and William Sweet at Massachusetts General Hospital imaged patients with suspected brain tumors.) The following year David Kuhl introduces radionuclide emission tomography leading to the first computerized axial tomography, as well as to refinements in PET scanning, which is used most often to detect cancer and to examine the effects of cancer therapy. A decade later single-photon emission tomography (SPECT) methods become capable of yielding accurate information similar to PET by incorporating mathematical algorithms by Thomas Budinger and Grant Gullberg of the University of California at Berkeley.
1962	**Nickel-titanium (Ni-Ti) alloy shape memory**

	Researchers at the Naval Ordnance Laboratory in White Oak, Maryland, discover that a nickel-titanium (Ni-Ti) alloy has so-called shape memory properties, meaning that the metal can undergo deformation yet "remember" its original shape, often exerting considerable force in the process. Although the shape memory effect was first observed in other materials in the 1930s, research now begins in earnest into the metallurgy and practical uses of these materials. Today a number of products using Ni-Ti alloys are on the market, including eyeglass frames that can be bent without sustaining permanent damage, guide wires for steering catheters into blood vessels in the body, and arch wires for orthodontic correction.
1962	**Spray mist added to iron** Sunbeam ushers in a new era in iron technology by adding "spray mist" to the steam and dry functions of its S-5A model. The S-5A is itself an upgrade of the popular S-4 steam or dry iron that debuted in 1954.
1962	**ARPA Information Processing Techniques Office** J. C. R. Licklider becomes the first director of the Information Processing Techniques Office established by the Advanced Research Projects Agency (ARPA, later known as DARPA) of the U.S. Department of Defense (DOD). Licklider articulates the vision of a "galactic" computer network—a globally interconnected set of processing nodes through which anyone anywhere can access data and programs.
1962	**First commercial digital transmission system** Illinois Bell turns on the first commercial digital transmission system, known as the T1 (Transmission One), which eventually replaces analog lines. The multiplexed system carrying voice signals has a total capacity of 1.5 million bits (or binary digits) per second and is less susceptible to electrical interference from high-tension wires. The T1 quickly becomes the main transmission system for long-distance telephone service and, eventually, local calls. Bell Systems demonstrates the first paging system at the Seattle World's Fair. Called Bellboy, the personal pager is one of the first consumer applications for the transistor. An audible signal alerts customers, who then call their offices or homes from a regular phone to retrieve their messages.
1962	**Telstar 1** Communications satellite *Telstar 1* is launched by a NASA Delta rocket on July 10, transmitting the first live transatlantic telecast as well as telephone and data signals. At a cost of $6 million provided by AT&T, Bell Telephone Laboratories designs and builds *Telstar*, a faceted sphere 34 inches in diameter and weighing 171 pounds. The first international television broadcasts shows images of the American flag flying over Andover, Maine to the sound of "The Star-Spangled Banner." Later that day AT&T chairman Fred Kappel makes the first long-distance telephone call via satellite to Vice President Lyndon Johnson. *Telstar I* remains in orbit for seven months, relaying live baseball games, images from the Seattle World's Fair, and a presidential news conference.
1962	**John Glenn is the first American to circle Earth** John Glenn becomes the first American to circle Earth, making three orbits in his *Friendship 7* Mercury spacecraft. Glenn flies parts of the last two orbits manually because of an autopilot failure and during reentry leaves the normally jettisoned retro-rocket pack attached to his capsule because of a loose heat shield. Nonetheless, the flight is enormously successful. The public, more than celebrating the technological

	success, embraces Glenn as the personification of heroism and dignity.
1962	**First advanced gas-cooled reactor** The first advanced gas-cooled reactor is built at Calder Hall in England. Intended originally to power a naval vessel, the reactor is too big to be installed aboard ship and is instead successfully used to supply electricity to British consumers. A smaller pressurized-water reactor, supplied by the United States, is then installed on Britain's first nuclear-powered submarine, the HMS *Dreadnaught*.
1962	**Pavement standards** The AASHO (American Association of State Highway Officials) road test near Ottawa, Illinois, which subjects sections of pavements to carefully monitored traffic loads, establishes pavement standards for use on the interstate system and other highways.
1962	**Kleinrock thesis describes underlying principles of packet-switching technology** Leonard Kleinrock, a doctoral student at MIT, writes a thesis describing queuing networks and the underlying principles of what later becomes known as packet-switching technology.
1962	**Telstar 1 transmits the first live transatlantic telecast** Communications satellite Telstar 1 is launched by a NASA Delta rocket on July 10, transmitting the first live transatlantic telecast as well as telephone and data signals. At a cost of $6 million provided by AT&T, Bell Telephone Laboratories designs and builds Telstar, a faceted sphere 34 inches in diameter and weighing 171 pounds. The first international television broadcast shows images of the American flag flying over Andover, Maine, to the sound of ‘‘The Star-Spangled Banner." Later that day AT&T chairman Fred Kappel makes the first long-distance telephone call via satellite to Vice President Lyndon Johnson. Telstar 1 remains in orbit for seven months, relaying live baseball games, images from the Seattle World's Fair, and a presidential news conference.
1962	**Gallium arsenide laser developed** Three groups—at General Electric, IBM, and MIT's Lincoln Laboratory—simultaneously develop a gallium arsenide laser that converts electrical energy directly into infrared light and that much later is used in CD and DVD players as well as computer laser printers.

1963	**Self-cleaning electric oven** General Electric introduces the self-cleaning electric oven and in 1967 the first electronic oven control-beginning the revolution that would see microprocessors incorporated into household appliances of all sorts.
1963	**First small jet aircraft to enter mass production** The prototype Learjet 23 makes its first flight on October 7. Powered by two GE CJ610 turbojet engines, it is 43 feet long, with a wingspan of 35.5 feet, and can carry seven passengers (including two pilots) in a fully pressurized cabin. It becomes the first small jet aircraft to enter mass production, with more than 100 sold by the end of 1965.
1963	**Syncom communications satellites launched** On February 14 NASA launches the first of a series of Syncom communications satellites into near-geosynchronous orbit, following procedures developed by Harold Rosen of Hughes Aircraft. In July, *Syncom 2* is placed over the Atlantic Ocean and

	Brazil at 55 degrees longitude to demonstrate the feasibility of geosynchronous satellite communications. It successfully transmits voice, teletype, facsimile, and data between a ground station in Lakehurst, New Jersey, and the USNS *Kingsport* while the ship is off the coast of Africa. It also relays television transmissions from Lakehurst to a ground station in Andover, Maine. Forerunners of the Intelsat series of satellites, the Syncom satellites are cylinders covered with silicon solar cells that provide 29 watts of direct power when the craft is in sunlight (99 percent of the time). Nickel-cadmium rechargeable batteries provide power when the spacecraft is in Earth's shadow.
1963	**GE introduces the self-cleaning oven** General Electric introduces the self-cleaning electric oven and in 1967 the first electronic oven control—beginning the revolution that would see microprocessors incorporated into household appliances of all sorts.
1963	**Laser treatments to prevent blindness** Francis L'Esperance, of the Columbia-Presbyterian Medical Center, begins working with a ruby laser photo-coagulator to treat diabetic retinopathy, a complication of diabetes and a leading cause of blindness in the United States. In 1965 he begins working with Bell researchers Eugene Gordon and Edward Labuda to design an argon laser for eye surgery. (They learn that the blue-green light of the argon laser is more readily absorbed by blood vessels than the red light of the ruby laser.) In early 1968, after further refinements and careful experiments, L'Esperance begins using the argon-ion laser to treat patients with diabetic retinopathy.
1963	**Heterostructures** Physicist Herbert Kroemer proposes the idea of heterostructures, combinations of more than one semiconductor built in layers that reduce energy requirements for lasers and help them work more efficiently. These heterostructures will later be used in cell phones and other electronic devices.
1963	**Touch-tone telephone is introduced** The touch-tone telephone is introduced, with the first commercial service available in Carnegie and Greensburg, Pennsylvania, for an extra charge. The Western Electric 1500 model features 10 push buttons that replace the standard rotary dial. A 12-button model featuring the * and # keys comes out soon afterward and replaces the 10-button model.

1964	**Chesapeake Bay Bridge- Tunnel opens** The Chesapeake Bay Bridge-Tunnel opens, connecting Virginia Beach and Norfolk to Virginia's Eastern Shore. Its bridges and tunnels stretch 17.6 miles shore to shore and feature a pair of mile-long tunnels that run beneath the surface to allow passage above of commercial and military ships. In 1965 the bridge-tunnel is named one of the "Seven Engineering Wonders of the Modern World" in a competition that includes 100 major projects.
1964	**On Distributed Communications Networks** The RAND Corporation publishes a report, principally authored by Paul Baran, for the Pentagon called On Distributed Communications Networks. It describes a distributed radio communications network that could survive a nuclear first strike, in part by dividing messages into segments that would travel independently.

1964	**Carbon fiber developed** British engineer Leslie Phillips makes carbon fiber by stretching synthetic fibers and then heating them to blackness. The result is fibers that are twice as strong as the same weight of steel. Carbon fibers find their way into bulletproof vests, high performance aircraft, automobile tires, and sports equipment.
1964	**BASIC** Dartmouth professors John Kemeny and Thomas Kurtz develop the BASIC (Beginners All-Purpose Symbolic Instruction Code) programming language specifically for the school's new timesharing computer system. Designed for non-computer-science students, it is easier to use than FORTRAN. Other schools and universities adopt it, and computer manufacturers begin to provide BASIC translators with their systems.
1964	**First large-scale magneto-hydrodynamics plant** The Soviet Union completes the first large-scale magnetohydrodynamics plant. Based on pioneering efforts in Britain, the plant produces electricity by shooting hot gases through a strong magnetic field.
1964	**Acrylic paints** Chemists develop acrylic paints, which dry more quickly than previous paints and drip and blister less. They are used for fabric finishes in industry and on automobiles.

1965	**Edward H. White, Jr. is the first American to perform a spacewalk** The second piloted Gemini mission, *Gemini IV*, stays aloft for four days, (June 3-7), and astronaut Edward H. White, Jr. performs the first extravehicular activity (EVA)—or spacewalk—by an American. This critical task will have to be mastered before a landing on the Moon.
1965	**Automatic adaptive equalizer invented by Robert Lucky** The automatic adaptive equalizer is invented in 1965 at Bell Laboratories by electrical engineer Robert Lucky. Automatic equalizers correct distorted signals, greatly improving data performance and speed. All modems still use equalizers.
1965	**First electronic central office switching system** The first electronic central office switching system, the 1 ESS, is installed in Succasunna, New Jersey, after years of research and planning and at a cost of $500 million. Switching systems switch telephone traffic through local central offices that also house transmission equipment and other support systems. The 1 ESS has the capacity to store programs and allows such features as call forwarding and speed dialing. The 4 ESS, developed by Western Electric in 1976, is the first digital switch and will remain the workhorse system for several decades before increases in the transmission of data, as well as voice signals, spur new advances.

1966	**Advanced Testing Reactor** The Advanced Testing Reactor at the Idaho National Engineering and Environmental Laboratory begins operation for materials testing and isotope generation.
1966	**Electronic monitoring devices allow farmers to plant crops more efficiently** The DICKEY-john Manufacturing Company introduces electronic monitoring devices for farmers that allow them to plant crops more efficiently. Attached to mechanical

	planters and air seeders, the devices monitor the number and spacing of seeds being planted. The newest devices monitor the planting of up to 96 rows at a time. During the 1990s, similar devices are used at harvest time for yield mapping, or measuring and displaying the quality and quantity of a harvest as the combine moves through the field.
1966	**Highway Safety Act** The Highway Safety Act establishes the National Highway Program Safety Standards to reduce traffic accidents.
1966	**Self-aligned gate process for fabricating field effect transistors** In 1966 Dr. Robert W. Bower invents the self-aligned gate process for fabricating field effect transistors, providing the foundation for later developments establishing the core technology for the fabrication of high performance MOS integrated circuits.
1966	**ARPANET project** Larry Roberts of MIT's Lincoln Lab is hired to manage the ARPANET project. He works with the research community to develop specifications for the ARPA computer network, a packet-switched network with minicomputers acting as gateways for each node using a standard interface.
1966	**Electronic fuel injection system developed** An electronic fuel injection system is developed in Britain. Fuel injection delivers carefully controlled fuel and air to the cylinders to keep a car's engine running at its most efficient.
1966	**Landmark paper on optical fiber** Charles Kao and George Hockham of Standard Telecommunications Laboratories in England publish a landmark paper demonstrating that optical fiber can transmit laser signals with much reduced loss if the glass strands are pure enough. Researchers immediately focus on ways to purify glass.

1967	**Packet switching** Donald Davies, of the National Physical Laboratory in Middlesex, England, coins the term *packet switching* to describe the lab's experimental data transmission.
1967	**First handheld calculator invented** A Texas Instruments team, led by Jack Kilby, invents the first handheld calculator in order to showcase the integrated circuit. Housed in a case made from a solid piece of aluminum, the battery-powered device fits in the palm of a hand and weighs 45 ounces. It accepts six-digit numbers and performs addition, subtraction, multiplication, and division, printing results up to 12 digits on a thermal printer.
1967	**750,000 volt transmission line developed** The highest voltage transmission line to date (750,000 volts) is developed by AEP. The same year the Soviet Union completes the Krasnoyansk Dam power station in Siberia, which generates three times more electric power than the Grand Coulee Dam.

1968	**Bell Labs team develops molecular beam epitaxy** Alfred Y. Cho heads a Bell Labs team that develops molecular beam epitaxy, a process that deposits single-crystal structures one atomic layer at a time, creating materials that cannot be duplicated by any other known technique. This ultra-precise method of

	growing crystals is now used worldwide for making semiconductor lasers used in compact disc players. (The term epitaxy is derived from the Greek words *epi*, meaning "on" and *taxis*, meaning "arrangement.")
1968	**Interface message processors** Bolt Beranek and Newman, Inc. (BBN) wins a DARPA contract to develop the packet switches called interface message processors (IMPs).
1968	**Apollo 8 flight to the Moon views Earth from lunar orbit.** Humans first escape Earth's gravity on the *Apollo 8* flight to the Moon and view Earth from lunar orbit. *Apollo 8* takes off from the Kennedy Space Center on December 21 with three astronauts aboard—Frank Borman, James A. Lovell, Jr., and William A. Anders. As their ship travels outward, the crew focuses a portable television camera on Earth and for the first time humanity sees its home from afar, a tiny "blue marble" hanging in the blackness of space. When they arrive at the Moon on Christmas Eve, the crew sends back more images of the planet along with Christmas greetings to humanity. The next day they fire the boosters for a return flight and splash down in the Pacific Ocean on December 27.
1968	**Computer mouse makes its public debut** The computer mouse makes its public debut during a demonstration at a computer conference in San Francisco. Its inventor, Douglas Engelbart of the Stanford Research Institute, also demonstrates other user-friendly technologies such as hypermedia with object linking and addressing. Engelbart receives a patent for the mouse 2 years later.
1968	**First 911 call is made** On February 16 the first 911 call is made in Haleyville, Alabama. Legislation calling for a single nationwide phone number for citizens to use to report fires and medical emergencies was passed by Congress in 1967, and in January 1968 AT&T announced plans to put such a system into place. An independent company, Alabama Telephone, scrambled to build its own system and succeeded in beating AT&T to the punch. The numbers 911 were chosen because they were easy to remember and did not include three digits already in use in a U.S. or Canadian area code. In Britain a national emergency number—999—had been in place since the late 1930s.
1968	**200 million television sets** There are 200 million television sets in operation worldwide, up from 100 million in 1960. By 1979 the number reaches 300 million and by 1996 over a billion. In the United States the number grows from 1 million in 1948 to 78 million in 1968. In 1950 only 9 percent of American homes have a TV set; in 1962, 90 percent; and in 1978, 98 percent, with 78 percent owning a color TV.

1969	**Boeing 747** Boeing conducts the first flight of a wide-body, turbofan-powered commercial airliner, the 747, one of the most successful aircraft ever produced.
1969	**Dynamic random access memory** In 1969 Dr. Robert H. Dennard invents the 1-transistor dynamic random access memory (DRAM), providing a large increase in memory density and speed. Dennard's design remains today as the critical memory component in all computers.
1969	**DARPA deploys the IMPs**

	DARPA deploys the IMPs. Kleinrock, at the Network Measurement Center at the University of California at Los Angeles, receives the first IMP in September. BBN tests the "one-node" network. A month later the second IMP arrives at Stanford, where Doug Englebart manages the Network Information Center, providing storage for ARPANET documentation. Dave Evans and Ivan Sutherland, professors researching computer systems and graphics at the University of Utah, receive the third IMP, and the fourth goes to the University of California at Santa Barbara, where Glen Culler is conducting research on interactive computer graphics.
1969	**More than half of new automobiles are equipped with air conditioning** More than half of new automobiles (54 percent) are equipped with air conditioning, which is soon a necessity, not only for comfort but also for resale value. By now, most new homes are built with central air conditioning, and window air conditioners are increasingly affordable.
1969	**Zero Power Physics Reactor** The Zero Power Physics Reactor (ZPPR), a specially designed facility for building and testing a variety of types of reactors, goes operational at Argonne National Laboratory-West in Idaho. Equipped with a large inventory of materials from which any reactor could be assembled in a few weeks, ZPPR operates at very low power, so the materials do not become highly radioactive and can be reused many times. Nuclear reactors can be built and tested in ZPPR for about 0.1% of the capital cost of construction of the whole power plant.
1969	**Neil Armstrong becomes the first person to walk on the Moon** Neil Armstrong becomes the first person to walk on the Moon. The first lunar landing mission, *Apollo 11* lifts off on July 16 to begin the 3-day trip. At 4:18 p.m. EST on July 20, the lunar module—with astronauts Neil Armstrong and Edwin E. (Buzz) Aldrin—lands on the Moon’s surface while Michael Collins orbits overhead in the command module. After more than 21 hours on the lunar surface, they return to the command module with 20.87 kilograms of lunar samples, leaving behind scientific instruments, an American flag, and other mementos, including a plaque bearing the inscription: "Here Men From Planet Earth First Set Foot Upon the Moon. July 1969 A.D. We came in Peace For All Mankind."

1970	**Initial ARPANET host-to-host protocol** In December the Network Working Group (NWG), formed at UCLA by Steve Crocker, deploys the initial ARPANET host-to-host protocol, called the Network Control Protocol (NCP). The primary function of the NCP is to establish connections, break connections, switch connections, and control flow over the ARPANET, which grows at the rate of one new node per month.
1970	**The first CD-ROM patented** James T. Russell, working at Battelle Memorial Institute’s Pacific Northwest Laboratories in Richland, Washington, patents the first systems capable of digital-to-optical recording and playback. The CD-ROM (compact disc read-only memory) is years ahead of its time, but in the mid-1980s audio companies purchase licenses to the technology. (See computers.) Russell goes on to earn dozens of patents for CD-ROM

	technology and other optical storage systems.
1970	**Optical fibers that meet purity standards** Corning Glass Works scientists Donald Keck, Peter Schultz, and Robert Maurer report the creation of optical fibers that meet the standards set by Kao and Hockham. The purest glass ever made, it is composed of fused silica from the vapor phase and exhibits light loss of less than 20 decibels per kilometer (1 percent of the light remains after traveling 1 kilometer). By 1972 the team creates glass with a loss of 4 decibels per kilometer. Also in 1970, Morton Panish and Izuo Hayashi of Bell Laboratories, along with a group at the Ioffe Physical Institute in Leningrad, demonstrate a semiconductor laser that operates continuously at room temperature. Both breakthroughs will pave the way toward commercialization of fiber optics.
1970	**Palo Alto Research Center (PARC)** Xerox Corporation assembles a team of researchers in information and physical sciences in Palo Alto, California, with the goal of creating "the architecture of information." Over the next 30 years innovations emerging from the Palo Alto Research Center (PARC) include the concept of windows (1972), the first real personal computer (Alto in 1973), laser printers (1973), the concept of WYSIWYG (what you see is what you get) word processors (1974), and EtherNet (1974). In 2002 Xerox PARC incorporates as an independent company—Palo Alto Research Center, Inc.
1970	**UNIX operating system** At Bell Labs, Dennis Ritchie and Kenneth Thompson complete the UNIX operating system, which gains a wide following among scientists.
1970s	**Digital seismology** The introduction of digital seismology in oil exploration increases accuracy in locating underground pools of oil. The technique of using seismic waves to look for oil is based on determining the time interval between the sending of a sound wave (generated by an explosion, an electric vibrator, or a falling weight) and the arrival of reflected or refracted waves at one or more seismic detectors. Analysis of differences in arrival times and amplitudes of the waves tells seismologists what kinds of rock the waves have traveled through.
1970s	**Airbags become standard** Airbags, introduced in some models in the 1970s, become standard in more cars. Originally installed only on the driver's side, they begin to appear on the front passenger side as well.
1970s	**Mud pulse telemetry** Teleco, Inc., of Greenville, South Carolina, and the U.S. Department of Energy introduce mud pulse telemetry, a system of relaying pressure pulses through drilling mud to convey the location of the drill bit. Mud pulse telemetry is now an oil industry standard, saving millions of dollars in time and labor.
1970s	**Aswan High Dam** The Aswan High Dam construction is completed, about 5 kilometers upstream from the original Aswan Dam (1902). Known as Saad el Aali in Arabic, it impounds the waters of the Nile to form Lake Nasser, the world's third-largest reservoir, with a capacity of 5.97 trillion cubic feet. The project requires the relocation of thousands of people and floods some of Egypt's monuments and temples, which are later raised. But the new dam controls annual floods along the Nile, supplies water for municipalities and

	irrigation, and provides Egypt with more than 10 billion kilowatt-hours of electric power every year.
1970s	**Amorphous metal alloys created** Amorphous metal alloys are made by cooling molten metal alloys extremely rapidly (more than a million degrees a second), producing a glassy solid with distinctive magnetic and mechanical properties. Such alloys are put to use in signal and power transformers and as sensors.
1970s	**Fuel prices escalate, driving demand for fuel-efficient cars** Fuel prices escalate, driving a demand for fuel-efficient cars, which increases the sale of small Japanese cars. This helps elevate the Japanese automobile industry to one of the greatest in the world.
1970s (Late)	**Arthroscope introduced** Advances in fiber-optics technology give surgeons a view into joints and other surgical sites through an arthroscope, an instrument the diameter of a pencil, containing a small lens and light system, with a video camera at the outer end. Used initially as a diagnostic tool prior to open surgery, arthroscopic surgery, with its minimal incisions and generally shorter recovery time, is soon widely used to treat a variety of joint problems.

1971	**First soft contact lens** Bausch & Lomb licenses Softlens, the first soft contact lens. The new product is the result of years of research by Czech scientists Otto Wichterle and Drahoslav Lim and is based on their earlier invention of a "hydrophilic" gel, a polymer material that is compatible with living tissue and therefore suitable for eye implants. Soft contacts allow more oxygen to reach the eye's cornea than do hard plastic lenses.
1971	**Intel introduces "computer on a chip"** Intel, founded in 1968 by Robert Noyce and Gordon Moore, introduces a "Computer on a chip," the 4004 four-bit microprocessor, design by Frederico Faggin, Ted Hoff, and Stan Mazor. It can execute 60,000 operations per second and changes the face of modern electronics by making it possible to include data processing hundreds of devices. A 4004 provides the computing power for NASA's Pioneer 10 spacecraft, launched the following year to survey Jupiter. 3M Corporation introduces the ceramic chip carrier, designed to protect integrated circuits when they are attached or removed from circuit boards. The chip is bonded to a gold base inside a cavity in the square ceramic carrier, and the package is then hermetically sealed.
1971	**First space station, Salyut 1** The Soviet Union launches the world's first space station, *Salyut 1*, in 1971. Two years later the United States sends its first space station, *Skylab*, into orbit, where it hosts three crews before being abandoned in 1974. Russia continues to focus on long-duration space missions, launching the first modules of the *Mir* space station in 1986.

1972	**First percolator with an automatic drip process**

	Sunbeam develops the Mr. Coffee, the first percolator with an automatic drip process as well as an automatic cut-off control that lessens the danger of over-brewing. Mr. Coffee quickly becomes the country's leading coffeemaker.
1972	**First public demonstration of the new network technology** Robert Kahn at BBN, who is responsible for the ARPANET's system design, organizes the first public demonstration of the new network technology at the International Conference on Computer Communications in Washington, D.C., linking 40 machines and a Terminal Interface Processor to the ARPANET.
1972	**Home video game systems become available** In September, Magnavox ships Odyssey 100 home game systems to distributors. The system is test marketed in 25 cities, and 9,000 units are sold in Southern California Alone during the first month at a price of $99.95. In November, Nolan Bushnell forms Atari and ships Pong, a coin-operated video arcade game, designed and built by Al Alcorn. The following year Atari introduces its home version of the game, which soon outstrips Odyssey 100.
1972	**Pioneer 10 sent to the outer solar system** *Pioneer 10*, the first mission to be sent to the outer solar system, is launched on March 2 by an Atlas-Centaur rocket. The spacecraft makes its closest approach to Jupiter on December 3, 1973, after which it is on an escape trajectory from the Solar System. NASA launches *Pioneer 11* on April 5, 1973, and in December 1974 the spacecraft gives scientists their closest view of Jupiter, from 26,600 miles above the cloud tops. Five years later *Pioneer 11* makes its closest approach to Saturn, sending back images of the planet's rings, and then heads out of the solar system in the opposite direction from *Pioneer 10*. The last successful data acquisitions from *Pioneer 10* occur on March 3, 2002, the 30th anniversary of its launch date, and on April 27, 2002. Its signal is last detected on January 23, 2003, after an uplink is transmitted to turn off the last operational experiment.
1972	**First e-mail program** Ray Tomlinson at BBN writes the first e-mail program to send messages across the ARPANET. In sending the first message to himself to test it out, he uses the @ sign—the first time it appears in an e-mail address.
1972	**CAT or CT scan is introduced** Computerized axial tomography, popularly known as CAT or CT scan, is introduced as the most important development in medical filming since the X ray some 75 years earlier. (See Imaging)
1972	**MRI adapted for medical purposes** Using high-speed computers, magnetic resonance imaging (MRI) is adapted for medical purposes, offering better discrimination of soft tissue than x-ray CAT and is now widely used for noninvasive imaging throughout the body. Among the pioneers in the development of MRI are Felix Bloch and Edward Purcell (Nobel Prize winners in 1952), Paul Lauterbur, and Raymond Damadian.
1972	**CAT scan** Engineer Godfrey Hounsfield of Britain's EMI Laboratories and South African–born American physicist Allan Cormack of Tufts University develop the computerized axial tomography scanner, or CAT scan. With the help of a computer, the device combines

	many x-ray images to generate cross-sectional views as well as three-dimensional images of internal organs and structures. Used to guide the placement of instruments or treatments, CAT eventually becomes the primary tool for diagnosing brain and spinal disorders. (In 1979, Hounsfield and Cormack are awarded the Nobel Prize in physiology or medicine.)

1973	**Paper describes basic design of the Internet and TCP** In September, Kahn and Vinton Cerf, an electrical engineer and head of the International Network Working Group, present a paper at the University of Sussex in England describing the basic design of the Internet and an open-architecture network, later known as TCP (transmission control protocol), that will allow networks to communicate with each other. The paper is published as "A Protocol for Packet Network Interconnection" in *IEEE Transactions on Communications*.
1973	**Chemical vapor deposition process** John MacChesney and Paul O'Connor at Bell Laboratories develop a modified chemical vapor deposition process that heats chemical vapors and oxygen to form ultratransparent glass that can be mass-produced into low-loss optical fiber. The process still remains the standard for fiber-optic cable manufacturing.
1973	**Interstate 70 opens west of Denver** Interstate 70 in Colorado opens from Denver westward. It features the 1.75-mile Eisenhower Memorial Tunnel, the longest tunnel in the interstate program.
1973	**First portable cell phone call is made** The first portable cell phone call is made by Martin Cooper of Motorola to his research rival at Bell Labs, Joel Engel. Although mobile phones had been used in cars since the mid-1940s, Cooper's was the first one invented for truly portable use. He and his team are awarded a patent in 1975.

1974	**Energy Reorganization Act of 1974** The Energy Reorganization Act of 1974 splits the Atomic Energy Commission into the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). ERDA's responsibilities include overseeing the development and refinement of nuclear power, while the NRC takes up the issue of safe handling of nuclear materials.
1974	**Texas Instruments introduces the TMS 1000** Texas Instruments introduces the TMS 1000, destined to become the most widely used computer on a chip. Over the next quarter-century, more than 35 different versions of the chip are produced for use in toys and games, calculators, photcopying machines, appliances, burglar alarms, and jukeboxes. (Although TI engineers Michael Cochran and Gary Boone create the first microcomputer, a four-bit microprocessor, at about the same time Intel does in 1971, TI does not put its chip on the market immediately, using it in a calculator introduced in 1972.)

1975	**First commercial semiconductor laser**

	Engineers at Laser Diode Labs develop the first commercial semiconductor laser to operate continuously at room temperatures. The continuous-wave operation allows the transmission of telephone conversations. Standard Telephones and Cables in the United Kingdom installs the first fiber-optic link for interoffice communications after a lightning strike damages equipment and knocks out radio transmission used by the police department in Dorset.
1975	**U.S. military begins using fiber optics** The U.S. military begins using fiber optics to improve communications systems when the navy installs a fiber-optic telephone link on the USS Little Rock. Used to transmit data modulated into light waves, the specially designed bundles of transparent glass fibers are thinner and lighter than metal cables, have greater bandwidth, and can transmit data digitally while being less susceptible to interference. The first commercial applications come in 1977 when AT&T and GTE install fiber-optic telephone systems in Chicago and Boston. By 1988 and 1989, fiber-optic cables are carrying telephone calls across the Atlantic and Pacific Oceans.
1975	**First home computer is marketed to hobbyists** The Altair 8800, widely considered the first home computer, is marketed to hobbyists by Micro Instrumentation Telemetry Systems. The build-it-yourself kit doesn't have a keyboard, monitor, or its own programming language; data are input with a series of switches and lights. But it includes an Intel microprocessor and costs less than $400. Seizing an opportunity, fledgling entrepreneurs Bill Gates and Paul Allen propose writing a version of BASIC for the new computer. They start the project by forming a partnership called Microsoft.
1975	**Initial testing of packet radio networks** Initial testing of packet radio networks takes place in the San Francisco area. The SATNET program is initiated in September with one Intelsat ground station in Etam, West Virginia, and another in Goonhilly Downs, England.
1975	**NASA launches two Mars space probes** NASA launches two Mars space probes, *Viking 1* on August 20 and *Viking 2* on November 9, each consisting of an orbiter and a lander. The first probe lands on July 20, 1976, the second one on September 3. The Viking project's primary mission ends on November 15, 11 days before Mars's superior conjunction (its passage behind the Sun), although the two spacecraft continue to operate for several more years. The last transmission reaches Earth on November 11, 1982. After repeated efforts to regain contact, controllers at NASA's Jet Propulsion Laboratory close down the overall mission on May 21, 1983.

1976	**Common channel interoffice signaling** AT&T introduces common channel interoffice signaling, a protocol that allows software-controlled, networked computers or switches to communicate with each other using a band other than those used for voice traffic. Basically a dedicated trunk, the network separates signaling functions from the voice path, checks the continuity of the circuit, and then relays the information.

1976	**TCP/IP incorporated** At DARPA's request, Bill Joy incorporates TCP/IP (internet protocol) in distributions of Berkeley Unix, initiating broad diffusion in the academic scientific research community.
1976	**Concorde SST introduced into commercial airline service** The Concorde SST is introduced into commercial airline service by both Great Britain and France on January 21. It carries a hundred passengers at 55,000 feet and twice the speed of sound, making the London to New York run in 3.5 hours—half the time of subsonic carriers. But the cost per passenger-mile is high, ensuring that flights remain the privilege of the wealthy. After a Concorde accident kills everyone on board in July 2000, the planes are grounded for more than a year. Flights resume in November 2001, but with passenger revenue falling and maintenance costs rising, British Airways and Air France announce they will decommission the Concorde in October 2003.

1977	**Voyager I and Voyager 2 are launched** *Voyager I* and *Voyager 2* are launched on trajectories that take them to Jupiter and Saturn. Over the next decade the Voyagers rack up a long list of achievements. They find 22 new satellites (3 at Jupiter, 3 at Saturn, 10 at Uranus, and 6 at Neptune); discover that Jupiter has rings and that Saturn's rings contain spokes and braided structures; and send back images of active volcanism on Jupiter's moon lo—the only solar body other than Earth with confirmed active volcanoes.
1977	**Apple II is released** Apple Computer, founded by electronics hobbyists Steve Jobs and Steve Wozniak, releases the Apple II, a desktop personal computer for the mass market that features a keyboard, video monitor, mouse, and random-access memory (RAM) that can be expanded by the user. Independent software manufacturers begin to create applications for it.
1977	**Voyager 1 and Voyager 2 launched** Voyager 1 and Voyager 2 are launched on trajectories that take them to Jupiter and Saturn. Over the next decade the Voyagers rack up a long list of achievements. They find 22 new satellites (3 at Jupiter, 3 at Saturn, 10 at Uranus, and 6 at Neptune); discover that Jupiter has rings and that Saturn's rings contain spokes and braided structures; and send back images of active volcanism on Jupiter's moon Io- the only solar body other than Earth with confirmed active volcanoes.
1977	**Demonstration of independent networks to communicate** Cerf and Kahn organize a demonstration of the ability of three independent networks to communicate with each other using TCP protocol. Packets are communicated from the University of Southern California across the ARPANET, the San Francisco Bay Packet Radio Net, and Atlantic SATNET to London and back.
1977	**Theorynet** Larry Landweber, of the University of Wisconsin, creates Theorynet, to link researchers for e-mail via commercial packet-switched networks like Telenet.
1977	**Telephone companies fiber optic trials** Telephone companies begin trials with fiber-optic links carrying live telephone traffic. GTE opens a line between Long Beach and Artesia, California, whose transmitter uses

	a light-emitting diode. Bell Labs establishes a similar link for the phone system of downtown Chicago, 1.5 miles of underground fiber that connects two switching stations.
1977	**Electrically conducting organic polymers discovered** Researchers Hideki Shirakawa, Alan MacDiarmid, and Alan Heeger announce the discovery of electrically conducting organic polymers. These are developed into light-emitting diodes (LEDs), solar cells, and displays on mobile telephones. The three are awarded the Nobel Prize in chemistry in 2000.

1978	**First electronic sewing machine** Singer introduces the Athena 2000, the world's first electronic sewing machine. A wide variety of stitches, from basic straight to complicated decorative, are available at the touch of a button. The "brain" of the system is a chip that measures less than one-quarter of an inch and contains more than 8,000 transistors.
1978	**First cochlear implant surgery** Graeme Clarke in Australia carries out the first cochlear implant surgery. Advances in integrated circuit technology enable him to design a multiple electrode receiver-stimulator unit about the size of a quarter.
1978	**Public Utility Regulatory Policies Act** Congress passes the Public Utility Regulatory Policies Act (PURPA), which spurs the growth of nonutility unregulated power generation. PURPA mandates that utilities buy power from qualified unregulated generators at the "avoided cost"—the cost the utility would pay to generate the power itself. Qualifying facilities must meet technical standards regarding energy source and efficiency but are exempt from state and federal regulation under the Federal Power Act and the Public Utility Holding Company Act. In addition, the federal government allows a 15 percent energy tax credit while continuing an existing 10 percent investment tax credit.
1978	**Public tests of a new cellular phone system** Public tests of a new cellular phone system begin in Chicago, with more than 2,000 trial customers and mobile phone sets. The system, constructed by AT&T and Bell Labs, includes a group of small, low-powered transmission towers, each covering an area a few miles in radius. That test is followed by a 1981 trial in the Washington-Baltimore area by Motorola and the American Radio Telephone Service. The Federal Communications Commission officially approves commercial cellular phone service in 1982, and by the late 1980s commercial service is available in most of the United States.

1979	**Internet Configuration Control Board** DARPA establishes the Internet Configuration Control Board (ICCB) to help manage the DARPA Internet program. The ICCB acts as a sounding board for DARPA's plans and ideas. Landweber convenes a meeting of computer researchers from universities, the National Science Foundation (NSF), and DARPA to explore creation of a "computer science research network" called CSNET.
1979	**USENET**

	USENET, a "poor man's ARPANET," is created by Tom Truscott, Jim Ellis, and Steve Belovin to share information via e-mail and message boards between Duke University and the University of North Carolina, using dial-up telephone lines and the UUCP protocols in the Berkeley UNIX distributions.
1979	**First laptop computer is designed** What is thought to be the first laptop computer is designed by William Moggridge of GRiD Systems Corporation in England. The GRiD Compass 1109 has 340 kilobytes of bubble memory and a folding electroluminescent display screen in a magnesium case. Used by NASA in the early 1980s for its shuttle program, the "portable computer" is patented by GriD in 1982.
1979	**Three Mile Island** The nuclear facility at Three Mile Island near Harrisburg, Pennsylvania, experiences a major failure when a water pump in the secondary cooling system of the Unit 2 pressurized-water reactor malfunctions. A jammed relief valve then causes a buildup of heat, resulting in a partial meltdown of the core but only a minor release of radioactive material into the atmosphere.
1979	**First commercially successful business application** Harvard MBA student Daniel Bricklin and programmer Bob Frankston launch the VisiCalc spreadsheet for the Apple II, a program that helps drive sales of the personal computer and becomes its first commercially successful business application. VisiCalc owns the spreadsheet market for nearly a decade before being eclipsed by Lotus 1-2-3, a spreadsheet program designed by a former VisiCalc employee.

1980	**First circuit boards that have built-in self-testing technology** Chuck Stroud, while working at Bell Laboratories, develops and designs 21 different microchips and three different circuit boards—the first to employ built-in self-testing (BIST) technology. BIST results in a significant reduction in the cost, and a significant increase in the quality of producing electronic components.
1980	**TCP/IP standard adopted** U.S. Department of Defense adopts the TCP/IP (transmission control protocol/internet protocol) suite as a standard.
1980	**Fiber-optic cable links major cities** AT&T announces that it will install fiber-optic cable linking major cities between Boston and Washington, D.C. The cable is designed to carry three different wavelengths through graded-index fiber—technology that carries video signals later that year from the Olympic Games in Lake Placid, New York. Two years later MCI announces a similar project using single-mode fiber carrying 400 bits per second.
1980	**California wind farms** In California more than 17,000 wind machines, ranging in output from 20 to 350 kilowatts, are installed on wind farms. At the height of development, these turbines have a collected rating of more than 1,700 megawatts and produce more than 3 million megawatt-hours of electricity, enough at peak output to power a city of 300,000.
1980s	**Japanese popularize "just in time" delivery of auto parts** The Japanese popularize "just in time" delivery of auto parts to factory floors, thus reducing warehousing costs. They also popularize statistical process control, a method

	developed but not applied in the United States until the Japanese demonstrate how it improves quality.
1980s	**ROVs developed for subsea oil work** Remotely operated vehicles (ROVs) are developed for subsea oil work. Controlled from the surface, ROVs vary from beachball-size cameras to truck-size maintenance robots.
1980s	**Controlled drug delivery technology developed** Robert Langer, professor of chemical and biochemical engineering at MIT, develops the foundation of today's controlled drug delivery technology. Using pellets of degradable and nondegradable polymers such as polyglycolic acid, he fashions a porous structure that allows the slow diffusion of large molecules. Such structures are turned into a dime-size chemotherapy wafer to treat brain cancer after surgery. Placed at the site where a tumor has been removed, the wafer slowly releases powerful drugs to kill any remaining cancer cells. By confining the drug to the tumor site, the wafer minimizes toxic effects on other organs.
1980s	**Rare earth metals** Materials engineers develop "rare earth metals" such as iron neodymium boride, which can be made into magnets of high quality and permanency for use in sensors, computer disk drives, and automobile electrical motors. Other rare earth metals are used in color television phosphors, fluorescent bulbs, lasers, and magneto-optical storage systems with a capacity 15 times greater than that of conventional magnetic disks.
1980s	**Bardenpho process** James Barnard, a South African engineer, develops a wastewater treatment process that removes nitrates and phosphates from wastewater without the use of chemicals. Known as the Bardenpho process, it converts the nitrates in activated sludge into nitrogen gas, which is released into the air, removing a high percentage of suspended solids and organic material.
1980s	**"just in time" delivery introduced in auto manufacturing** The Japanese popularize "just in time" delivery of auto parts to factory floors, thus reducing warehousing costs. They also popularize statistical process control, a method developed but not applied in the United States until the Japanese demonstrate how it improves quality. Airbags, introduced in some models in the 1970s, become standard in more cars. Originally installed only on the driver's side, they begin to appear on the front passenger side as well.
1980s and 1990s	**Introduction of the open-graded friction course** Introduction of the open-graded friction course, allowing asphalt to drain water more efficiently and thus reducing hydroplaning and skidding, and Superpave, or Superior Performing Asphalt Pavement, which can be tailored to the climate and traffic of each job, are among refinements that improve the country's 4 million miles of roads and highways, 96 percent of which are covered in asphalt. By the end of the century, 500 million tons of asphalt will be laid every year.

1981	**MRI (magnetic resonance imaging) scanner introduced** The first commercial MRI (magnetic resonance imaging) scanner arrives on the medical market. (*See Imaging*.)

1981	**IBM Personal Computer released** IBM introduces the IBM Personal Computer with an Intel 8088 microprocessor and an operating system—MS-DOS—designed by Microsoft. Fully equipped with 64 kilobytes of memory and a floppy disk drive, it costs under $3,000.
1981	**NSF and DARPA establish ARPANET nodes** NSF and DARPA agree to establish ARPANET nodes at the University of Wisconsin at Madison, Purdue University, the University of Delaware, BBN, and RAND Corporation to connect ARPANET to CSNET sites on a commercial network called Telenet using TCP/IP.
1981	**Space Shuttle Columbia is launched** The Space Shuttle *Columbia*, the first reusable winged spaceship, is launched on April 12 from Kennedy Space Center. Astronauts John W. Young and Robert L. Crippin fly *Columbia* on the first flight of the Space Transportation System, landing the craft at Edwards Air Force Base in Southern California on April 14. Using pressurized auxiliary tanks to improve the total vehicle weight ratio so that the craft can be inserted into its orbit, the mission is the first to use both liquid- and solid-propellant rocket engines for the launch of a spacecraft carrying humans.
1981	**First scanning tunneling microscope** Gerd Binnig and Heinrich Rohrer, German physicists working at the IBM Research Laboratory in Zürich design and build the first scanning tunneling microscope (STM), with a small tungsten probe tip about one or two atoms wide. In 1986, Binnig, Cal Quate, and Christoph Gerber introduce the atomic force microscope (AFM), which is used in surface science, nanotechnology, polymer science, semiconductor materials processing, microbiology, and cellular biology. For invention of the STM Binnig and Rohrer share the 1986 Nobel Prize in physics with Ernst Ruska, who receives the award for his work on electron optics.

1982	**ARPANET hosts convert to new TCP/IP protocols** All hosts connected to ARPANET are required to convert to the new TCP/IP protocols by January 1, 1983. The interconnected TCP/IP networks are generally known as the Internet.
1982	**First permanent artificial heart implant** Seattle dentist Barney Clark receives the first permanent artificial heart, a silicone and rubber device designed by many collaborators, including Robert Jarvik, Don Olsen, and Willem Kolff. William DeVries of the University of Utah heads the surgical transplant team. Clark survives for 112 days with his pneumatically driven heart.

1983	**Internet Activities Advisory Board** The Internet Activities Advisory Board (later the Internet Activities Board, or IAB) replaces the ICCB. It organizes the research community into task forces on gateway algorithms, new end-to-end service, applications architecture and requirements, privacy, security, interoperability, robustness and survivability, autonomous systems, tactical interneting, and testing and evaluation. One of the task forces, soon known as "Internet Engineering," deals with the Internet's operational needs.

1983	**The Internet** ARPANET, and all networks attached to it, officially adopts the TCP/IP networking protocol. From now on, all networks that use TCP/IP are collectively known as the Internet. The number of Internet sites and users grow exponentially.
1983	**Solar Electric Generating Stations** Solar Electric Generating Stations (SEGs) producing as much as 13.8 megawatts are developed in California and sell electricity to the Southern California Edison Company.
1983	**UNIX scientific workstation introduced** Sun Microsystems introduces its UNIX scientific workstation. TCP/IP, now known as the Internet protocol suite, is included, initiating broad diffusion of the Internet into the scientific and engineering research communities.

1984	**Macintosh is introduced** Apple introduces the Macintosh, a low-cost, plug-and-play personal computer whose central processor fits on a single circuit board. Although it doesn't offer enough power for business applications, its easy-to-use graphic interface finds fans in education and publishing.
1984	**Advent of Domain Name Service** The advent of Domain Name Service, developed by Paul Mockapetris and Craig Partridge, eases the identification and location of computers connected to ARPANET by linking unique IP numerical addresses to names with suffixes such as .mil, .com, .org, and .edu.
1984	**CD-ROM introduced** Philips and Sony combine efforts to introduce the CD-ROM (compact disc read-only memory), patented in 1970 by James T. Russell. With the advent of the CD, data storage and retrieval shift from magnetic to optical technology. The CD can store more than 300,000 pages worth of information—more than the capacity of 450 floppy disks—meaning it can hold digital text, video, and audio files. Advances in the 1990s allow users not only to read prerecorded CDs but also to download, write, and record information onto their own disks.

1985	**Implantable cardioverter defibrillator (ICD) approved** The Food and Drug Administration approves Michel Mirowski's implantable cardioverter defibrillator (ICD), an electronic device to monitor and correct abnormal heart rhythms, and specifies that patients must have survived two cardiac arrests to qualify for ICD implantation. Inspired by the death from ventricular fibrillation of his friend and mentor Harry Heller, Mirowski has conceived and developed his invention almost single-handedly. It weighs 9 ounces and is roughly the size of a deck of cards.
1985	**NSF links five supercomputer centers across the country** NSF links scientific researchers to five supercomputer centers across the country at Cornell University, University of California at San Diego, University of Illinois at Urbana-Champaign, Pittsburgh Supercomputing Center, and Princeton University. Like CSNET, NSFNET employs TCP/IP in a 56-kilobits-per-second backbone to connect them.

1985	**Windows 1.0 is released** Microsoft releases Windows 1.0, operating system software that features a Macintosh-like graphical user interface (GUI) with drop-down menus, windows, and mouse support. Because the program runs slowly on available PCs, most users stick to MS-DOS. Higher-powered microprocessors beginning in the late 1980s make the next attempts—Windows 3.0 and Windows 95—more successful.
1985	**Antilock braking system (ABS) available on American cars** The Lincoln becomes the first American car to offer an antilock braking system (ABS), which is made by Teves of Germany. ABS uses computerized sensing of wheel movement and hydraulic pressure to each wheel to adjust pressure so that the wheels continue to move somewhat rather than "locking up" during emergency braking.

1986	**Fort McHenry Tunnel in Baltimore opens** The Fort McHenry Tunnel in Baltimore opens and at 1.75 miles is the longest and widest underwater highway tunnel ever built by the immersed-tube method. The tunnel was constructed in sections, then floated to the site and submerged in a trench. It also includes a computer-assisted traffic control system and communications and monitoring systems.
1986	**Internat Engineering Task Force expands** The Internet Engineering Task Force (IETF) expands to reflect the growing importance of operations and the development of commercial TCP/IP products. It is an open informal international community of network designers, operators, vendors, and researchers interested in the evolution of the Internet architecture and its smooth operation.
1986	**Space Shuttle Challenger destroyed during launch** On the 25th shuttle flight, the Space Shuttle Challenger is destroyed during its launch from the Kennedy Space Center on January 28, killing astronauts Francis R. (Dick) Scobee, Michael Smith, Judith Resnik, Ronald McNair, Ellison Onizuka, Gregory Jarvis, and Sharon Christa McAuliffe. The explosion occurs 73 seconds into the flight when a leak in one of two solid rocket boosters ignites the main liquid fuel tank. People around the world see the accident on television. The shuttle program does not return to flight until the fall of 1988.
1986	**Chernobyl** The Chernobyl nuclear disaster occurs in Ukraine during unauthorized experiments when four pressurized-water reactors overheat, releasing their water coolant as steam. The hydrogen formed by the steam causes two major explosions and a fire, releasing radioactive particles into the atmosphere that drift over much of the European continent.
1986	**Senator Gore proposes new legislation for using fiber-optic technology** Senator Albert Gore, of Tennessee, proposes legislation calling for the interconnection of the supercomputers centers using fiber-optic technology.
1986	**Voyager circumnavigates the globe (26,000 miles) nonstop in 9 days** Using a carbon-composite material, aircraft designer Burt Rutan crafts Voyager for flying around the world nonstop on a single load of fuel. Voyager has two centerline engines, one fore and one aft, and weighs less than 2,000 pounds (fuel for the flight

	adds another 5,000 pounds). It is piloted by Jeana Yeager (no relation to test pilot Chuck Yeager) and Burt's brother Dick Rutan, who circumnavigate the globe (26,000 miles) nonstop in 9 days.
1986-1990s	**Synthetic skin** Engineers develop "synthetic skin." One type seeds fibroblasts from human skin cells into a three-dimensional polymer structure, all of which is eventually absorbed into the body of the patient. Another type combines human lower skin tissue with a synthetic epidermal or upper layer.

1987	**Deep-brain electrical stimulation system** France's Alim-Louis Benabid, chief of neurosurgery at the University of Grenoble, implants a deep-brain electrical stimulation system into a patient with advanced Parkinson's disease. The experimental treatment is also used for dystonia, a debilitating disorder that causes involuntary and painful muscle contractions and spasms, and is given when oral medications fail.
1987	**Minimum energy efficiency requirements set** The National Appliance Energy Conservation Act mandates minimum energy efficiency requirements for refrigerators and freezers as well as room and central air conditioners.
1987	**The Montreal Protocol** The Montreal Protocol serves as an international agreement to begin phasing out CFC refrigerants, which are suspected of contributing to the thinning of the earth's protective, high-altitude ozone shield.
1987	**High-speed national research network** NSF convenes the networking community in response to a request by Senator Gore to examine prospects for a high-speed national research network. Gordon Bell at NSF reports to the White House Office of Science and Technology Policy (OSTP) on a plan for the National Research and Education Network. Presidential Science Advisor Allan Bromley champions the high-performance computing and communications initiatives that eventually implement the networking plans.
1987	**Echo-planar imaging (EPI)** Echo-planar imaging (EPI) is used to perform real-time movie imaging of a single cardiac cycle. (Peter Mansfield of the School of Physics and Astronomy, University of Nottingham, first developed the EPI technique in 1977.) In 1993 the advent of functional MRI opens up new applications for EPI in mapping regions of the brain responsible for thought and motor control and provides early detection of acute stroke.
1987	**UUNET and PSINET are formed** UUNET is formed by Rick Adams and PSINET is formed by Bill Schrader to provide commercial Internet access. At DARPA's request, Dan Lynch organizes the first Interop conference for information purposes and to bring vendors together to test product interoperability.
1987	**First laser surgery on a human cornea** New York City ophthalmologist Steven Trokel performs the first laser surgery on a human cornea, after perfecting his technique on a cow's eye. Nine years later the first computerized excimer laser—Lasik—designed to correct the refractive error myopia, is

	approved for use in the United States. The Lasik procedure has evolved from both the Russian-developed radial keratotomy and its laser-based successor photorefractive keratectomy.
1987	**"Doped" fiber amplifiers** David Payne at England's University of Southampton introduces fiber amplifiers that are "doped" with the element erbium. These new optical amplifiers are able to boost light signals without first having to convert them into electrical signals and then back into light.
1987	**Sunshine Skyway Bridge completed** The Sunshine Skyway Bridge is completed, connecting St. Petersburg and Bradenton, Florida. At 29,040 feet long, it is the world's largest cable-stayed concrete bridge. Twenty-one steel cables support the bridge in the center with two 40-foot roadways running along either side of the cable for an unobstructed view of the water.
1987	**Internet of administratively independent connected TCP/IP networks emerges** As the NSFNET backbone becomes saturated, NSF plans to increase capacity, supports the creation of regional networks, and initiates a program to connect academic institutions, which invest heavily in campus area networks. The Internet of administratively independent connected TCP/IP networks emerges.

1988	**Sony "Watchman"** Sony introduces the first in its "Watchman" series of handheld, battery-operated, transistorized television sets. Model FD-210, with its 1.75-inch screen, is the latest entry in a 30-year competition among manufacturers to produce tiny micro-televisions. The first transistorized TV, Philco's 1959 Safari, stood 15 inches high and weighed 15 pounds.
1988	**NSFNET contract awarded** An NSFNET contract is awarded to the team of IBM and MCI, led by Merit Network, Inc. The initial 1.5-megabits-per-second NSFNET is placed in operation.
1988	**First transatlantic fiber-optic cable** The first transatlantic fiber-optic cable is installed, using glass fibers so transparent that repeaters (to regenerate and recondition the signal) are needed only about 40 miles apart. The shark-proof TAT-8 is dedicated by science fiction writer Isaac Asimov, who praises "this maiden voyage across the sea on a beam of light." Linking North America and France, the 3,148-mile cable is capable of handling 40,000 telephone calls simultaneously using 1.3-micrometer wavelength lasers and single-mode fiber. The total cost of $361 million is less than $10,000 per circuit; the first transatlantic copper cable in 1956 costs $1 million per circuit to plan and install.

1989	**Interconnection of commercial and federal networks** The Federal Networking Council (FNC), program officer from cooperating agencies, give formal approval for interconnection of commercial and federal networks. The following year ARPANET is decommissioned.

1990	**Human Genome Project** Researchers begin the Human Genome Project, coordinated by the U.S. Department of Energy and the National Institutes of Health, with the goal of identifying all of the approximately 30,000 genes in human DNA and determining the sequences of the three billion chemical base pairs that make up human DNA. The project catalyzes the multibillion-dollar U.S. biotechnology industry and fosters the development of new medical applications, including finding genes associated with genetic conditions such as familial breast cancer and inherited colon cancer. A working draft of the genome is announced in June 2000.
1990	**Hubble Space Telescope** The Hubble Space Telescope goes into orbit on April 25, deployed by the crew of the Space Shuttle *Discovery*. A cooperative effort by the European Space Agency and NASA, Hubble is a space-based observatory first dreamt of in the 1940s. Stabilized in all three axes and equipped with special grapple fixtures and 76 handholds, the space telescope is intended to be regularly serviced by shuttle crews over the span of its 15-year design life.
1990	**FCC sets a testing schedule for proposed all-digital HDTV system** Following a demonstration by Philips two years earlier of a high-definition TV (HDTV) system for satellite transmission, the Federal Communications Commission sets a testing schedule for a proposed all-digital HDTV system. Tests begin the next year, and in 1996 Zenith introduces the first HDTV-compatible front-projection television. Also in 1996, broadcasters, TV manufacturers, and PC makers set inter-industry standards for digital HDTV. By the end of the century, digital HDTV, which produces better picture and sound than analog television and can transmit more data faster, is on the verge of offering completely interactive TV.
1990s	**U.S. Naval Nuclear Propulsion Program** The U.S. Naval Nuclear Propulsion Program pioneers new materials and develops improved material fabrication techniques, radiological control, and quality control standards.
1990s	**U.S. bulk power system evolves into three major grids** The bulk power system in the United States evolves into three major power grids, or interconnections, coordinated by the North American Electric Reliability Council (NERC), a voluntary organization formed in 1968. The ERCOT (Electric Reliability Council of Texas) interconnection is linked to the other two only by certain DC lines.
1990s	**B-2 bomber developed** Northrop Grumman develops the B-2 bomber, with a "flying wing" design. Made of composite materials rather than metal, it cannot be detected by conventional radar. At about the same time, Lockheed designs the F-117 stealth fighter, also difficult to detect by radar.
1990s	**Big Dig begins** Work begins in Boston on the Big Dig, a project to transform the section of I-93 known as the Central Artery, an elevated freeway built in the 1950s, into an underground tunnel. Scheduled for completion in 2004, it will provide a new harbor crossing to Logan Airport and replace the I-93 bridge across the Charles River.
1990s	**Environmentally friendly washers and dryers** Environmentally friendly washers and dryers that save water and conserve energy are

	introduced. They include the horizontal-axis washer, which tumbles rather than agitates the clothes and uses a smaller amount of water, and a dryer with sensors, rather than a timer, that shuts the appliance off when the clothes are dry.
1990s	**New tools and techniques to reduce the costs and risks of drilling** The combined efforts of private industry, the Department of Energy, and national laboratories such as Argonne and Lawrence Livermore result in the introduction of several new tools and techniques designed to reduce the costs and risks of drilling, including reducing potential damage to the geological formation and improving environmental protection. Among such tools are the near-bit sensor, which gathers data from just behind the drill bit and transmits it to the surface, and carbon dioxide/sand fracturing stimulation, a technique that allows for non-damaging stimulation of a natural gas formation.
1990s (Mid)	**Voice Over Internet Protocols** The advent of Voice Over Internet Protocols (VoIP)—methods of allowing people to make voice calls over the Internet on packet-switched routes— starts to gain ground as PC users find they can lower the cost of their long-distance calls. VoIP technology is also useful as a platform that enables voice interactions on devices such as PCs, mobile handhelds, and other devices where voice communication is an important feature.
1990s–2000	**Spacecraft imaging instruments** NASA launches robotic spacecraft equipped with a variety of imaging instruments as part of a program of solar system exploration. Spacecraft have returned images not only from the planets but also from several of the moons of the gas giants.
1990s-present	**Nanotechnology** Scientists investigate nanotechnology, the manipulation of matter on atomic and molecular scales. Electronic channels only a few atoms thick could lead to molecule-sized machines, extraordinarily sensitive sensors, and revolutionary manufacturing methods.

1991	**World Wide Web** The World Wide Web becomes available to the general public (see *Internet*).
1991	**World Wide Web software developed** CERN releases the World Wide Web software developed earlier by Tim Berners-Lee. Specifications for HTML (hypertext markup language), URL (uniform resource locator), and HTTP (hypertext transfer protocol) launch a new era for content distribution. At the University of Minnesota, a team of programmers led by Mark McCahill releases a point-and-click navigation tool, the "Gopher" document retrieval system, simplifying access to files over the Internet.
1991	**Optical Amplifiers** Emmanuel Desurvire of Bell Laboratories, along with David Payne and P. J. Mears of the University of Southampton, demonstrate optical amplifiers that are built into the fiber-optic cable itself. The all-optic system can carry 100 times more information than cable with electronic amplifiers.

1992	**Personal digital assistant** Apple chairman John Sculley coins the term "personal digital assistant" to refer to handheld computers. One of the first on the market is Apple's Newton, which has a liquid crystal display operated with a stylus. The more successful Palm Pilot is released by 3Com in 1996.
1992	**Internet Society is formed** The nonprofit Internet Society is formed to give the public information about the Internet and to support Internet standards, engineering, and management. The society later becomes home to a number of groups, including the IAB and IETF, and hold meetings around the world to promote diffusion of the Internet.
1992	**Minimum energy efficiency standards set for commercial buildings** The U.S. Energy Policy Act mandates minimum energy efficiency standards for commercial buildings, using research and standards developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers.
1992	**Operational 7.5- kilowatt solar dish prototype system developed** A joint venture of Sandia National Laboratories and Cummins Power Generation develops an operational 7.5-kilowatt solar dish prototype system using an advanced stretched-membrane concentrator.
1992	**Energy Policy Act of 1992 encourages alternative-fuel vehicles** Passage of the federal Energy Policy Act of 1992 encourages alternative- fuel vehicles. These include automobiles run with mixtures of alcohols and gasoline, with natural gas, or by some combination of conventional fuel and battery power.
1992	**Energy Policy Act** The Energy Policy Act establishes a permanent 10 percent investment tax credit for solar and geothermal powergenerating equipment as well as production tax credits for both independent and investor-owned wind projects and biomass plants using dedicated crops.

1993	**Glenn Anderson Freeway/Transitway opens** The Glenn Anderson Freeway/ Transitway, part of I-105, opens in Los Angeles, featuring a light rail train that runs in the median. Sensors buried in the pavement monitor traffic flow, and closed-circuit cameras alert officials to accidents.
1993	**Network Solutions manages domain names** NSF solicits proposal to manage domain names for nonmilitary registrations and awards a 5-year agreement to Network Solutions, Inc.
1993	**Distribution of a browser accelerates adoption of the web** Marc Andreessen and Eric Bina, of the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign, develop an easy-to-use graphical interface for the World Wide Web. Distribution of the "browser," NCSA Mosaic, accelerates adoption of the Web. The technology is eventually licensed to Microsoft as the basis for its initial Internet Explorer browser. In 1994 the team rewrites the browser, changing its name to Netscape. Later "browser wars" focus public attention on the emerging commercial Internet.
1993	**Interstate system praised**

	Officially designated the Dwight D. Eisenhower System of Interstate and Defense Highways, the interstate system is praised by the American Society of Civil Engineers as one of the "Seven Wonders of the United States" and "the backbone of the world's strongest economy."

1994	**Farmers begin using Global Positioning System (GPS) receivers** Ushering in the new "precision agriculture," farmers begin using Global Positioning System (GPS) receivers to record precise locations on their farms to determine which areas need particular quantities of water, fertilizer, and pesticides. The information can be stored on a card and transferred to a home computer. Farmers can now combine such data with yield information, weather forecasts, and soil analysis to create spreadsheets. These tools enable even greater efficiency in food production.

1995	**First aircraft produced through computer-aided design and engineering** Boeing debuts the twin-engine 777, the biggest two-engine jet ever to fly and the first aircraft produced through computer-aided design and engineering. Only a nose mockup was actually built before the vehicle was assembled—and the assembly was only 0.03 mm out of alignment when a wing was attached.
1995	**NSFNET decommissioned** NSF decommissions the NSFNET.

1996	**Telecommunications Act of 1996** President Clinton signs the Telecommunications Act of 1996. Among its provisions it gives schools and libraries access to state-of-the-art services and technologies at discounted rates.
1996	**All-optic fiber cable that uses optical amplifiers is laid across the Pacific Ocean** TPC-5, an all-optic fiber cable that is the first to use optical amplifiers, is laid in a loop across the Pacific Ocean. It is installed from San Luis Obispo, California, to Guam, Hawaii, and Miyazaki, Japan, and back to the Oregon coast and is capable of handling 320,000 simultaneous telephone calls.
1996	**TPC-5 loops across the Pacific Ocean** TPC-5, an all-optic fiber cable that is the first to use optical amplifiers, is laid in a loop across the Pacific Ocean. It is installed from San Luis Obispo, California, to Guam, Hawaii, and Miyazaki, Japan, and back to the Oregon coast and is capable of handling 320,000 simultaneous telephone calls.
1996	**UV Waterworks** Ashok Gadgil, a scientist at the Lawrence Berkeley National Laboratory in California, invents an effective and inexpensive device for purifying water. UV Waterworks, a portable, low-maintenance, energy-efficient water purifier, uses ultraviolet light to render viruses and bacteria harmless. Operating with hand-pumped or hand-poured water, a single unit can disinfect 4 gallons of water a minute, enough to provide safe drinking water for up to 1,500 people, at a cost of only one cent for every 60 gallons of water—making safe drinking water economically feasible for populations in poor and

	rural areas all over the world.
1996-1998	**Joint research program to develop second-generation supersonic airliner** NASA teams with American and Russian aerospace industries in a joint research program to develop a second-generation supersonic airliner for the 21st century. The centerpiece is the Tu-144LL, a first-generation Russian supersonic jetliner modified into a flying laboratory. It conducts supersonic research comparing flight data with results from wind tunnels and computer modeling.

1997	**First American carmaker offers automatic stability control** Cadillac is the first American carmaker to offer automatic stability control, increasing safety in emergency handling situations.
1997	**Fiber Optic Link Around the Globe** The Fiber Optic Link Around the Globe (FLAG) becomes the longest single-cable network in the world and provides infrastructure for the next generation of Internet applications. The 17,500-mile cable begins in England and runs through the Strait of Gibraltar to Palermo, Sicily, before crossing the Mediterranean to Egypt. It then goes overland to the FLAG operations center in Dubai, United Arab Emirates, before crossing the Indian Ocean, Bay of Bengal, and Andaman Sea; through Thailand; and across the South China Sea to Hong Kong and Japan.
1997	**First prototype of a robotic vacuum cleaner** Swedish appliance company Electrolux presents the first prototype of a robotic vacuum cleaner. The device, billed as "the world's first true domestic robot," sends and receives high-frequency ultrasound to negotiate its way around a room, much as bats do. In the production model, launched in Sweden a few years later, eight microphones receive and measure the returning signals to give the vacuum an accurate picture of the room. It calculates the size of a room by following around the walls for 90 seconds to 15 minutes, after which it begins a zigzag cleaning pattern and turns itself off when finished.
1997	**IBM develops a copper-based chip technology** IBM announces that it has developed a copper-based chip technology, using copper wires rather than traditional aluminum to connect transistors in chips. Other chip manufacturers are not far behind, as research into copper wires has been going on for about a decade. Copper, the better conductor, offers faster performance, requires less electricity, and runs at lower temperatures, This breakthrough allows up to 200 million transistors to be placed on a single chip.

1998	**Coordination of Internet domain names transitions from federal to private sector** The Internet Corporation for Assigned Names and Numbers is chartered by the U.S. Department of Commerce to transition from the federal government to the private sector the coordination and assignment of Internet domain names, IP address numbers and various protocol parameters.
1998	**Plastic transistors developed** A team of Bell Labs researchers—Howard Katz, V. Reddy Raju, Ananth Dodabalapur, Andrew Lovinger, and chemist John Rogers—present their latest findings on the first

	fully "printed" plastic transistor, which uses a process similar to silk screening. Potential uses for plastic transistors include flexible computer screens and "smart" cards, full of vital statistics and buying power, and virtually indestructible.
1998	**International Space Station** The first two modules of the International Space Station are joined together in orbit on December 5 by astronauts from the Space Shuttle *Endeavour*. In a series of spacewalks, astronauts connect cables between the two modules—from the United States and *Zarya* from Russia—affix antennae, and open the hatches between the two spacecraft.

1999	**Palm VII connected organizer** Responding to a more mobile workforce, handheld computer technology leaps forward with the Palm VII connected organizer, the combination of a computer with 2 megabytes of RAM and a port for a wireless phone. At less than $600, the computer weighs 6.7 ounces and operates for up to 3 weeks on two AAA batteries. Later versions offer 8 megabytes of RAM, Internet connectivity, and color screens for less than $500.

2000	**Expedition One of the International Space Station** On October 31 Expedition One of the International Space Station is launched from Baikonur Cosmodrome in Kazakhstan—the same launch-pad from which Yuri Gagarin became the first human in space. Prior to its return on March 21, 2001, the crew conducts scientific experiments and prepares the station for long-term occupation.
2000	**Hoover-Diana goes into operation** The Hoover-Diana, a 63,000-ton deep-draft caisson vessel, goes into operation in the Gulf of Mexico. A joint venture by Exxon Mobil and BP, it is a production platform mounted atop a floating cylindrical concrete tube anchored in 4,800 feet of water. The entire structure is 83 stories high, with 90 percent of it below the surface. Within half a year it is producing 20,000 barrels of oil and 220 million cubic feet of gas a day. Two pipelines carry the oil and gas to shore.
2000	**100 million cellular telephone subscribers** The number of cellular telephone subscribers in the United States grows to 100 million, from 25,000 in 1984. Similar growth occurs in other countries as well, and as phones shrink to the size of a deck of cards, an increasingly mobile society uses them not only for calling but also to access the Internet, organize schedules, take photographs, and record moving images.
2000	**Semiconductor switches enable long-range DC transmission** By the end of the century, semiconductor switches are enabling the use of long-range DC transmission.
2000	**World record reliability benchmarks** The fleet of more than 100 nuclear power plants in the United States achieve world record reliability benchmarks, operating annually at more than 90 percent capacity for the last decade—the equivalent of building 10 gigawatt nuclear power plants in that period. In the 21 years since the Three Mile Island accident, the fleet can claim the equivalent of 2,024.6 gigawatt-years of safe reactor operation, compared to a total operational history of fewer than 253.9 gigawatt-years before the accident. Elsewhere

	in the world, nuclear power energy production grows, most notably in China, Korea, Japan, and Taiwan, where more than 28 gigawatts of nuclear power plant capacity is added in the last decade of the century.

