children's illustrated encyclopedia

The Story of Transport

Orpheus

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Text Christopher Oxlade

Illustrators Elisabetta Ferrero, Giuliano Fornari, Lee Montgomery, Steve Noon, Nicki Palin, Sebastian Quigley, Alessandro Rabatti, Colin Rose, Ivan Stalio, Roger Stewart, Thomas Trojer, Alan Weston, Martin Woodward, David Wright

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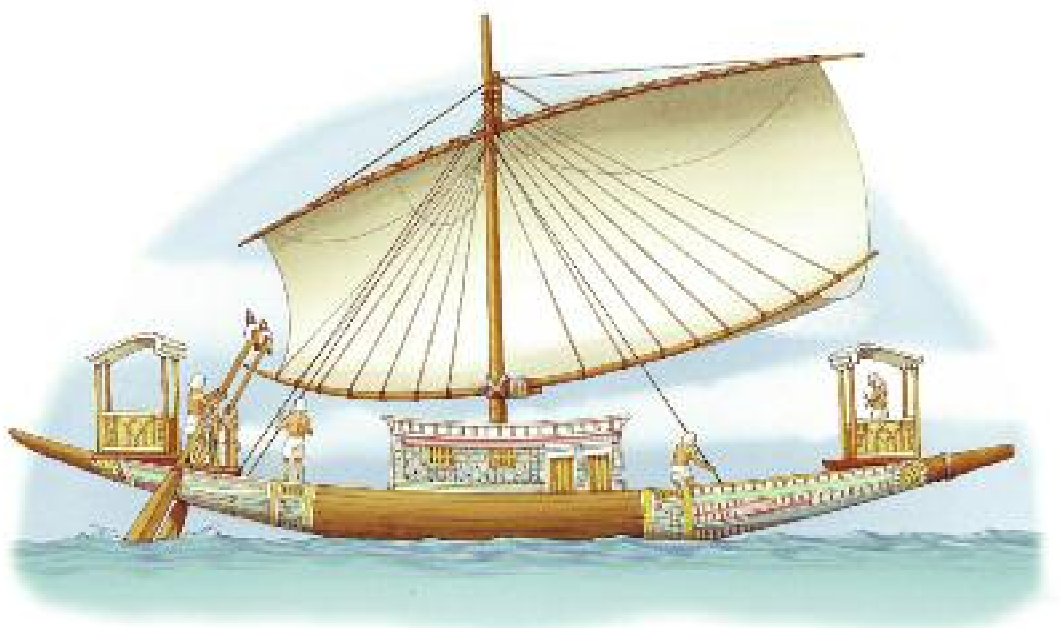


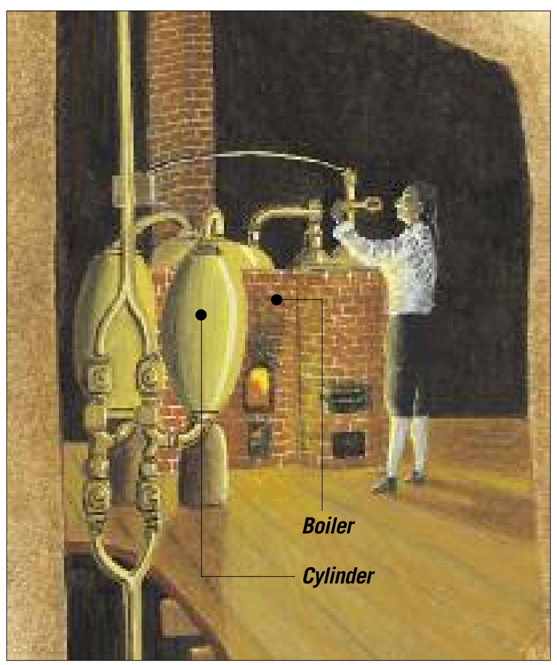
Contents

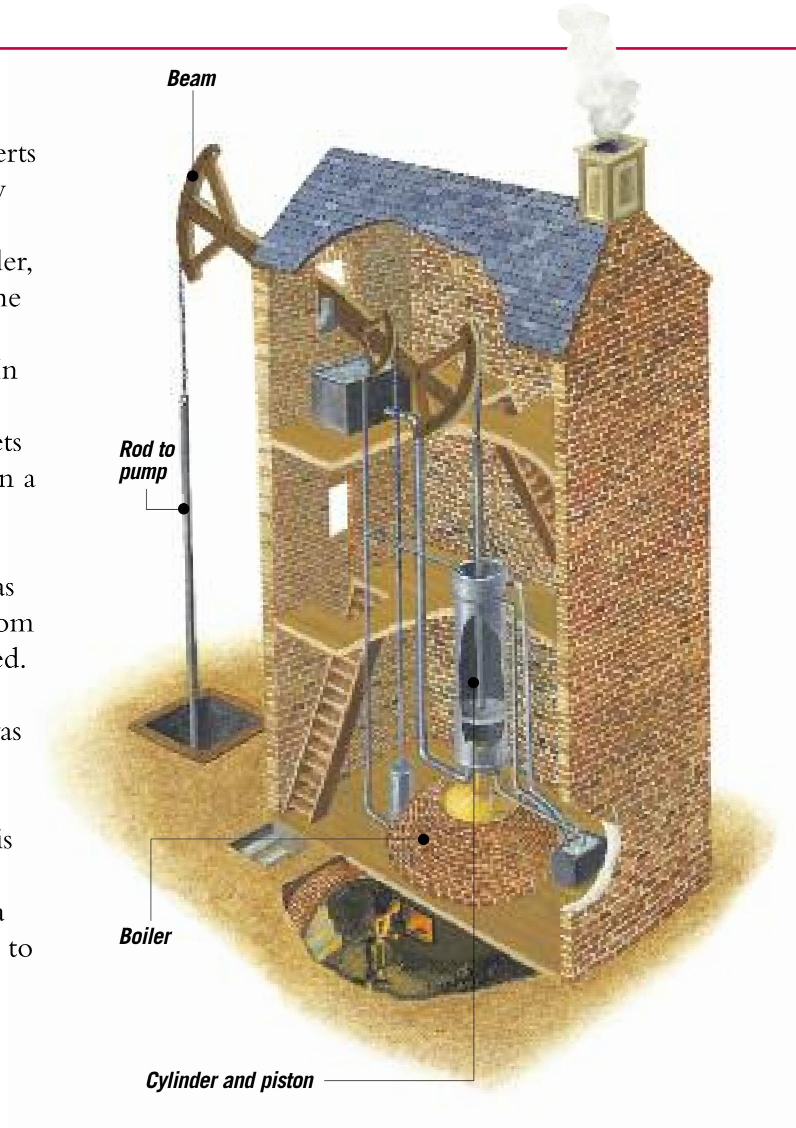
STEAM ENGINES

AN ENGINE is a machine that converts the energy stored in fuel into energy for operating other machines. In a steam engine, burning fuel heats water in a boiler, turning it to steam, which builds up in the boiler. The pressurized steam is used to operate the moving parts of the engine. In the first century AD, the Greek inventor Hero built a device that was turned by jets of steam, but it was a curiosity rather than a useful machine.

The first steam-powered machine was built in 1698 by English engineer Thomas Savery. It was designed to pump water from flooded mines, but was never actually used. In Savery's engine, steam from the boiler filled a large cylinder. Then cold water was poured over the outside of the cylinder, which cooled it, making the steam condense (turn back to liquid water). This created a vacuum in the cylinder, which sucked in water from the mine through a pipe. More steam was fed to the cylinder to push the water up an outlet pipe.

Thomas Savery called his steam engine the "miner's friend". It pumped water from the pipe at the bottom into the pipe at the top via the two large cylinders.





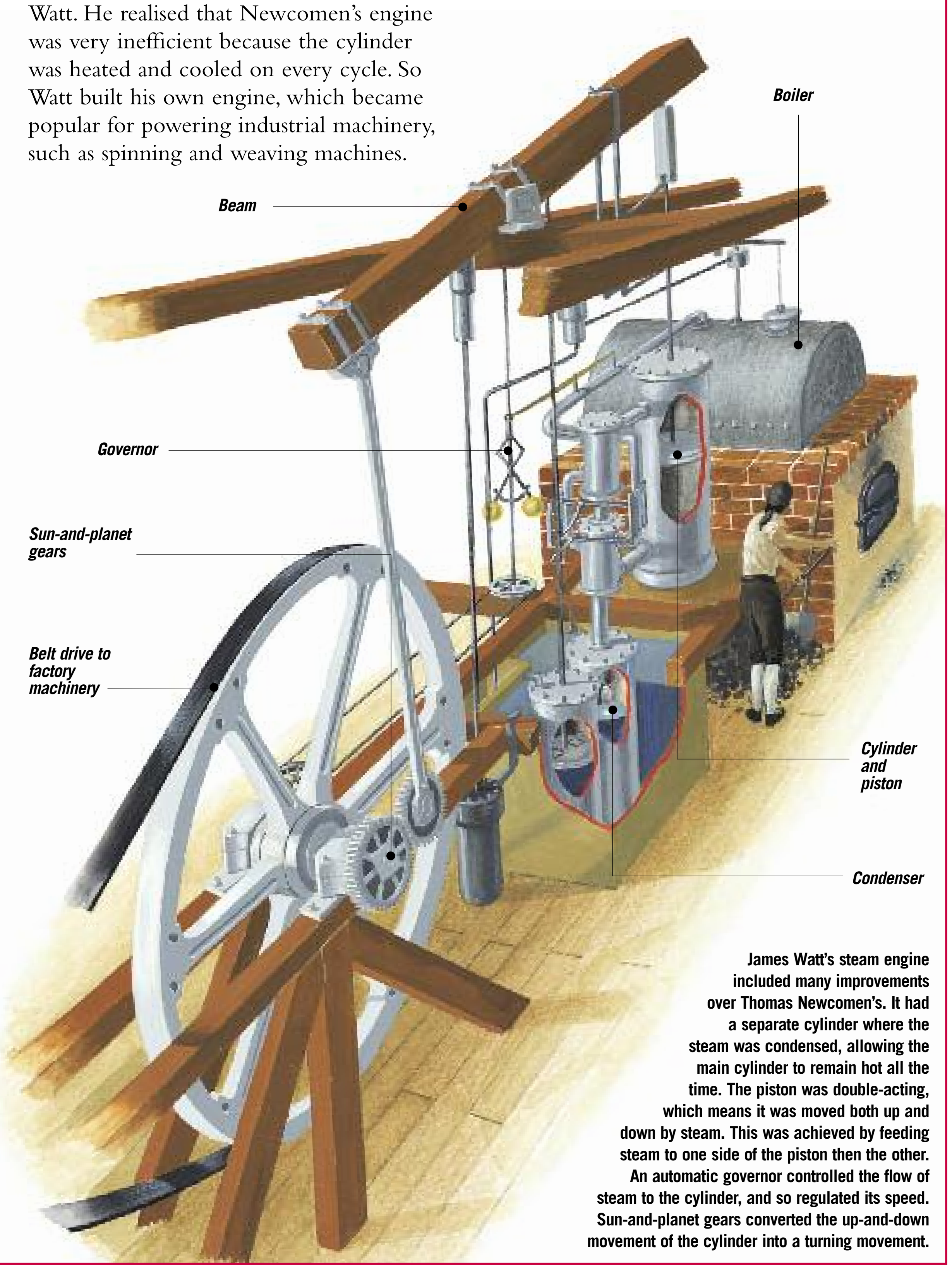
In Thomas Newcomen's atmospheric steam engine, movement of the piston was transferred to the pump by a rocking beam.

In 1712 another English engineer, Thomas Newcomen, also completed a steam engine for pumping mine water. In Newcomen's engine, steam from the boiler went along pipes to a cylinder, where its pressure pushed a piston upwards. Then cold water was sprayed into the cylinder, which made the steam condense. This reduced the pressure in the cylinder, and the pressure of the air in the atmosphere outside pushed the piston back down. This is why Newcomen's engine is often called an atmospheric engine. Although it used a huge amount of coal, it was very successful, especially at coal mines, where there was an endless supply of coal.

WATT'S IMPROVEMENTS

Steam engine design was greatly improved in the 1770s by Scottish engineer James Watt. He realised that Newcomen's engine was very inefficient because the cylinder was heated and cooled on every cycle. So Watt built his own engine, which became popular for powering industrial machinery, such as spinning and weaving machines.

Steam engines are still used today in power stations in the form of the steam turbine, where high-pressure steam makes a fan-like turbine spin at high speed.

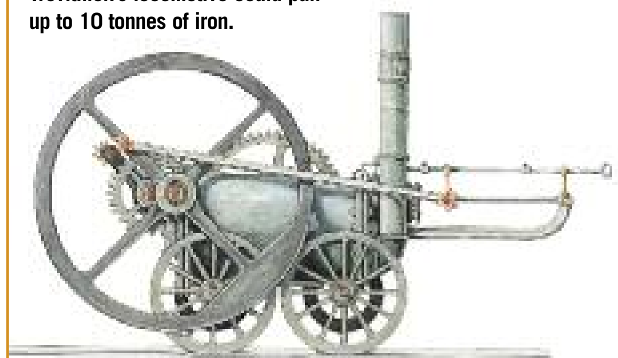


James Watt's steam engine included many improvements over Thomas Newcomen's. It had a separate cylinder where the steam was condensed, allowing the main cylinder to remain hot all the time. The piston was double-acting, which means it was moved both up and down by steam. This was achieved by feeding steam to one side of the piston then the other. An automatic governor controlled the flow of steam to the cylinder, and so regulated its speed. Sun-and-planet gears converted the up-and-down movement of the cylinder into a turning movement.

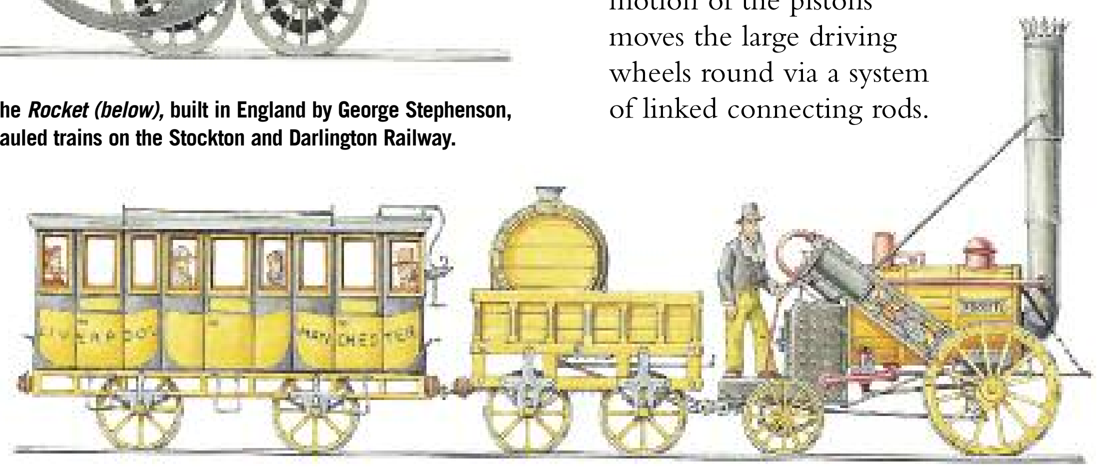
Steam Trains

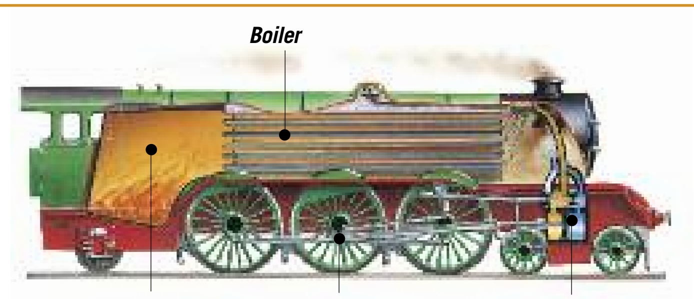
A TRAIN is a vehicle that runs on guide rails called a railway. Miners have used simple wooden or iron railways called wagon-ways for hundreds of years to move rock, coal and ore in trucks. The trucks were pulled and pushed by animals or the miners themselves. The first locomotive powered by a steam engine *(see page 4)* was built in 1804 by English engineer Richard Trevithick, to haul trucks at an ironworks. The first passenger railway was the Stockton and Darlington Railway in England, which opened in 1828.

Trevithick's locomotive could pull up to 10 tonnes of iron.



The *Rocket (below),* built in England by George Stephenson, hauled trains on the Stockton and Darlington Railway.

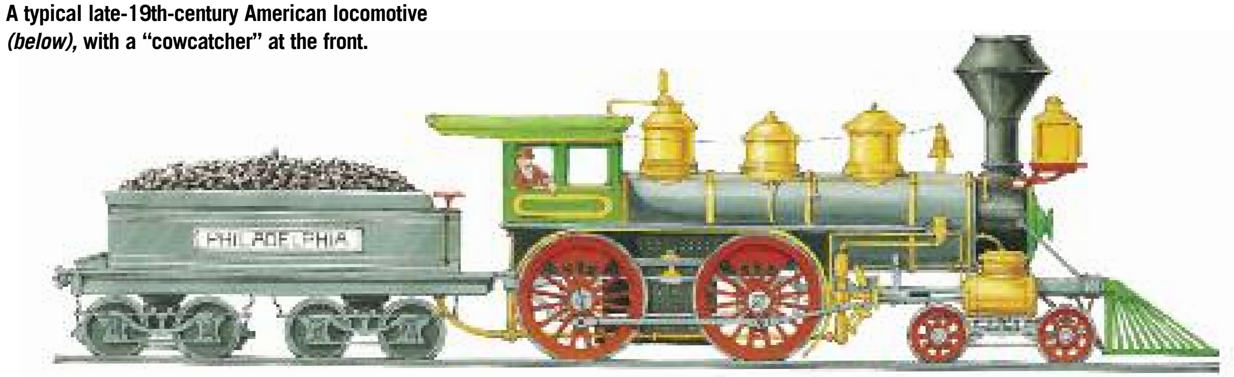




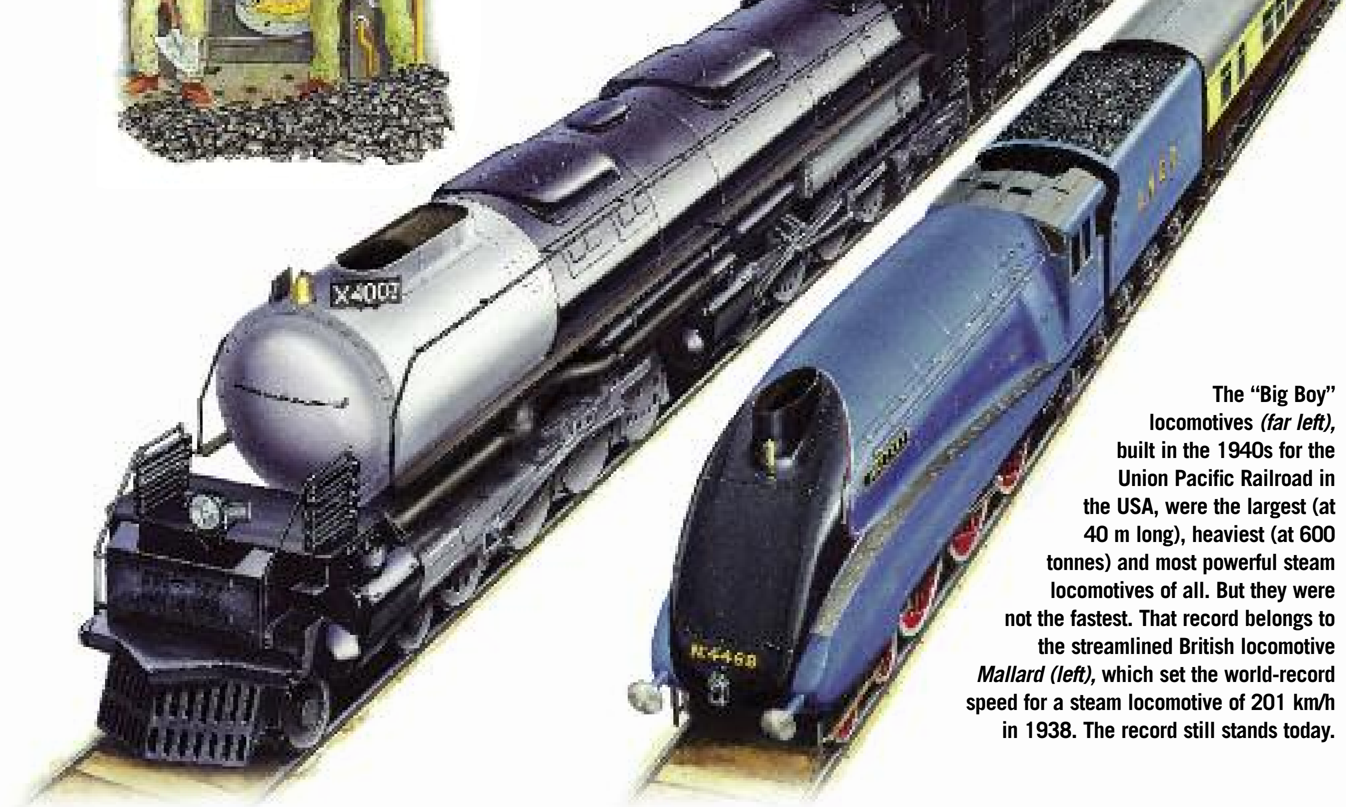
How a Steam Locomotive Works

A steam locomotive is simply a steam engine on wheels. Fuel burns in the firebox, creating hot gases that pass along tubes inside the boiler. The heat from the tubes boils the water, creating steam. As more steam collects at the top of the boiler, its pressure builds up, and it escapes along pipes to the cylinders, where, controlled by valves, it pushes the pistons one way then the other (this is called double action). The sliding motion of the pistons moves the large driving wheels round via a system of linked connecting rods.

A typical late-19th-century American locomotive *(below),* with a "cowcatcher" at the front.



As well as a driver, steam locomotives needed firemen to keep the firebox supplied with fuel *(left).* The fuel (coal or timber) was carried in a tender behind the engine. The "Big Boy" locomotives *(below)* had a mechanical stoker to supply the fire with fuel.



The "Big Boy" locomotives *(far left),* built in the 1940s for the Union Pacific Railroad in the USA, were the largest (at 40 m long), heaviest (at 600 tonnes) and most powerful steam locomotives of all. But they were not the fastest. That record belongs to the streamlined British locomotive *Mallard (left),* which set the world-record speed for a steam locomotive of 201 km/h in 1938. The record still stands today.

Spread of the Railways

Extensive railway networks were developed during the second half of the nineteenth century, especially in the USA, Canada, Europe and Russia. Improvements in tracks, including the introduction of steel rails in the 1860s, allowed for heavier locomotives, with increased power and speed. Carriage design also improved, and dining cars and sleeping cars were introduced by George Pullman in the USA. Railway networks relied on other engineering improvements. Long-span steel bridges carried trains over wide rivers, and rock tunnels took them under mountain ranges such as the Alps. From the 1850s the electric telegraph allowed communications between stations so that signalling staff could keep track of where the trains were.

By the 1930s powerful, streamlined steam locomotives could haul passenger trains at high speeds. But steam locomotives are very inefficient. Only about five per cent of the energy in the fuel gets to the wheels, and time is needed to start the fire and get the water boiling. In the 1950s and 1960s, steam locomotives disappeared from most railways and were replaced by electric-powered and diesel-powered locomotives. However, steam engines are still used in some countries, such as India and China.

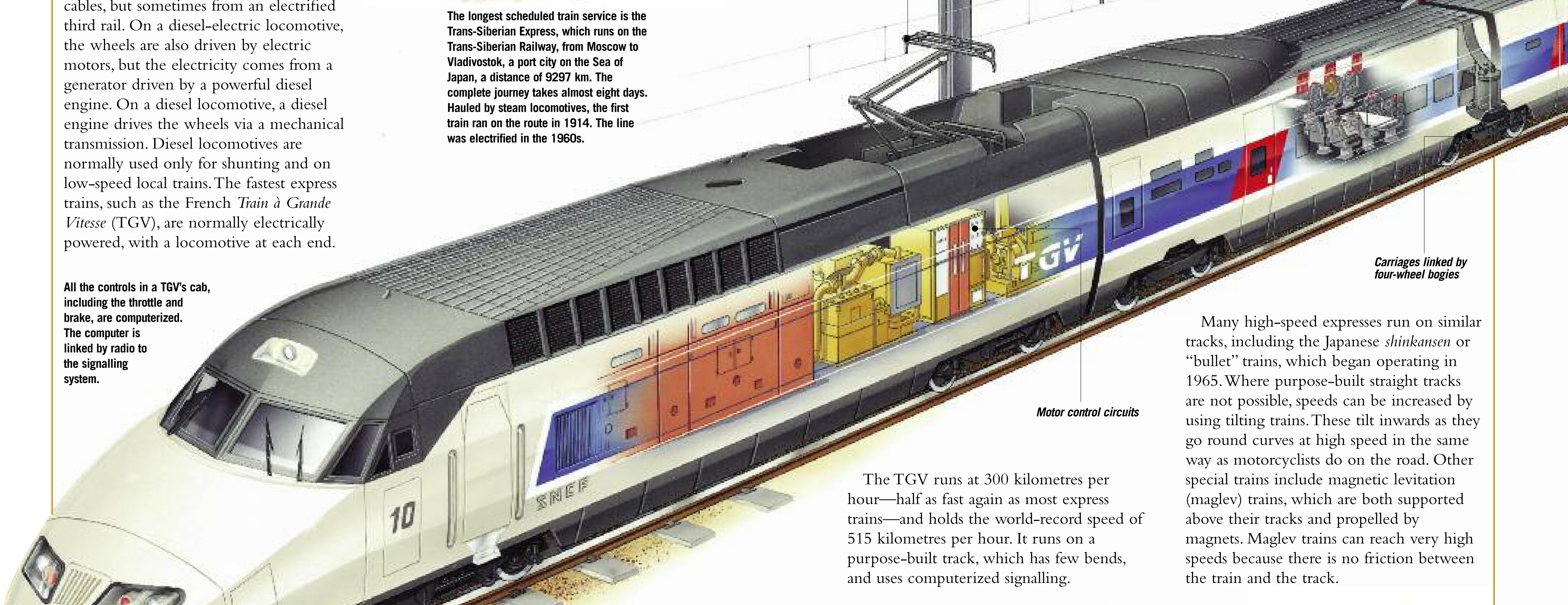
Electric locomotives ran as early as 1879 in Germany. In 1890 they began pulling trains on underground railways in London, and in 1903 on mainline railways in Europe. Diesel locomotives started operating in the USA in the 1930s.

RAIL TRANSPORT

MODERN TRAINS

THERE ARE three types of modern locomotive—electric, diesel-electric and diesel. On an electric locomotive, the wheels are moved by electric motors (normally one for each pair of wheels). The electricity usually comes from overhead cables, but sometimes from an electrified third rail. On a diesel-electric locomotive, the wheels are also driven by electric motors, but the electricity comes from a generator driven by a powerful diesel engine. On a diesel locomotive, a diesel engine drives the wheels via a mechanical transmission. Diesel locomotives are normally used only for shunting and on low-speed local trains. The fastest express trains, such as the French *Train à Grande Vitesse* (TGV), are normally electrically powered, with a locomotive at each end.

The longest scheduled train service is the Trans-Siberian Express, which runs on the Trans-Siberian Railway, from Moscow to Vladivostok, a port city on the Sea of Japan, a distance of 9297 km. The complete journey takes almost eight days. Hauled by steam locomotives, the first train ran on the route in 1914. The line was electrified in the 1960s.



A pantograph collects electricity from the overhead cable. Electronic circuits in the locomotive control how the electricity flows to the motors.

All the controls in a TGV's cab, including the throttle and brake, are computerized. The computer is linked by radio to the signalling system.

The TGV runs at 300 kilometres per hour—half as fast again as most express trains—and holds the world-record speed of 515 kilometres per hour. It runs on a purpose-built track, which has few bends, and uses computerized signalling.

Many high-speed expresses run on similar tracks, including the Japanese *shinkansen* or "bullet" trains, which began operating in 1965. Where purpose-built straight tracks are not possible, speeds can be increased by using tilting trains. These tilt inwards as they go round curves at high speed in the same way as motorcyclists do on the road. Other special trains include magnetic levitation (maglev) trains, which are both supported above their tracks and propelled by magnets. Maglev trains can reach very high speeds because there is no friction between the train and the track.

The TGV can climb steeper slopes than other trains, allowing its purpose-built track to go straight over hills instead of around them.

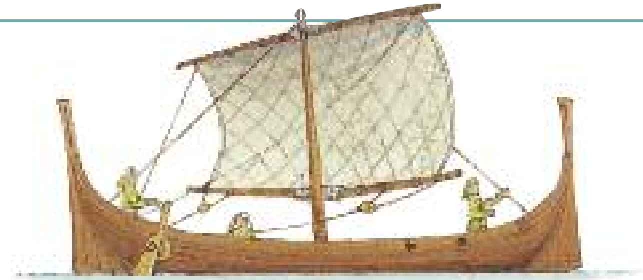
Specialized trains are often used in city centres. In Wuppertal, Germany *(left)*, trains are suspended in the air from a monorail (single rail) track. Underground trains *(right)* always use electricity because this does not create fumes. They have good acceleration in order to move quickly between closely-spaced stations.

SAILING SHIPS

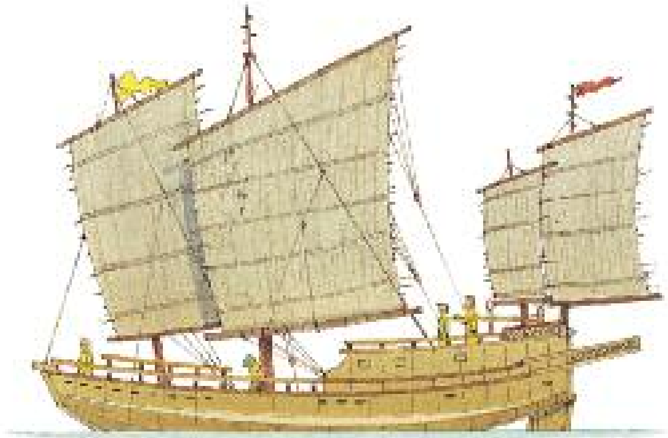
PEOPLE made their first journeys across water tens of thousands of years ago. Their first craft must have been logs, used as buoyancy aids. Later, they tied logs together to make rafts, or hollowed them out to make canoes. Where there were no big trees, they made boats from locally available materials, such as reeds or animal skins. Their boats allowed them to travel on rivers and lakes, searching for better fishing, or visiting hunting grounds.

These early craft were propelled by simple paddles, or poles pushed into the river bed. The first sailing boats we know about were built in ancient Egypt in about 3500 BC. Some were built from reeds bundled together, others from wood. They had a single mast with a square sail, which was used in addition to oars when the wind was blowing in a favourable direction. The crew steered with long oars hanging over the stern (rear).

The ancient Greeks and Romans used sturdy, seaworthy cargo boats and sleek fighting boats called galleys, both with a square sail. In battle, the galleys were propelled with oars and attacked enemy ships with a ram on their bows.

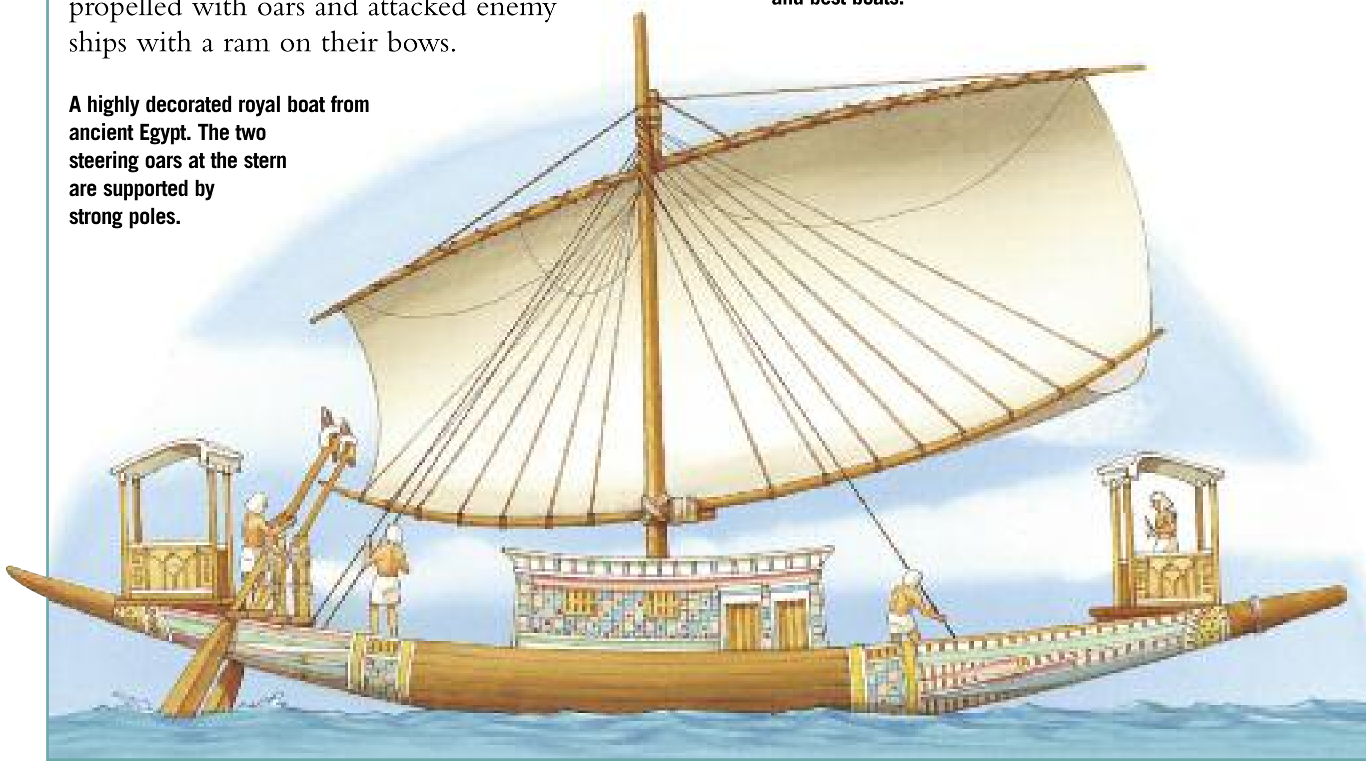


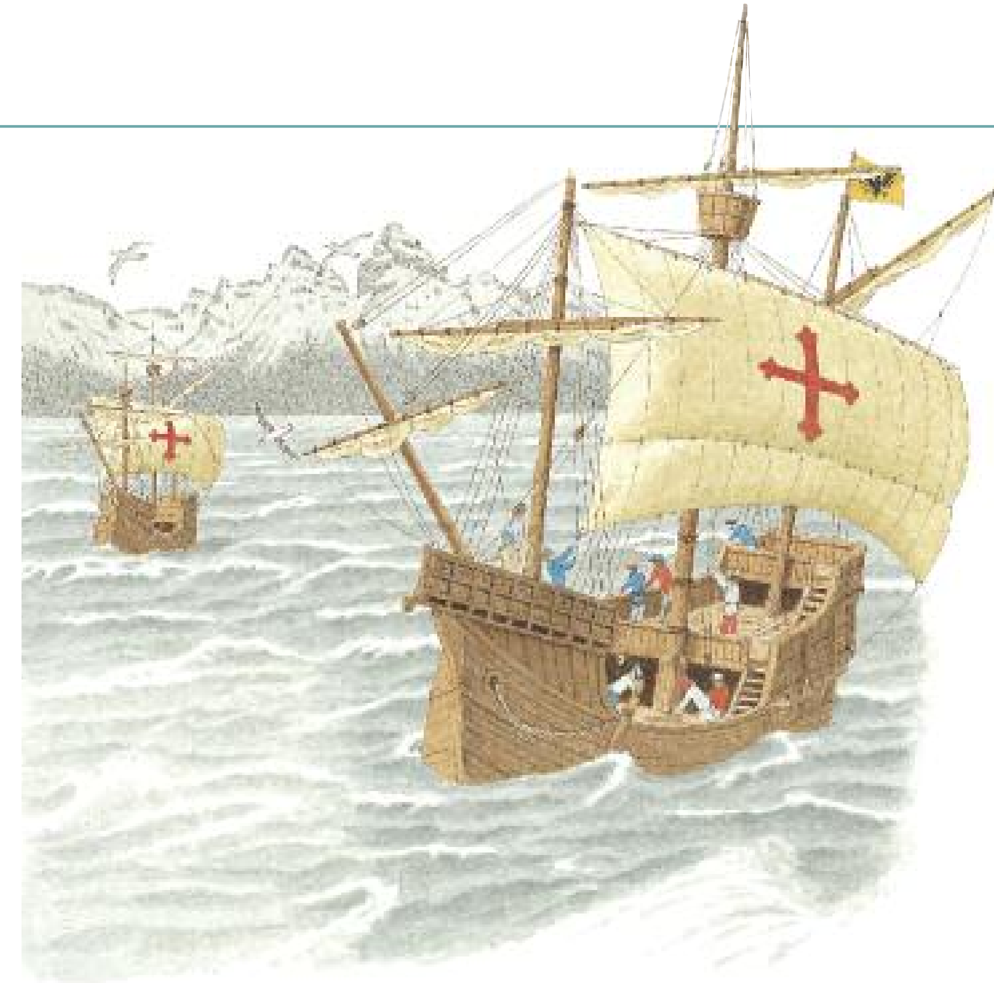
About 1000 years ago, the Vikings, who lived in northern Europe, started to explore new lands. Their ships were called knorrs *(above)*. Each had a hull (body of vessel) made of overlapping or "clinkered" planks.



Chinese boats called junks *(above)* had sails stiffened by thick bamboo poles, and a sternpost rudder for steering. Until the 15th century they were the world's biggest and best boats.

A highly decorated royal boat from ancient Egypt. The two steering oars at the stern are supported by strong poles.



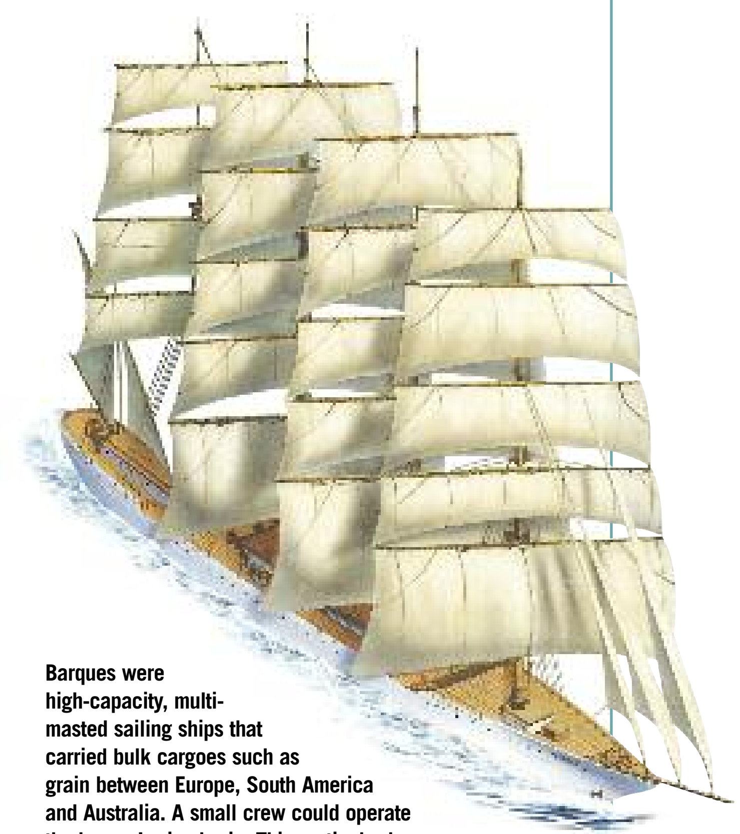


By the 16th century, small, sturdy ships such as carracks *(left)* and galleons were capable of long ocean crossings. With the aid of compasses to stop them accidentally sailing in circles, sailors set out from European ports to explore the world and to try to find new sea routes to the Spice Islands of Asia.

Among these explorers was the Portuguese navigator Ferdinand Magellan, who left Spain in 1519 with five ships to sail to Asia around the southern tip of newly-discovered America. Magellan himself was killed in the Philippines, two years into the voyage. Only one of the ships, the *Vittoria,* under the captaincy of Sebastian del Cano, finally got back to Spain, 1082 days after it left. It was the first ship to circumnavigate the world.

The arrangement of sails on a boat is called its rig. A square rig consists of sails hung on a boom across the boat (as in ancient Egyptian and Viking boats). This sort of rig cannot make the best use of wind blowing from side-on. The fore-and-aft rig, with a triangular sail hanging from a boom parallel with the boat's sides, is more effective. The Chinese had developed a similar rig on their early junks in about 500 BC. It was developed in the Mediterranean in the third century AD. In Europe in the fifteenth century, ships began to appear with a mixture of rigs—square-rigged sails on some masts and fore-and-aft rigs on others. Through the centuries, sailing ships grew larger, with more, taller masts and more sails on each one.

The fastest sailing ships were the "clippers", which had a huge sail area to take advantage of light winds, and streamlined hulls. They were used to carry important cargoes around the world, such as the new crop of tea from China to Europe.



Barques were high-capacity, multi-masted sailing ships that carried bulk cargoes such as grain between Europe, South America and Australia. A small crew could operate the barque's simple rig. This particular barque, *France II*, built in 1911, was the biggest sailing ship ever built. Its steel hull was 127 metres long.

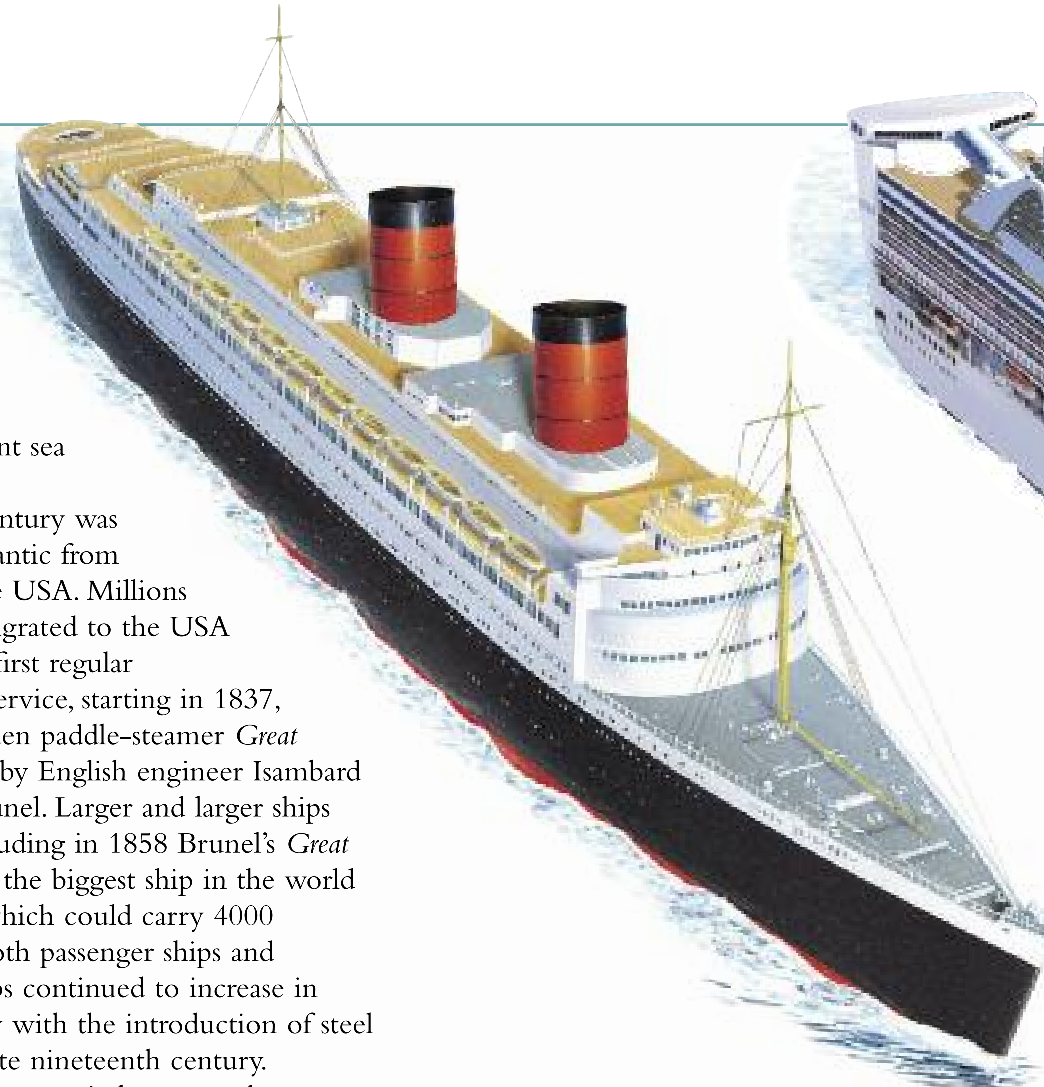
STEAMSHIPS

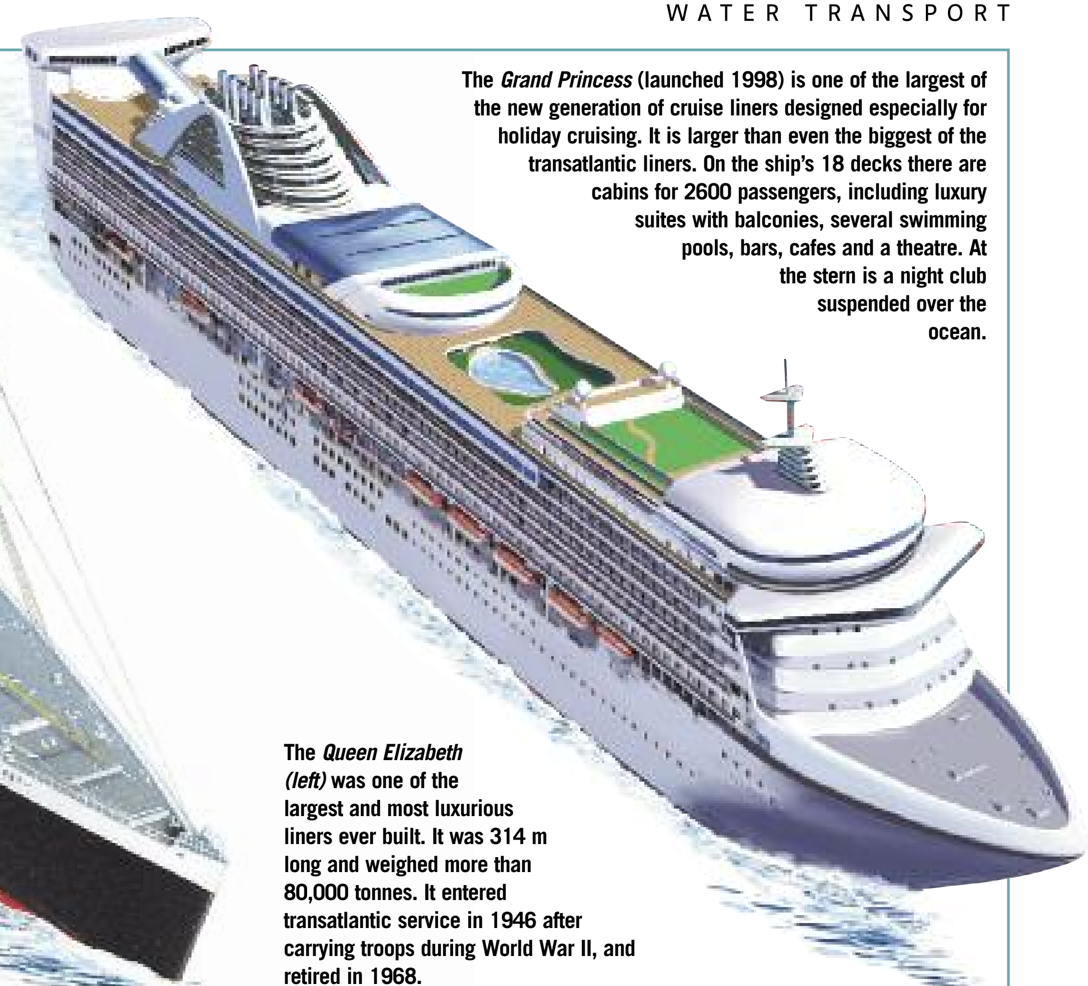
DURING the nineteenth century, large sailing ships almost completely disappeared as steam power took over. The first successful steam-powered vessel was a river steamer built in the USA by Robert Fulton in 1808. On early steamships the steam engine turned paddle wheels that moved the ship along, but by the 1850s most ships were using propellers instead. Ocean-going steamships kept sails, too, because they could not carry enough coal or water for long-distance voyages, and their engines were not very reliable.

Fifteen hundred people lost their lives when the liner *Titanic* *(above)* sank after hitting an iceberg on its maiden voyage in 1912. Following the disaster, new safety regulations for ships were introduced.

One of the most important sea routes in the nineteenth century was across the Atlantic from Europe to the USA. Millions of people emigrated to the USA in ships. The first regular transatlantic service, starting in 1837, was the wooden paddle-steamer *Great Western*, built by English engineer Isambard Kingdom Brunel. Larger and larger ships followed, including in 1858 Brunel's *Great Eastern*, easily the biggest ship in the world at the time, which could carry 4000 passengers. Both passenger ships and merchant ships continued to increase in size, especially with the introduction of steel hulls in the late nineteenth century.

By the early twentieth century, huge luxury liners were crossing the Atlantic, and steam-powered merchant ships were carrying most of the world's cargo. The fastest liners used the new steam turbine engine, in which the steam turned a fan-like turbine, which turned the propellers at high speed.





The *Grand Princess* (launched 1998) is one of the largest of the new generation of cruise liners designed especially for holiday cruising. It is larger than even the biggest of the transatlantic liners. On the ship's 18 decks there are cabins for 2600 passengers, including luxury suites with balconies, several swimming pools, bars, cafes and a theatre. At the stern is a night club suspended over the ocean.

The *Queen Elizabeth* *(left)* was one of the largest and most luxurious liners ever built. It was 314 m long and weighed more than 80,000 tonnes. It entered transatlantic service in 1946 after carrying troops during World War II, and retired in 1968.

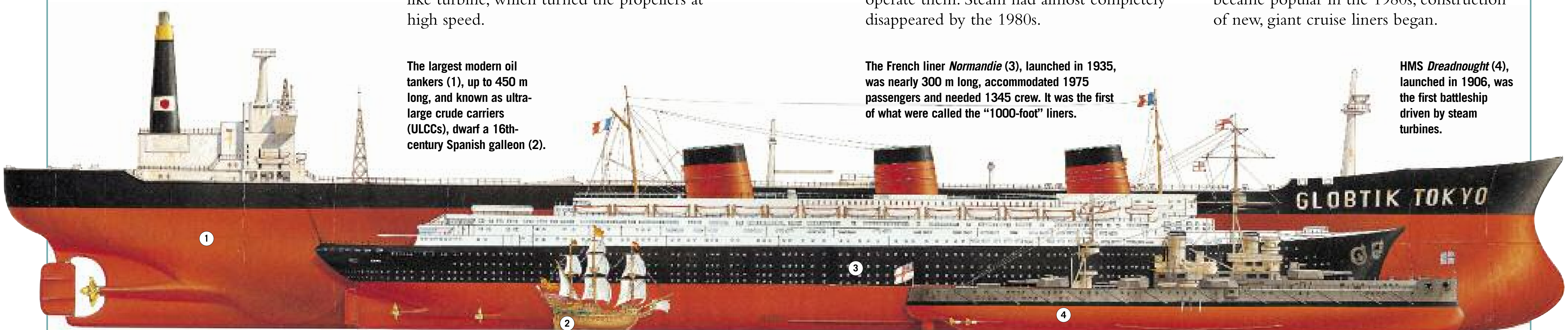
In the middle of the twentieth century, steam power began to give way to diesel power. Diesel engines are smaller, cleaner, far more efficient, and need fewer crew to operate them. Steam had almost completely disappeared by the 1980s.

As air travel became convenient and cheap in the 1960s, passengers stopped travelling by sea and the age of the liner came to an end. But as cruise holidays became popular in the 1980s, construction of new, giant cruise liners began.

The largest modern oil tankers (1), up to 450 m long, and known as ultra-large crude carriers (ULCCs), dwarf a 16th-century Spanish galleon (2).

The French liner *Normandie* (3), launched in 1935, was nearly 300 m long, accommodated 1975 passengers and needed 1345 crew. It was the first of what were called the "1000-foot" liners.

HMS *Dreadnought* (4), launched in 1906, was the first battleship driven by steam turbines.



Modern Ships

MODERN SHIPS and boats can be categorized by the the jobs they do. Merchant ships include cruise liners, ferries, cargo ships, and utility ships, such as dredgers and tugs. Military ships include warships and support ships, called auxiliaries. There are also numerous different types of fishing boat and leisure craft, from luxury yachts to sailing dinghies.

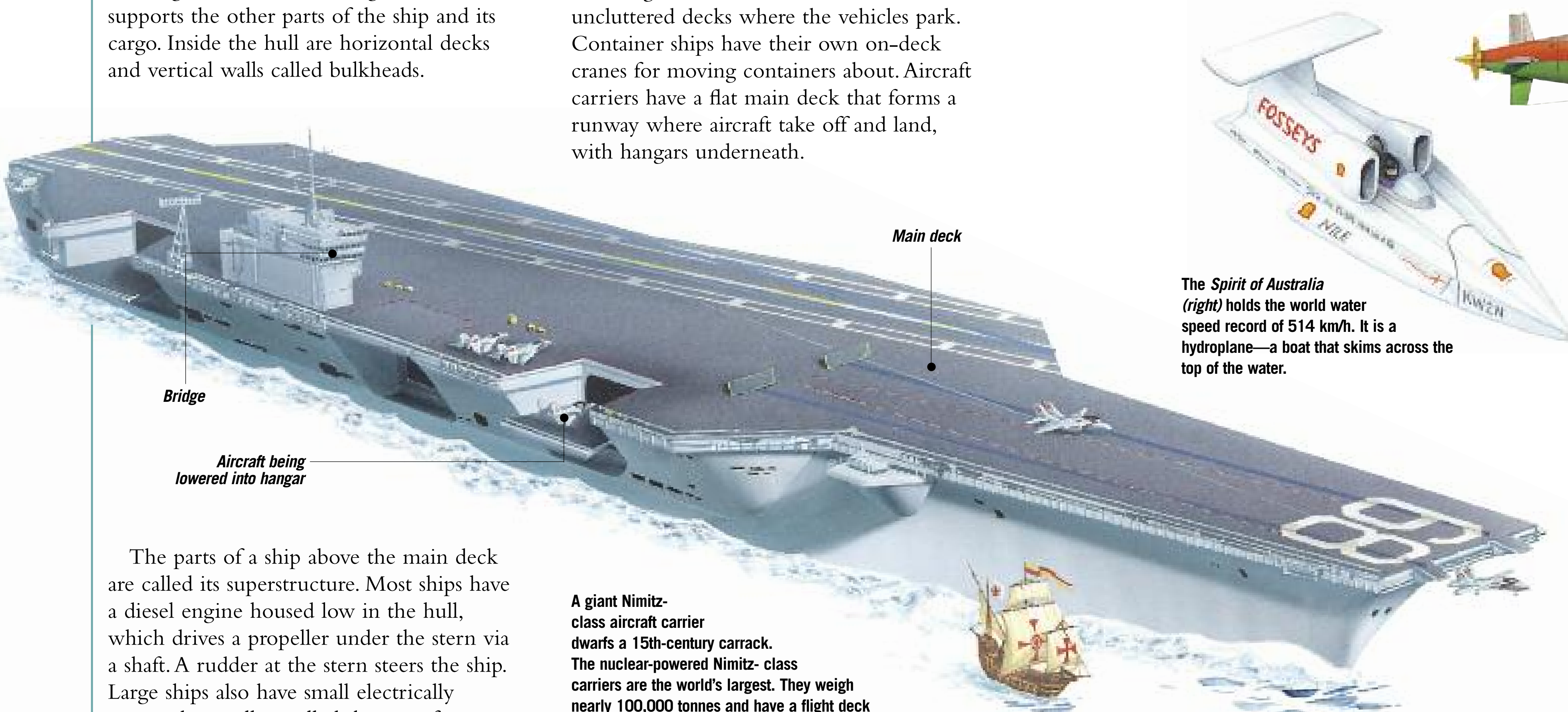
Small cargoes are carried in standard-sized metal boxes called containers on container ships, which are loaded and unloaded at dedicated container terminals. Cargoes such as ores, coal and grain are carried by bulk carriers. Oil and other liquids are carried by tankers.

The main part of a ship is its hull, the part that sits in the water. It keeps the ship watertight and forms a strong structure that supports the other parts of the ship and its cargo. Inside the hull are horizontal decks and vertical walls called bulkheads.

The SeaCat is a high-speed vehicle ferry. It is a catamaran, which means it has two hulls. Fast ferries like this are powered by gas turbine (jet) engines, giving them top speeds in excess of 40 knots (70 km/h).

Different types of ship have their own specialized parts. For example, vehicle ferries called roll-on roll-off (ro-ro) ferries, designed for a quick turnaround in port, have huge bow or stern doors, and uncluttered decks where the vehicles park. Container ships have their own on-deck cranes for moving containers about. Aircraft carriers have a flat main deck that forms a runway where aircraft take off and land, with hangars underneath.

Ships are controlled from a room high up near the bow, called a bridge. From here, the crew navigate from place to place, using engine and steering controls, and keeping track of their position using charts, satellite navigation systems, lighthouses and buoys. Radar helps to avoid collisions at night or in fog, and sonar warns of shallow water under the ship.



A giant Nimitz-class aircraft carrier dwarfs a 15th-century carrack. The nuclear-powered Nimitz- class carriers are the world's largest. They weigh nearly 100,000 tonnes and have a flight deck 333 m long. They provide an operations base for nearly 100 attack aircraft.

Santa Maria *(Columbus' ship) for scale comparison*

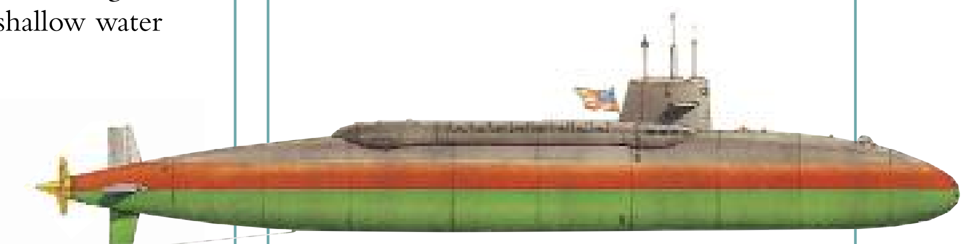
The *Spirit of Australia (right)* holds the world water speed record of 514 km/h. It is a hydroplane—a boat that skims across the top of the water.

The parts of a ship above the main deck are called its superstructure. Most ships have a diesel engine housed low in the hull, which drives a propeller under the stern via a shaft. A rudder at the stern steers the ship. Large ships also have small electrically powered propellers called thrusters for manoeuvring accurately in port.

Submarines

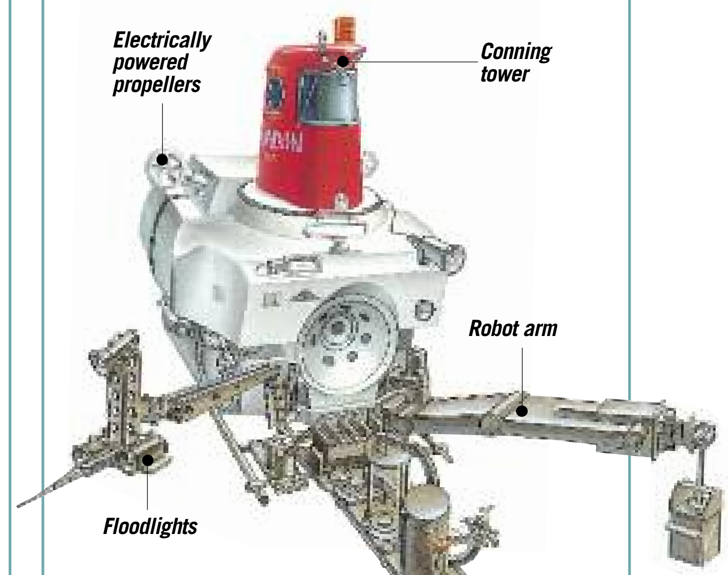
A SUBMARINE IS a vessel that can travel submerged under the water as well as on the surface. A submarine needs an extremely strong hull to resist the pressure deep under water. Ballast tanks in the hull are filled with water to make the submarine heavier so that it dives. The tanks are "blown" with air to empty them and make the submarine surface again.

While submerged, submarines are propelled by battery-powered electric motors that do not produce dangerous exhaust fumes. On the surface, diesel engines take over. They recharge the batteries at the same time.



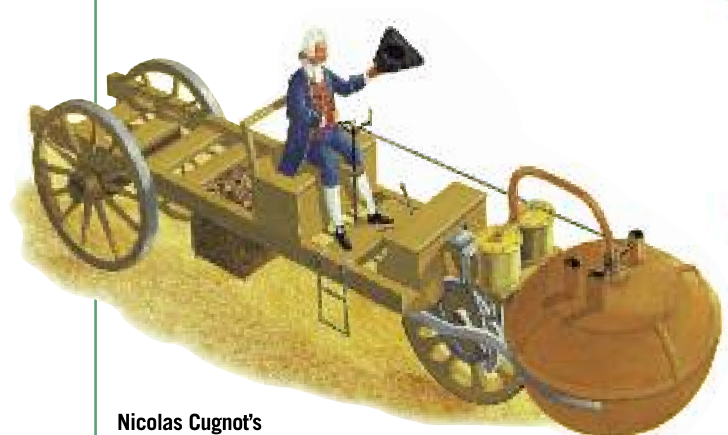
Huge military submarines such as USS *George Washington (above)* lurk under the water and attack enemy ships with torpedoes. Nuclear-powered submarines can stay submerged for months.

A submersible such as *Alvin (below)* is a miniature submarine. Submersibles are mostly used for research in the ocean depths. Robot submersibles also carry out underwater repairs on oil rigs.

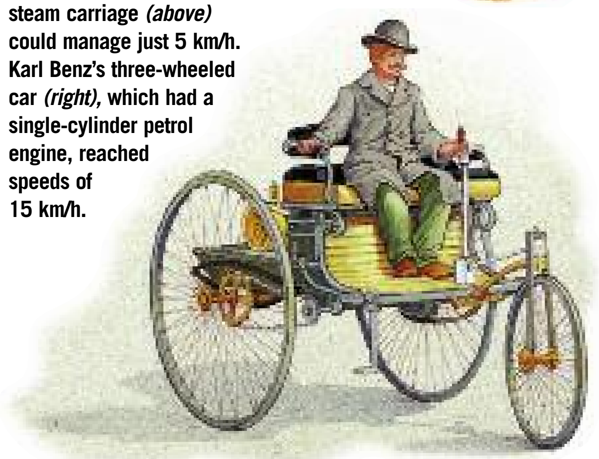


History of Cars

People had used carts pulled by horses, oxen or other large animals for more than 5000 years before the first self-propelled vehicle was built. This was a clumsy steam-powered carriage designed to pull artillery guns, built by Frenchman Nicolas Cugnot in 1769. Steam-powered vehicles called traction engines took the place of horses on farms from the 1850s. Cars driven by small steam engines were popular in the USA in the 1890s.



Nicolas Cugnot's steam carriage *(above)* could manage just 5 km/h. Karl Benz's three-wheeled car *(right)*, which had a single-cylinder petrol engine, reached speeds of 15 km/h.



The age of the car really started with the development of the internal combustion engine. This development began in the 1850s, but it was not until the 1880s that small, lightweight, petrol-driven engines were perfected, first of all by Gottlieb Daimler in Germany. The first petrol-driven car was built by German engineer Karl Benz in 1885.

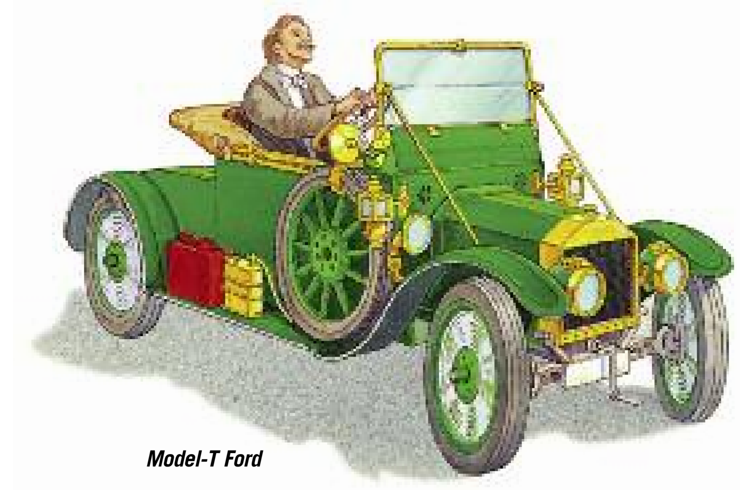
The first two strokes of the four-stroke cycle are the inlet stroke *(left)* and the compression stroke *(right)*.

The cycle is completed by the ignition stroke *(left)*, which creates the power, and the exhaust stroke *(right)*.

Internal Combustion Engine

The job of the internal combustion engine is to convert the energy stored in its fuel into movement. Inside the heavy engine block are cylinders (normally four in a car engine). Pistons fit snugly inside the cylinders. When the engine is running, the pistons move up and down, turning a crankshaft (which turns the wheels) via connecting rods.

Most internal combustion engines work on a four-stroke cycle which is repeated again and again as the pistons move up and down. On the first stroke, as the piston moves down, the inlet valve opens to allow a mixture of fuel and air to be sucked into the cylinder (1). On the second stroke, as the piston moves up, the air and fuel is squeezed into the top of the cylinder (2). Now a spark is created electrically by the spark plug, igniting the fuel, which forces the cylinder down (3). This is the third stroke. On the fourth stroke, the exhaust valve opens to let waste gases be forced out as the piston moves up again (4).



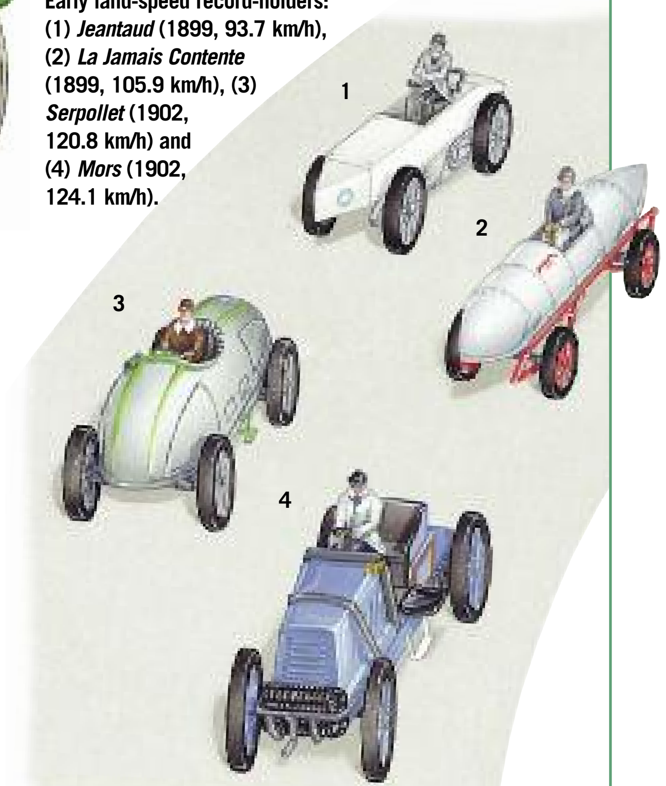
Model-T Ford

The Motor Age Begins

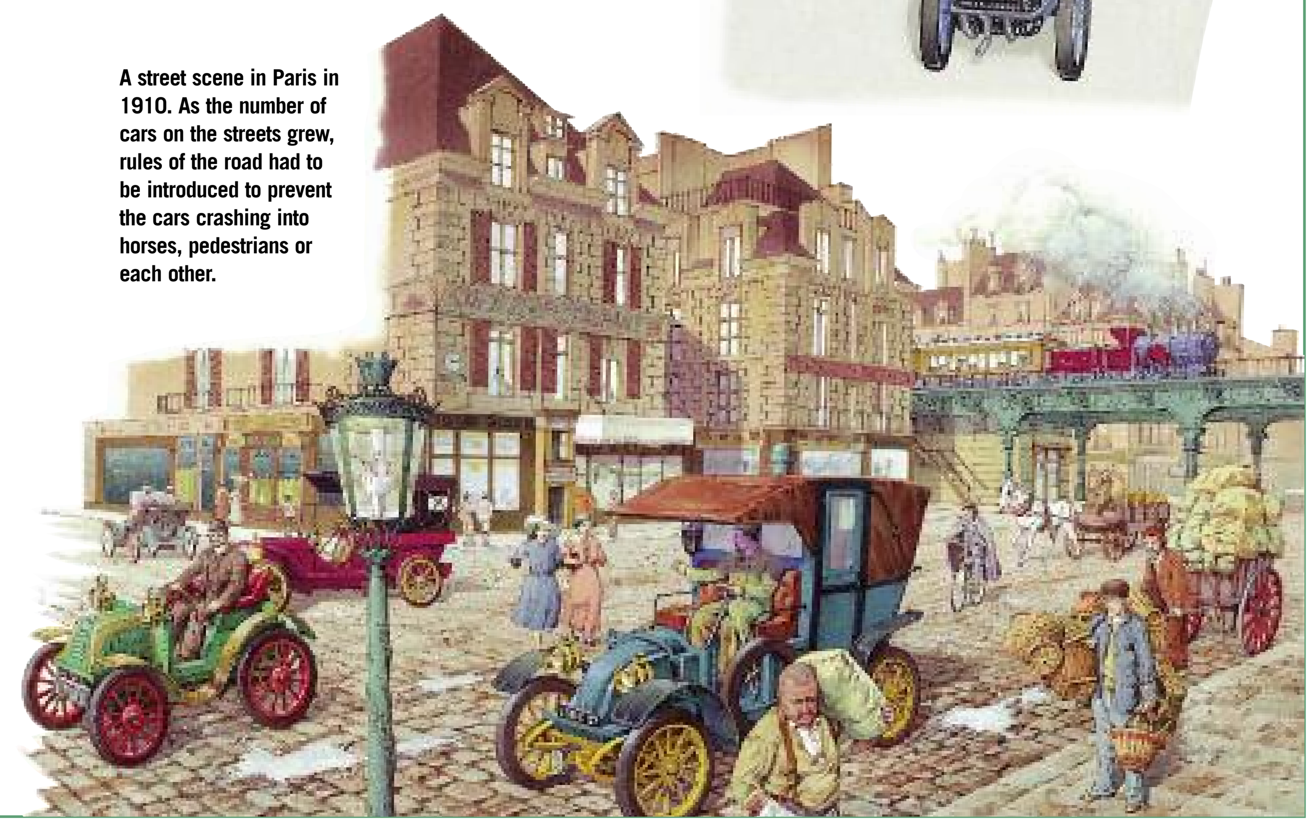
Benz and Daimler started selling cars in the late 1890s. In 1891 the first car with a front engine and rear-wheel drive appeared. Early cars were tricky to operate, slow and hand-built, which made them expensive. In 1908 motoring was opened up to ordinary people with the introduction in the USA of the Model-T Ford *(above)*. This small car was built on a production line, making it cheap to make and so cheap to buy.

Meanwhile, motor sports were becoming popular, with cars taking part in races and rallies, and car builders competing to build the world's fastest car. The land-speed record was first set in 1898, at 63 kilometres per hour.

Early land-speed record-holders: (1) *Jeantaud* (1899, 93.7 km/h), (2) *La Jamais Contente* (1899, 105.9 km/h), (3) *Serpollet* (1902, 120.8 km/h) and (4) *Mors* (1902, 124.1 km/h).

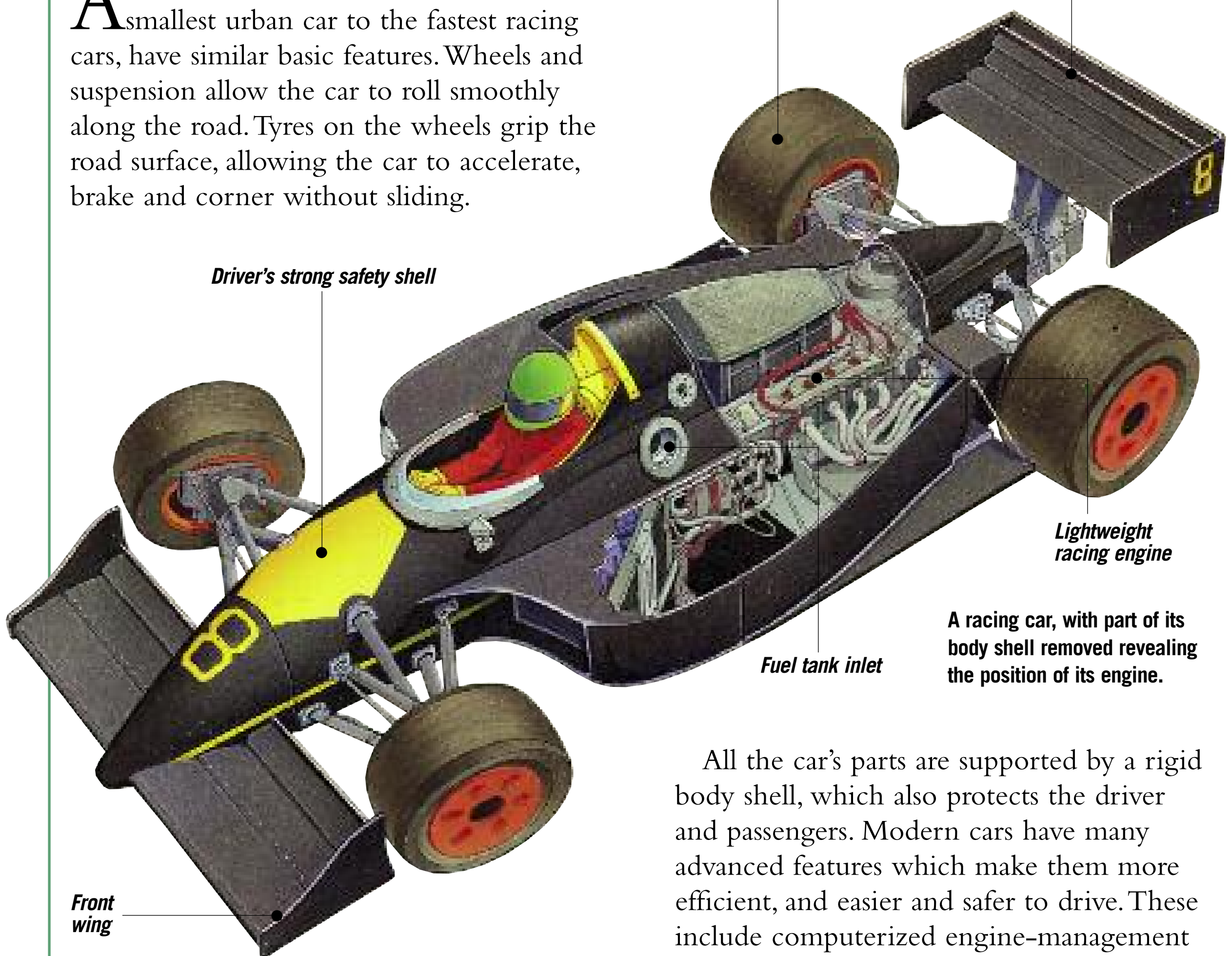


A street scene in Paris in 1910. As the number of cars on the streets grew, rules of the road had to be introduced to prevent the cars crashing into horses, pedestrians or each other.



Modern Cars

ALL MODERN CARS, from the smallest urban car to the fastest racing cars, have similar basic features. Wheels and suspension allow the car to roll smoothly along the road. Tyres on the wheels grip the road surface, allowing the car to accelerate, brake and corner without sliding.



A racing car, with part of its body shell removed revealing the position of its engine.

Power from the engine is transferred to the wheels by the transmission, including the gears. The fuel and exhaust systems supply fuel to the engine and carry away waste gases. The electrical system supplies electricity to the engine's spark plugs, the car's lights and other electrical gadgets.

All the car's parts are supported by a rigid body shell, which also protects the driver and passengers. Modern cars have many advanced features which make them more efficient, and easier and safer to drive. These include computerized engine-management systems which control the flow of fuel to the engine, navigation computers which give the driver directions, anti-lock brakes which prevent skidding, and air bags which protect the driver in an accident. Many of these features were originally developed to improve the performance of racing cars, but have become standard on road cars.

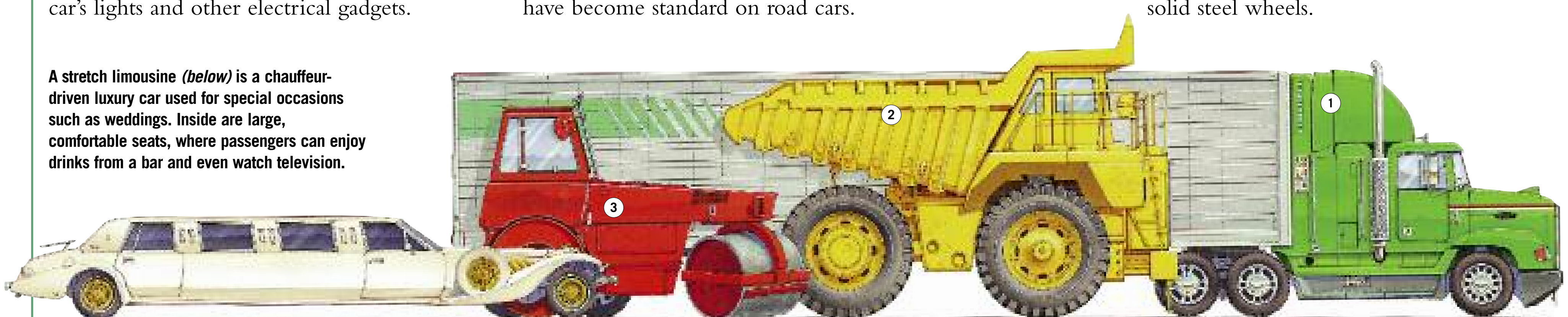
Aerodynamics

The way air flows around a moving body is called aerodynamics. As cars move along, the air flowing around them tries to slow them down. The effect is called drag, and it prevents cars from continuing to speed up. The more streamlined the shape of a car, the lower the drag on it, and so the faster its top speed. Racing cars *(left)* have special aerodynamic features, such as wings that create downforce. These force a car's tyres on to the road, increasing grip and allowing the car to corner more quickly without skidding sideways.

Aerodynamics are especially important in very high-speed cars, such as *Thrust SSC*, which holds the land-speed record of 1227.723 km/h. It is the only car to have gone faster than sound.

All road vehicles have similar features to cars, but the features are often specialized. For example, large haulage trucks (1) have many wheels to spread their heavy load. Off-road vehicles, such as dumper trucks (2), have large wheels with chunky tyres for good grip in the mud. Road-rollers (3) have solid steel wheels.

A stretch limousine *(below)* is a chauffeur-driven luxury car used for special occasions such as weddings. Inside are large, comfortable seats, where passengers can enjoy drinks from a bar and even watch television.



Bicycles

A BICYCLE is a human-powered vehicle with two wheels. The first bicycles, called "hobby horses", were built about 200 years ago. The rider moved along by pushing his or her feet against the ground. The first pedal-powered bicycle was made by Scottish blacksmith Kirkpatrick Macmillan in 1839. In 1861 in Paris, Pierre Michaux built a bicycle on which the pedals turned the front wheels. It was known as the "boneshaker" and was the first popular bicycle. The modern bicycle, with a diamond-shaped frame and chain-driven back wheel, was designed in 1885 by Englishman John Starley.

Motorcycles

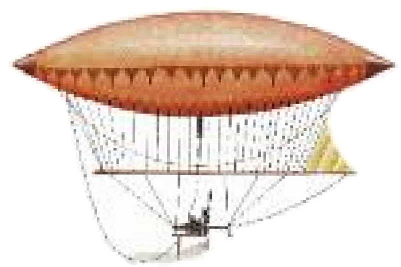
Early motorcycles were simply bicycles with a small steam engine attached, but they were not practical machines. The first modern-style motorcycles, with a metal frame, two air-filled tyres and a lightweight petrol engine, appeared around 1900. Modern motorcycles have similar features to cars, but have much greater acceleration.

Story of Flight I

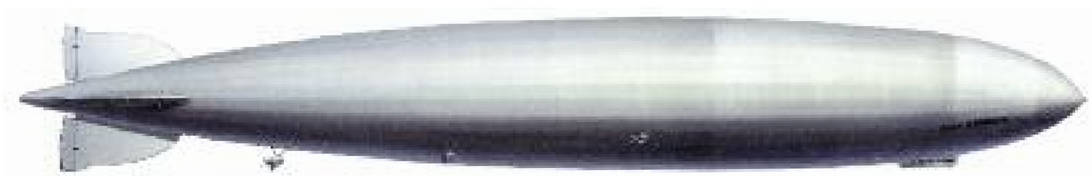
FOR THOUSANDS of years, people must have watched birds flying around them and dreamed of copying them. Many actually tried it. These “birdmen” strapped on wings and leapt from towers, trying to flap their arms. Most were killed.

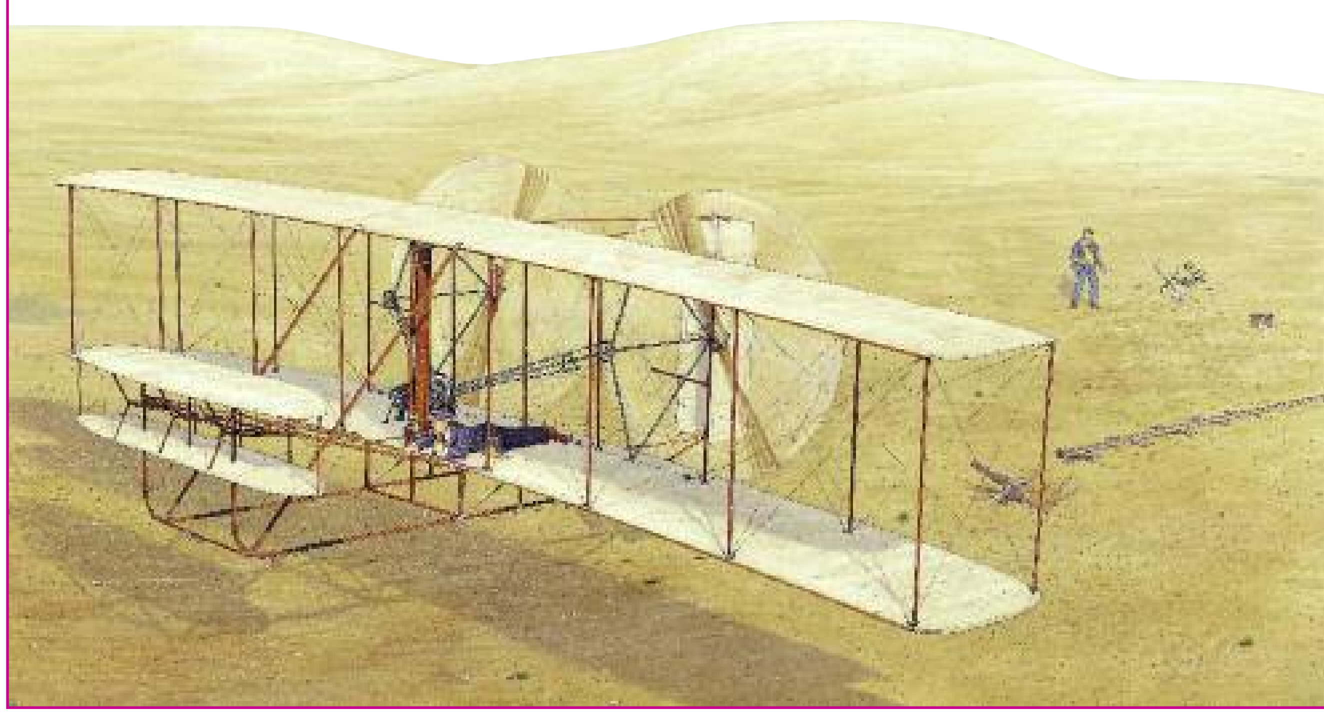
The first manned flight took place in Paris in 1783, in a hot-air balloon built by the French brothers Joseph and Etienne Montgolfier. Aviators also began to develop airships—balloons with a streamlined shape, pushed through the air by an engine. Balloons and airships are described as lighter-than-air aircraft because they float upwards in the heavier air around them.

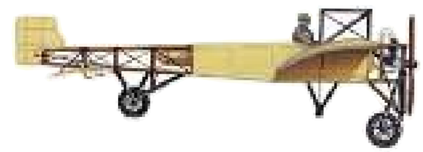
The first heavier-than-air aircraft were gliders, built and flown in the nineteenth century by pioneers such as the German Otto Lilienthal. In the USA, two brothers, Orville and Wilbur Wright, were experimenting with kites and gliders. They made thousands of test flights in their gliders, gradually perfecting their controls. In 1903 they finally built an aeroplane, called *Flyer 1*, with a petrol engine. It made the first-ever powered, controlled aeroplane flight, which lasted just 12 seconds *(below)*.



The Montgolfiers’ balloon *(above)* carried the first pilot and passenger on a 25-minute flight. The air in the balloon was heated by straw burning on the ground. In 1852 Frenchman Henry Giffard took off in his steam-powered airship *(above right)*. The envelope was filled with lighter-than-air hydrogen gas rather than hot air. Airships such as the 245-metre-long *Graf Zeppelin II (right)* had a steel skeleton covered in fabric. The gas was contained in huge bags inside.

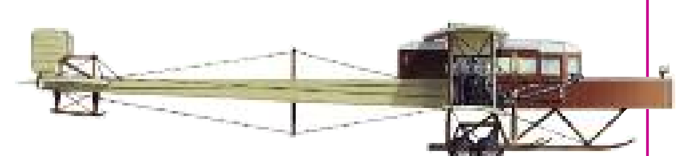






The Blériot XI, in which Louis Blériot crossed the English Channel in 1909.

In the decade after the Wright brothers’ historic flight, aviation became a popular sport. Race meetings and airshows were held, and pilots made historic long-distance flights. Aircraft technology steadily improved. Aviators began to understand how to build stronger aircraft structures without increasing weight, wings which gave better lift and created less drag, and controls that made life easier for the pilot. The standard aircraft shape, with a tail section supporting a fin and tailplane, began to become popular. More efficient and powerful engines and propellers gave aircraft greater speed, endurance and reliability. By 1913 the speed record was 203 kilometres per hour, and the distance record 1021 kilometres.



The Sikorsky *Le Grand (above)*, the first four-engined aeroplane, and the Spad S.XIII World War I fighter *(right)*.

Armies began ordering aircraft from manufacturers such as Glenn Curtiss in the USA and Louis Blériot in France. During World War I, aircraft became specialized for certain jobs, such as fast, manoeuvrable fighters and large, long-distance bombers. Large, flat decks were added to some battleships where aircraft could take off to attack enemy ships with torpedoes.

Helicopters

THE IDEA of a flying machine lifted by a spinning rotor is centuries’ old. The Italian painter and scientist Leonardo da Vinci designed a simple helicopter in about 1500, but he did not have an engine to power it. In 1907 Frenchman Paul Cornu rose 30 centimetres into the air in a twin-rotor helicopter, but he had no controls.

The Focke-Achgelis Fa-61 *(right)* of 1936, the first successful helicopter, and the Sikorsky VS-300, the first single-rotor helicopter *(below)*.

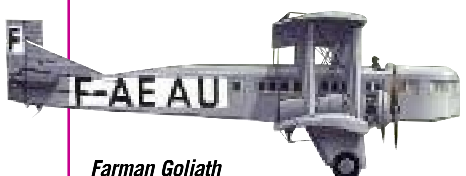
The first successful helicopters, built in the 1930s, had two rotors for lift and a propeller for propulsion. The single-rotor helicopter was developed by Russian-born American engineer Igor Sikorsky. The main rotor provided lift and propulsion, and the tail rotor prevented the fuselage (body of the aircraft) spinning in the opposite direction to the main rotor. Helicopters were soon being used by navies and for passenger services. The development of the jet engine in the 1950s made larger, faster helicopters possible.

Westland Sea King

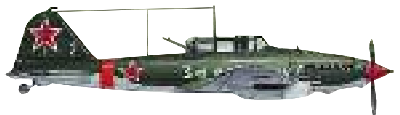
STORY OF FLIGHT II

THE FIRST PASSENGER airlines were formed in 1919, just after the end of World War I. Their airliners were converted wartime bombers, such as the Farman Goliath, which had seats for 11 passengers. Flying in them was cold and bumpy, and there was noise and vibration from the piston engines. In the 1920s and 1930s aviation engineers began building in metal instead of wood, creating aircraft with strong tubular fuselages and monoplane wings, such as the Martin B-10 bomber.

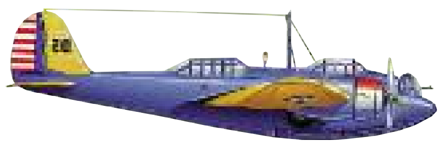
The first modern-style airliners, such as the Douglas DC-3, appeared in the mid-1930s. During World War II pilots needed heavy bombers, such as the B-24 Liberator, and fast fighters, such as the Ilyushin Il-2.



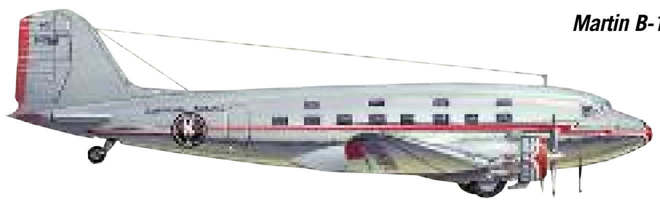
Farman Goliath



Ilyushin Il-2

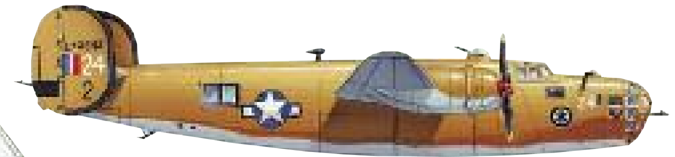


Martin B-10



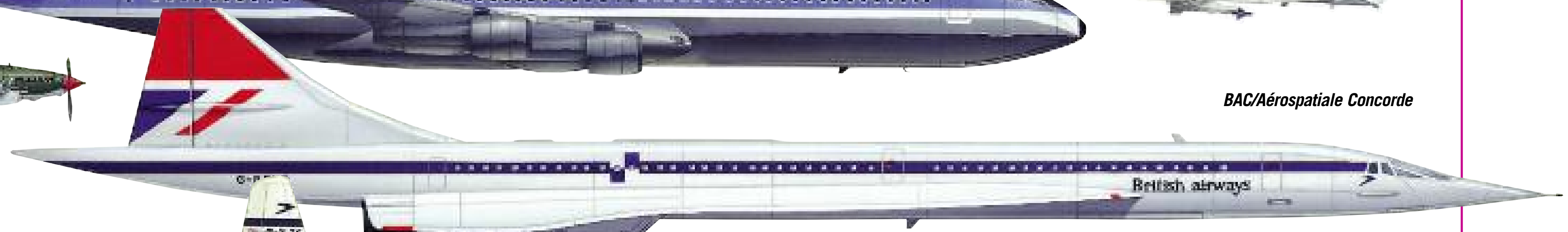
Douglas DC-3 Dakota

ALL AIRCRAFT TO SCALE

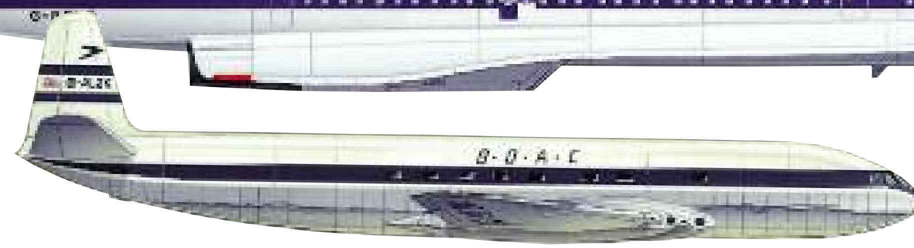


Consolidated B-24 Liberator

Boeing 707



BAC/Aérospatiale Concorde

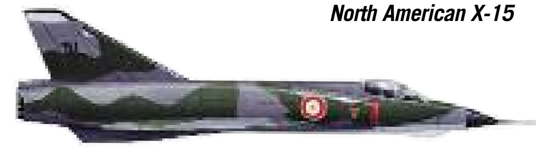


De Havilland Comet

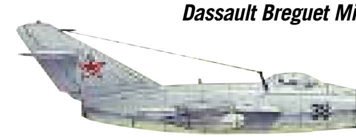
Lockheed C-130

In 1926 a prize of $25,000 was offered to the first pilot who could fly non-stop from New York to Paris. American airmail pilot Charles Lindbergh took up the challenge. He had a new, all-metal monoplane, the *Spirit of St. Louis,* built especially for the journey, and decided to fly on his own. Lindbergh took off from New York on 19th May 1927. Navigating virtually by guesswork, flying low to avoid fog and fighting sleep, Lindbergh reached Paris 33 hours and 30 minutes later, to achieve the first solo Atlantic crossing.

North American X-15



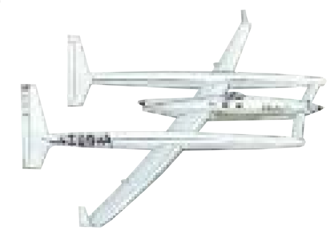
Dassault Breguet Mirage III



Mikoyan-Gurevich MiG-15

The introduction of long-range, economical, jet-powered airliners, such as the De Havilland Comet and the Boeing 707, the first "big jet", led to a huge boom in airline travel. The first (and so far the only) supersonic airliner, the Concorde, was introduced in 1969, and the first wide-bodied airliner, the Boeing 747, came into operation in 1970 *(see page 24).*

Eurofighter Typhoon



Two of the strangest aircraft are the Rutan *Voyager (right),* which made the first non-stop round-the-world flight in 1986, and the Northrop B-2 "stealth" bomber *(below).*

JET AIRCRAFT

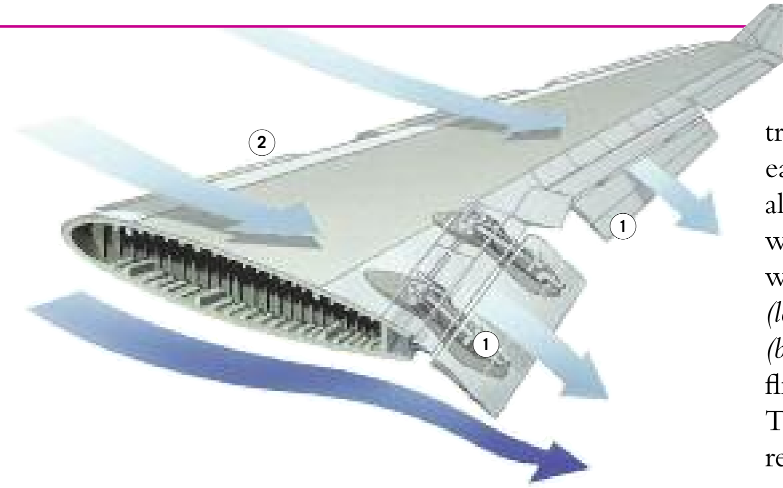
The jet engine was developed in the late 1930s, both by Hans von Ohain in Germany and Frank Whittle in Britain. The first jet aircraft flew in 1939. Jet engines powered new jet fighters with swept-back wings, such as the MiG-15 and later the Mirage, and a new generation of airliners. Rocket-powered aircraft such as the X-15 were built for research into high-speed flight. The X-15 still holds the world speed record of 7274 kilometres per hour.

The latest airliners, fighters such as the Eurofighter, and bombers such as the Northrop B-2, have sophisticated control systems, such as "fly-by-wire". In an aircraft with a fly-by-wire system, the pilot controls where the aircraft goes, but a computer actually does the flying. In an airliner, fly-by-wire can prevent the pilot making mistakes such as stalling. In a fighter, it allows the pilot to make manoeuvres that would be impossible if he or she were using a standard mechanical control system.

Boeing 747

ALL MODERN aeroplanes have similar features, although those of airliners such as the Boeing 747 are larger and more complex than those of smaller aeroplanes. The fuselage is a strong tube inside which the passengers, crew and their baggage travel. Wings support the aeroplane in the air by creating a force called lift. Engines *(see page 27)* provide a forward force called thrust, which pushes the aeroplane forwards against the resistance of the air (which is called drag). The fin and tailplane keep the plane flying straight and level. Hinged sections called control surfaces (the rudder, elevators, and ailerons) steer the aircraft through the air.

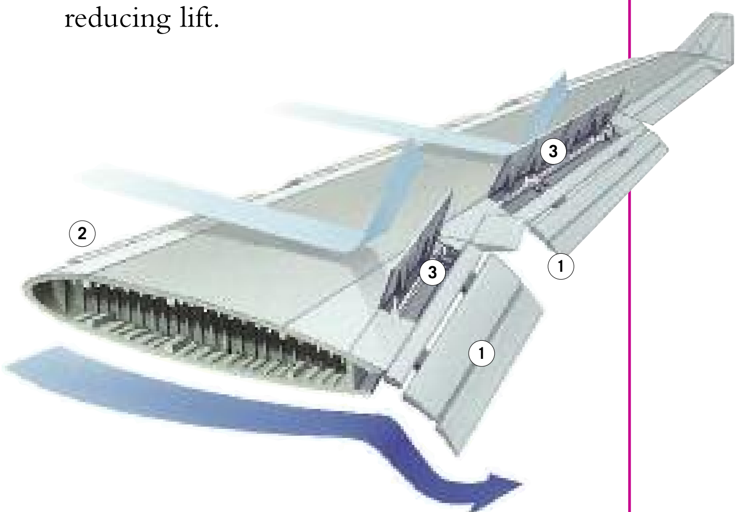
The Boeing 747-400, shown here, is one of the world's largest airliners, also known as the "Jumbo Jet". It can carry up to 569 passengers (but normally carries 420 in first, business and economy cabins), and cruises at up to 985 kilometres per hour, at an altitude of 10 kilometres. Its maximum range is 14,100 kilometres—more than a third of the way round the world.



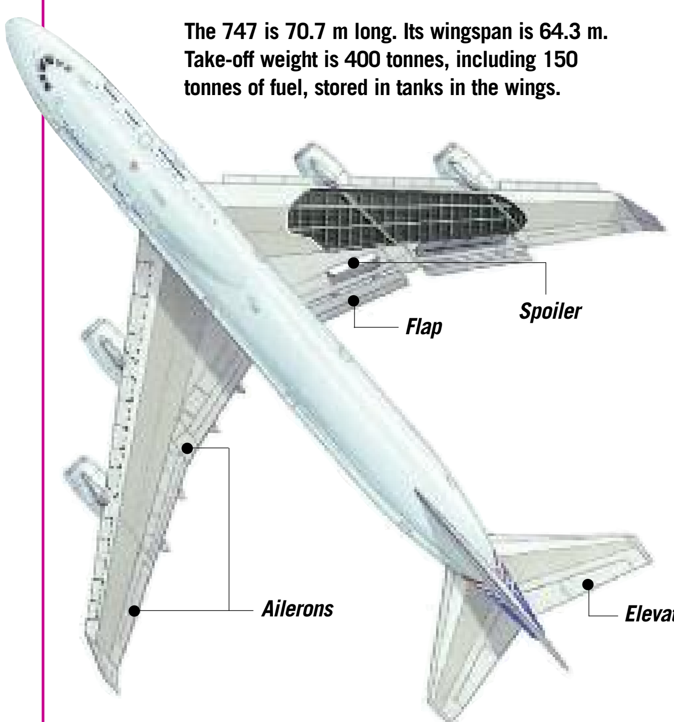
Controlling Lift

The amount of lift from a wing increases with the aeroplane's speed and also with the angle of attack, the angle at which the wing hits the air. At lower speeds, the pilot maintains lift by raising the nose of the plane to increase the angle of attack. But if the angle becomes too great, air cannot flow smoothly over the top of the wing and lift is lost. This is called a stall.

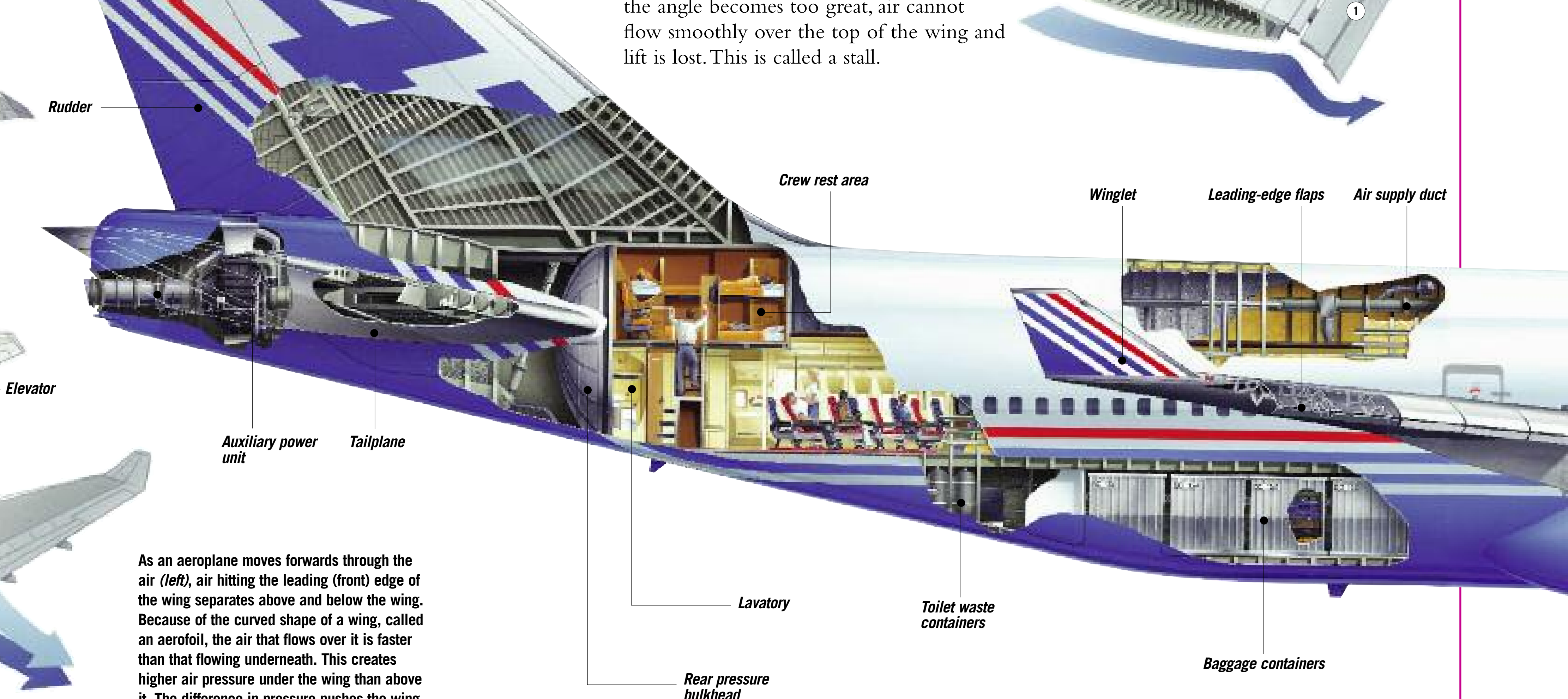
At low speed during take-off and landing, flaps (1) extend from the trailing (rear) edge of the wing. On the 747, each set of flaps has three sections. There are also small flaps on the leading edge of the wing (2). Flaps increase the size of the wing, and so create extra lift. For take-off *(left)*, flaps are partly extended. For landing *(below)* they are fully extended. Spoilers (3) flip up from the upper surface of the wing. They break the flow of air over the wing, reducing lift.



The 747 is 70.7 m long. Its wingspan is 64.3 m. Take-off weight is 400 tonnes, including 150 tonnes of fuel, stored in tanks in the wings.



As an aeroplane moves forwards through the air *(left)*, air hitting the leading (front) edge of the wing separates above and below the wing. Because of the curved shape of a wing, called an aerofoil, the air that flows over it is faster than that flowing underneath. This creates higher air pressure under the wing than above it. The difference in pressure pushes the wing upwards with a force called lift.

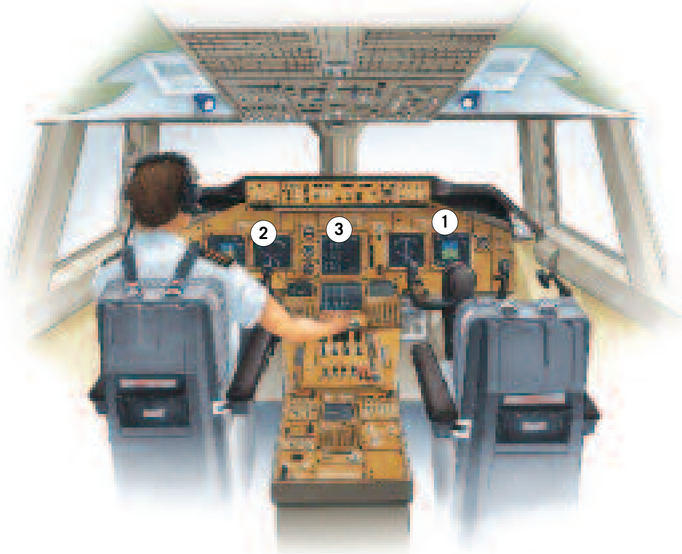


INSIDE AN AIRLINER

SEATED AT THE controls on the flight deck are the pilot and co-pilot. For much of the journey, the controls are switched to an automatic control system, or autopilot. This uses computers to sense outside conditions, such as wind speed, and to manipulate the controls accordingly to travel along a pre-set route. All the crew have to do is to keep an eye on the monitors to check that all systems are functioning correctly.

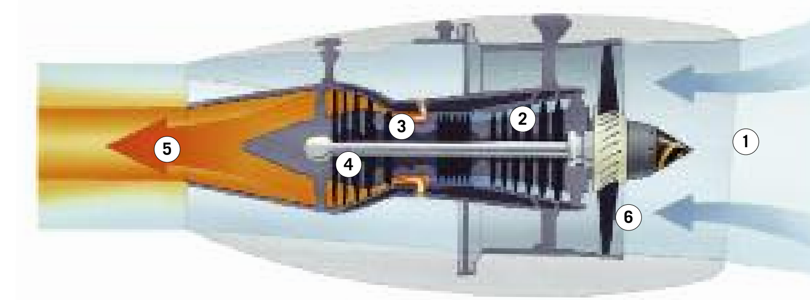
For safety reasons, a Boeing 747 is equipped with a voice recorder and a flight recorder, sometimes known as the "black box" (although it is actually a bright orange colour). These instruments record every manoeuvre the aircraft makes. In the event of an incident or a crash, the recordings can be played back and provide evidence for what went wrong.

Six display screens—three for each pilot—give all the information needed to fly the plane. The Primary Flight Display (1) shows the aeroplane's attitude—the angle at which it is flying in relation to the Earth. It also indicates the plane's course, its speed and the height of the plane above the land or sea. The Navigation Display (2) plots the plane's position on a map of the route. The Engine Indication and Crew Alerting System (EICAS) (3) gives information about the operation of the aeroplane's systems and engines.



A Boeing 747's flight deck controls

In a jet engine *(right),* air is drawn in (1), compressed by spinning blades (2), mixed with kerosene fuel and burned in a combustion chamber (3). The hot exhaust gas escapes at speed through the rear of the engine, turning a turbine (4) (which drives the compressor) as it spurts past. The backward-flowing air (5) provides a forward thrust, like the kick of a rifle after a bullet is fired.



JET ENGINES

There are four engines on a Boeing 747, two on each wing, contained within engine cowlings (casings) attached to the wing undersides. The front entrance to the engine, known as the intake, is so large a person could stand in it.

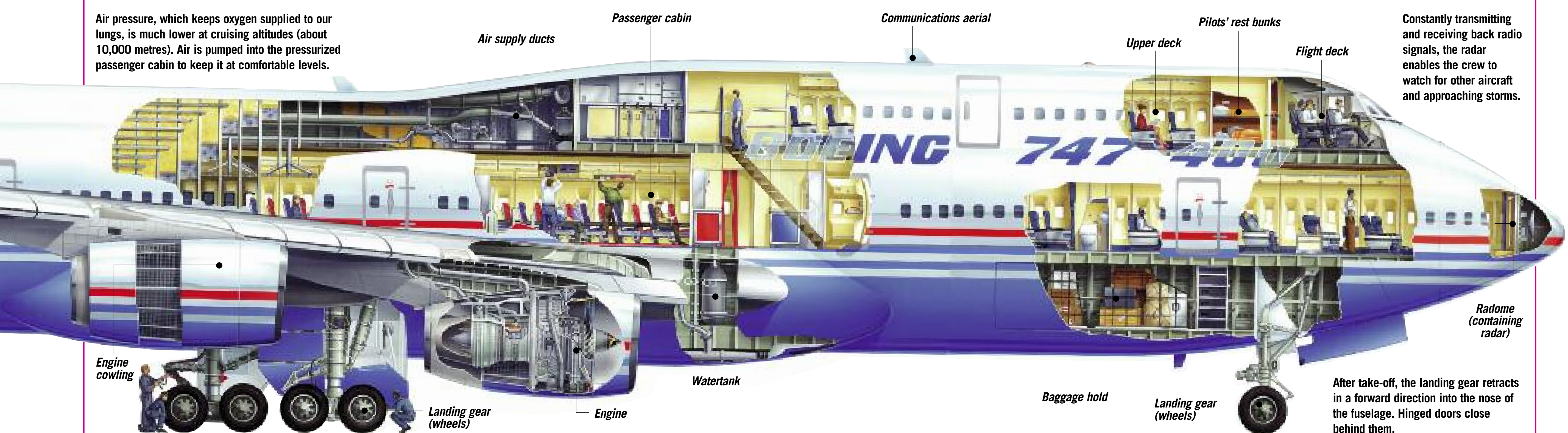
The 747 engine is a type of jet engine called a turbofan. All jets work in the same way: hot, compressed air is expelled from the back of the engine, driving it forwards (see illustration above). In a turbofan, air is sucked into the engine by a whirling fan (6) in front of the compressor. It is driven by another turbine at the rear of the engine.

Some of the inflowing air is ducted around the combustion chamber to join the exhaust gas. Besides being much more powerful than other types, the engine is cooler and quieter, and more economical in its use of fuel.

Turbofan engines are equipped with thrust reversers. When in use, the jet of hot exhaust gases is deflected forwards instead of backwards, producing a force which rapidly slows down the plane landing on the runway.

Besides driving the plane through the air, the engines supply the power needed for the electricity used on board. Air is also diverted from the engine compressor to pressurize the cabin.

Air pressure, which keeps oxygen supplied to our lungs, is much lower at cruising altitudes (about 10,000 metres). Air is pumped into the pressurized passenger cabin to keep it at comfortable levels.



Constantly transmitting and receiving back radio signals, the radar enables the crew to watch for other aircraft and approaching storms.

After take-off, the landing gear retracts in a forward direction into the nose of the fuselage. Hinged doors close behind them.

SPACE TRAVEL I

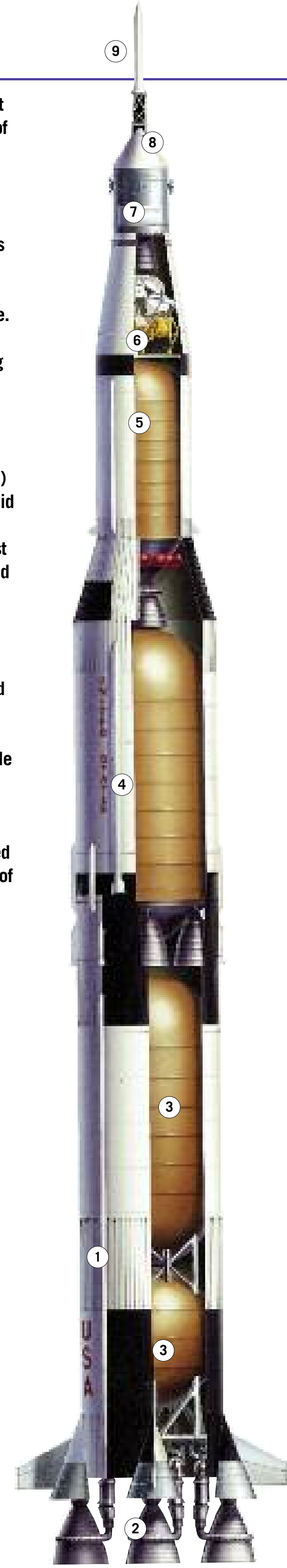
ALTHOUGH SPACE starts just 100 kilometres above the Earth's surface, it is very difficult to get there. Aeroplanes cannot reach space because the air gets thinner and thinner with altitude. Their wings begin to lose lift and their jet engines stop working through lack of oxygen. So spacecraft need rocket engines which work in the vacuum of space. To travel in space, a spacecraft must reach a speed of 28,500 kilometres per hour, the minimum speed required to escape the pull of the Earth's gravity. Once in space, the craft's engines can be turned off. It maintains its speed because there is no air to slow it down.

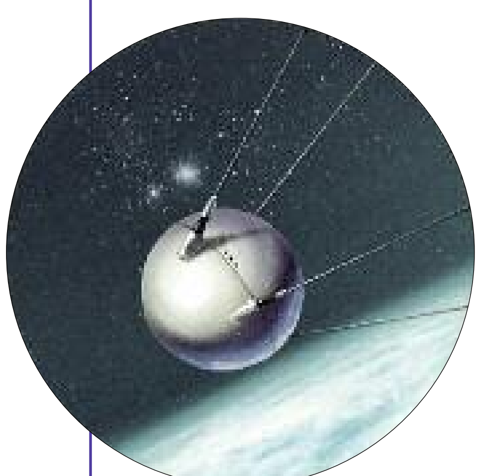
In a rocket engine, two different fuels mix and react together inside a combustion chamber, creating hot gases that rush out of a nozzle at great speed. The gases rushing in one direction push the engine and the spacecraft in the opposite direction. The first experimental rocket was launched in 1926 by the American inventor Robert Goddard, but it was not until the 1950s that a rocket powerful enough to reach space was developed. Spacecraft are normally carried into space by rocket-powered launch vehicles, which are huge compared to the spacecraft. For example, the 140-tonne Apollo spacecraft needed a 3000-tonne Saturn V rocket to launch it. Most of the weight was fuel.

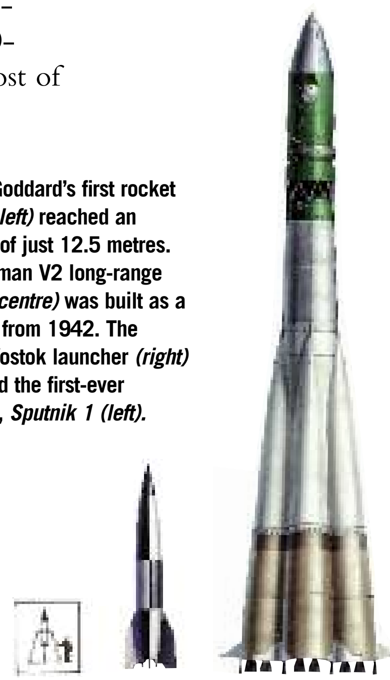
The enormous Saturn V, built to launch the Apollo series of spacecraft *(see opposite)*, consisted of three rocket stages. In a multi-stage rocket, the engines of each stage fire until their fuel runs out. Then the stage is jettisoned (cast off) and the engines of the next stage fire. The rocket gets lighter each time a stage is lost, allowing it to accelerate more easily. This is more efficient than one rocket.

The first stage (1) of a Saturn V had five engines (2) fuelled by kerosene and liquid oxygen stored in huge tanks (3). It created as much thrust as 50 jumbo jets. The second stage (4) also had five engines, fuelled by liquid hydrogen and oxygen. The third stage (5) had one engine, also fuelled by liquid hydrogen and oxygen.

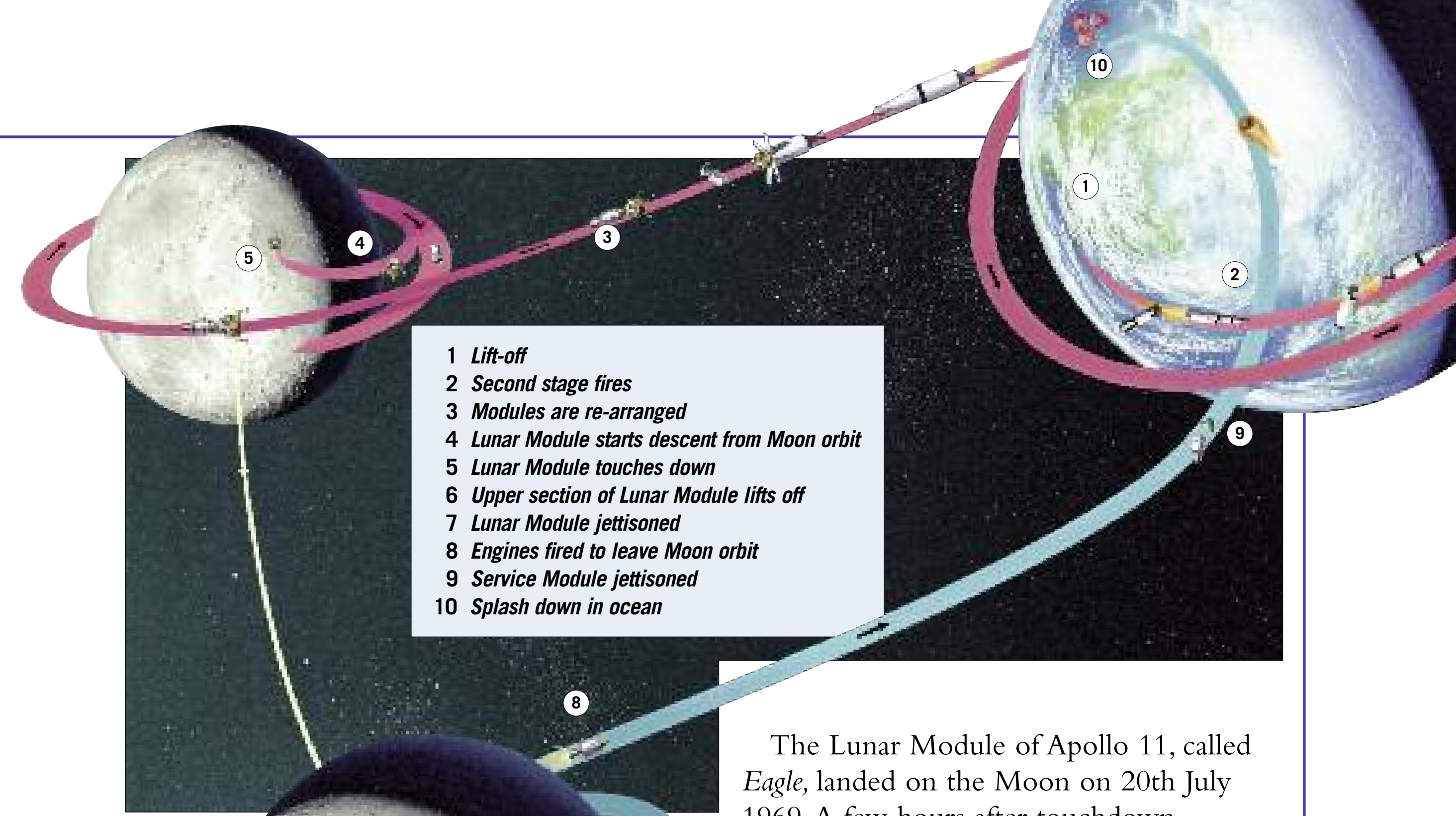
On top of the 111-metre rocket were the Lunar Module (6), Service Module (7) and Command Module (8) of the Apollo spacecraft, and an escape rocket (9), that pulled the Command Module clear of the rocket in case of an emergency during launch.

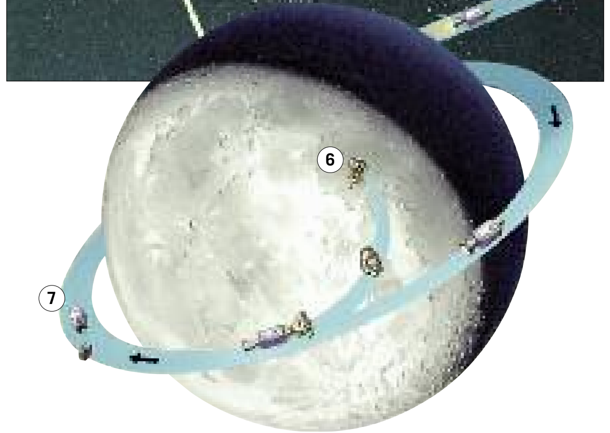






Robert Goddard's first rocket *(below, left)* reached an altitude of just 12.5 metres. The German V2 long-range rocket *(centre)* was built as a weapon from 1942. The Soviet Vostok launcher *(right)* launched the first-ever satellite, *Sputnik 1 (left).*





THE MOON MISSIONS

After the former Soviet Union launched the first man into orbit in 1961, American President John F. Kennedy announced that the USA would land a man on the Moon before the end of the 1960s. A new spacecraft specially designed for the mission, called Apollo, was built. It consisted of a Command Module, from where the astronauts controlled the craft, a Service Module, which contained a rocket engine and life-support systems, and a Lunar Module, the only section that was to descend to the Moon's surface. A new launch vehicle, the giant Saturn V, was also built. During a series of missions in Earth and Moon orbit throughout the 1960s, Apollo was thoroughly tested and astronauts trained for the Moon landing.

The Lunar Module of Apollo 11, called *Eagle,* landed on the Moon on 20th July 1969. A few hours after touchdown, watched by millions on live television, Neil Armstrong clambered down a ladder and stepped on to the surface to become the first human on the Moon. Edwin "Buzz" Aldrin followed him. The third astronaut on the mission, Michael Collins, orbited above in the Command Module. Armstrong and Aldrin gathered samples of Moon rock and soil *(below)* and planted a flag before lifting off in the upper section of the Lunar Module to dock with the Command Module. There they rejoined Collins, jettisoned the Lunar Module and began the return trip to Earth. Five more Apollo Moon missions followed, the last in 1972.

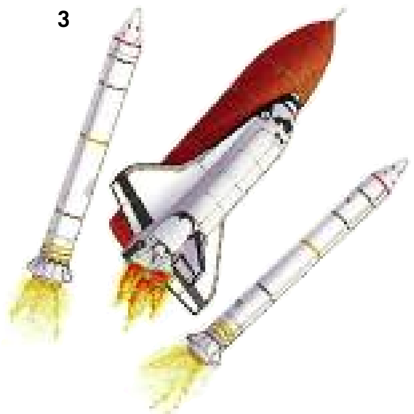
SPACE TRAVEL

SPACE TRAVEL II

SINCE the Apollo Moon missions were completed in 1972, no astronauts have been further than Earth orbit, but many unmanned spacecraft, called space probes, have visited the other planets in our Solar System. Probes carry cameras and sensing equipment that send back photographs and other data. Some probes actually land on the planets' surfaces. Hundreds of satellites for communications, weather forecasting, scientific research and astronomy, have also been launched into Earth orbit.

The first permanent space station, *Salyut 1,* was launched in 1971. Inside space stations, astronauts carry out experiments to see how people react to staying in space for long periods, and how plants and animals cope with very low gravity. Probes, satellites, space stations and their crews are lifted into space by launch vehicles such as the European Ariane space rocket, or by the American space shuttle.

3



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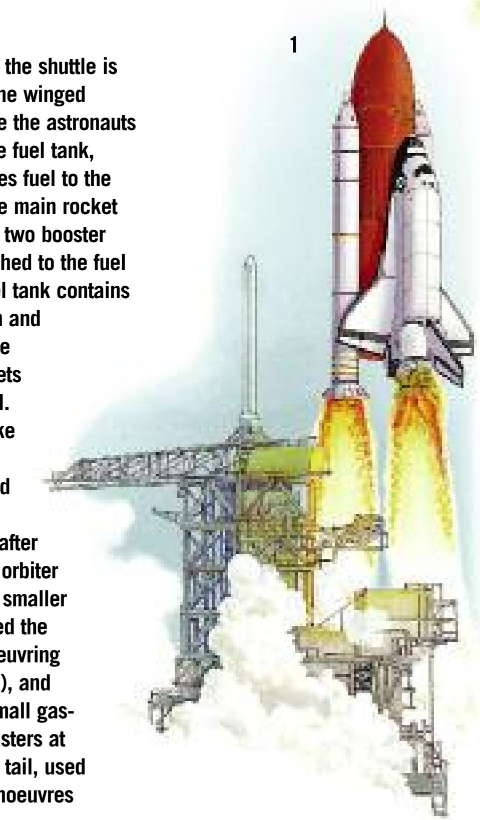
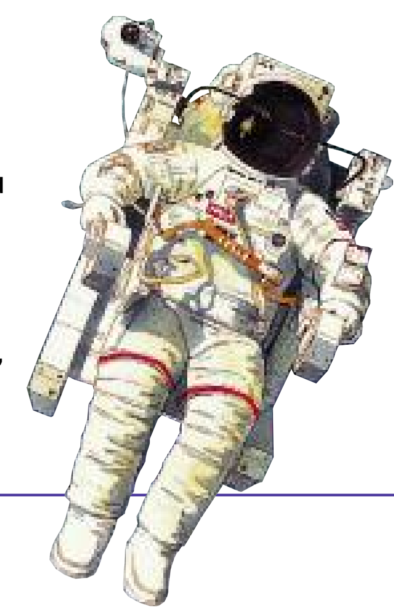
Soon after lift-off (2), the shuttle turns on to its back. The booster rockets last for two minutes, then separate from the fuel tank (3) and parachute back to Earth for re-use. The fuel in the external tank runs out after nine minutes, after which the orbiter jettisons it (4) and it falls back into the atmosphere, where it burns up because of the intense heat created. The orbiter is now on its own. The OMS engines are fired for a short time to accelerate the orbiter into its correct orbit.

1

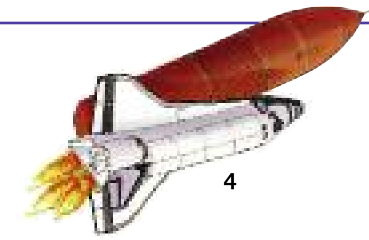


At lift-off (1), the shuttle is made up of the winged orbiter, where the astronauts travel, a huge fuel tank, which supplies fuel to the orbiter's three main rocket engines, and two booster rockets attached to the fuel tank. The fuel tank contains liquid oxygen and hydrogen. The booster rockets use solid fuel. They work like huge fireworks, and cannot be switched off after ignition. The orbiter also has two smaller engines called the orbital manoeuvring system (OMS), and clusters of small gas-powered thrusters at the nose and tail, used for small manoeuvres in orbit.

The space shuttle was designed as a re-usable spacecraft because of the huge cost of rockets and craft such as the Saturn V and Apollo, all the parts of which were completely destroyed during a mission. The shuttle flies into space like a rocket and glides back to Earth like an aeroplane.



During "extra-vehicular activity" outside their spacecraft *(right),* astronauts are protected from the cold, high-speed meteorites and radiation from the Sun by a complex spacesuit. Astronauts sometimes use a manned-manoeuvring unit (MMU), powered by tiny gas jets, which allows them to manoeuvre freely in space.

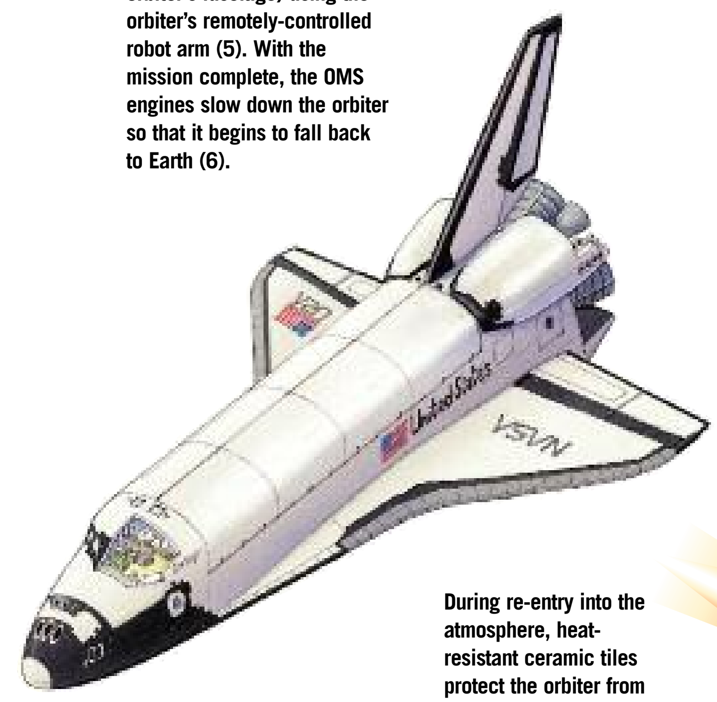


4

5

Less than fifteen minutes after launch, the shuttle is in orbit at an altitude of about 200 km. Now the astronauts can carry out their mission—in this case, launching a satellite from the "payload bay" (in the upper part of the orbiter's fuselage) using the orbiter's remotely-controlled robot arm (5). With the mission complete, the OMS engines slow down the orbiter so that it begins to fall back to Earth (6).

6



During re-entry into the atmosphere, heat-resistant ceramic tiles protect the orbiter from the intense heat. It gradually slows as it descends, and finally glides back on to a runway like an aeroplane (7).

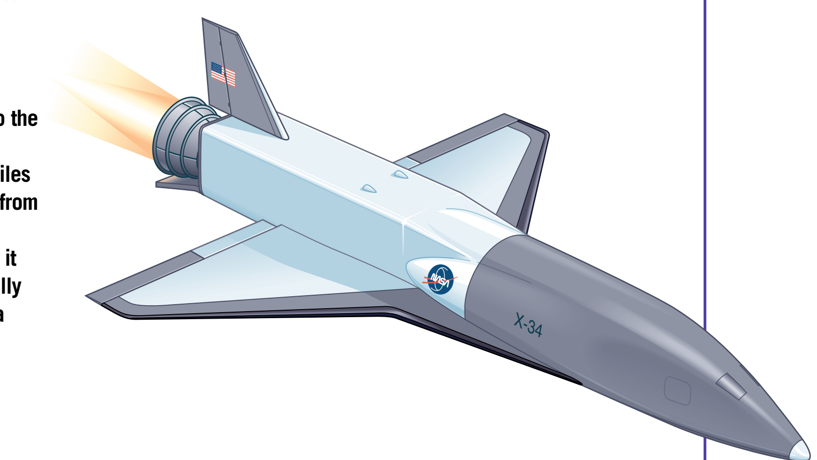
7

The whole shuttle, except for the large fuel tank, which is destroyed during launch, can be re-used. The first shuttle mission was flown by the shuttle *Columbia* in 1981. Since then, there have been dozens of missions to launch or repair satellites, service space stations, and carry out scientific and military research.

FUTURE SPACE TRAVEL

At the beginning of the twenty-first century, travelling even to Earth's closest neighbour planet Mars, let alone planets in other solar systems, is still impractical. A trip to Mars and back would take more than a year. The equipment, supplies and fuel for such a trip would require a vast rocket to launch a spacecraft from Earth. A return trip to the outer planets would take a lifetime without some new form of propulsion with much greater power than a rocket engine. For the time being, space probes remain the best way of exploring distant worlds.

Work is under way on a new international space station, which will be a base for scientific research. It is a modular structure, being built in space module-by-module, with sections being delivered into orbit by the shuttle and unmanned launch vehicles. In the future, space stations such as this, or permanent bases on the Moon, could be a starting point for space journeys. Spacecraft would be built and launched from there rather than from Earth.



New types of reusable vehicles, called spaceplanes, which will carry supplies to space stations, are under development. They will take off and gain altitude like aeroplanes, with their engines working like jet engines, and then make the jump to orbit with their engines working like rocket engines. Spaceplanes could also make passenger flights, cutting the journey time between Europe and Australia to under two hours. The international space station will have a spaceplane "lifeboat" for the crew.

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