MATT RALPHS

DIETER BRAUN

AVIATION

A VISUAL HISTORY OF AIRCRAFT

BIG PICTURE PRESS

AVIATION

For my dear friend Lucy, who in an alternative timeline is an adventuring aviatrix beyond compare. – M.R.

For Ju, the co-pilot of my heart. – D.B.

BIG PICTURE PRESS

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INTRODUCTION

Humans have dreamed about flying for thousands of years. It's not hard to imagine our primitive ancestors, who possessed the artistic skills to create beautiful cave paintings of the world around them – the landscapes, animals and each other – staring into the skies to watch birds wheel and swoop overhead and thinking to themselves: 'How does it feel to fly? And what does this world look like from up there?'. You've probably had a similar daydream yourself: visualising your house from above, then turning towards the sun, feeling the wind flow over your wings, and soaring towards the horizon and the unknown world beyond.

The first true aircraft capable of lifting people in relative safety and carrying them for decent distances were hot air balloons. The first was launched to great fanfare in France in 1783. Suddenly it was possible for people to take to the skies, and it kickstarted a frenzy of public interest in the notion of flight. Many more designs followed. Tethered balloons were immediately put to use by armies to spy on enemy movements from afar. But balloons are entirely at the mercy of the wind, and pilots have no control over their direction of travel.

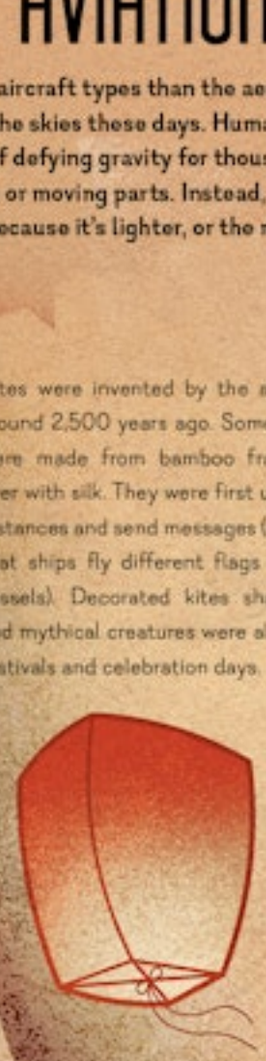
This changed one fateful day in 1903, when the first powered flight in an aeroplane called the *Flyer* was made. It only lasted for 12 seconds, but it was enough to change our world. From that moment on, the development of the aeroplane has never stopped. This constant advancement in aviation technology, funded with so much money, energy, materials and technical expertise, is carried out because aeroplanes are so useful. They transport people and cargo faster than any other vehicle. They are a vital part of military campaigns. They help us map, explore and learn about our world. They entertain us with **aerobatic** displays of speed and manoeuvrability. They rescue people lost in the wilderness and help put out wildfires.

Don your aviation goggles and prepare for a breath-taking journey through the skies!

ANCIENT AVIATION

The are many far older aircraft types than the aeroplanes and helicopters we see flying through the skies these days. Humans have been building contraptions capable of defying gravity for thousands of years. The earliest had no engines, motors or moving parts. Instead, they used hot air, which rises through cool air because it's lighter, or the natural force of the wind.

Kites were invented by the ancient Chinese around 2,500 years ago. Some of the earliest were made from bamboo frames stretched over with silk. They were first used to measure distances and send messages (in the same way that ships fly different flags to signal other vessels). Decorated kites shaped like birds and mythical creatures were also flown during festivals and celebration days.



The ancient Chinese also invented small hot air balloons called sky lanterns, which are still used today. The first hot air balloon big enough to lift people was invented in 1783 by the French Montgolfier brothers. Their *Aerostatic Globe* was filled with hot air created by a smouldering fire. Carrying two daring passengers, it rose to around 900m and drifted 9km over Paris before setting down gently in a field.

Lightweight, fixed-wing gliders were the first 'heavier-than-air' aircraft. Based on the theories of aviation and aircraft design put forward by English engineer George Cayley, many were invented throughout the 19th century by brave **aviators** willing to risk their lives to soar like birds. One of the most successful was Otto Lilienthal, the Glider King of Germany, who made hundreds of flights before being killed in 1896 when he lost control and crashed.

One of the first machines intended to fly was designed by Italian **polymath** Leonardo da Vinci in the 15th century. He based his 'ornithopter' on studies of how birds fly, and it included two flexible and flappable wings. As far as we know it was never built, but even if it had, it wouldn't have worked.

On December 17th, 1903, Wilbur and Orville Wright changed the world forever. For years, these mechanically minded American brothers had shared a vision of creating a machine that could fly further and more reliably than a glider, and, unlike a hot air balloon, wasn't forced to fly in a particular direction by the wind. In short: the first flying vehicle that the pilot had complete control over. After years of planning and countless experiments, their vision became a history-making reality on the sandy flats of Outer Banks, North Carolina, USA.

Orville Wright lay on his stomach, gripping the *Flyer*'s control stick. Two propellers whirled on either side of him. These were connected by bicycle chains to a lightweight petrol engine designed specially by the Wright brothers' mechanic friend Charlie Taylor; the engine had no throttle control: it was either 'on' or 'off'. Wilbur ran alongside as the *Flyer* trundled down a wooden launch rail, took off and flew close to the ground for 12 seconds. Three more flights occurred that day, the last being the longest at 59 seconds and 260m. Unfortunately, the *Flyer* was damaged on landing and never flew again.

But this was only the beginning. News of the Wright brothers' incredible achievement spread, and soon other inventors were building on their ideas to create even more airworthy powered aeroplanes. The first circumnavigation around the world was completed in four Douglas World Cruiser seaplanes only 21 years later. By the 1940s, jet aircraft were roaring through the air. Today, we use aircraft to defend ourselves, ferry cargo, carry out life-saving rescue operations, and explore and travel the world – miracles of flight all kickstarted by the Wright brothers.

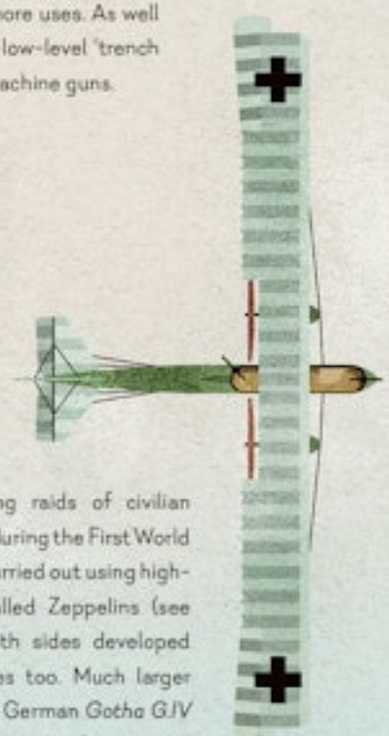
WOOD, CANVAS AND STRING

The aeroplane was only 11 years old and had hardly ever been used in combat when the First World War broke out in 1914. But over the course of the next five years, both sides realised just how useful these flying machines could be. Aeroplane technology advanced rapidly as each side strove to gain air superiority.

Aeroplanes were first used for reconnaissance missions. Flying high over the battlefields, 'spotters' (or 'observers') could look down and take photographs of enemy positions and trench systems, and help artillery hit their targets more accurately. This French *Nieuport 12* biplane had a pilot and observer, and a rear-firing machine gun to fend off attackers.

Most aircraft were unarmed at the start of the war. Pilots had to shoot at enemy planes with pistols, rifles or hand-held machine guns. Some later aircraft had rear-firing machine guns for defence, but a true fighter plane needs guns that fire forwards. Introduced in 1915, this German *Fokker E.III* monoplane had forward-firing guns designed to shoot bullets between the propeller blades as they rotated.

As the war progressed, both sides developed aircraft that were more manoeuvrable, could fly and gain altitude faster, and take more damage. As technology improved, combat aircraft could be put to more uses. As well as a fighter, this British *Sopwith Camel* was also used as a low-level 'trench strafer': attacking targets on the ground with bombs and machine guns.



The first bombing raids of civilian targets occurred during the First World War. Most were carried out using high-flying airships called Zeppelins (see page 21), but both sides developed bomber aeroplanes too. Much larger than fighters, this German *Gotha G.IV* biplane dropped bombs from under its fuselage and defended itself with machine guns.

The pilots who duelled over war-torn Europe needed calm nerves and skill. However, many had very little training, and life expectancy was short. Pilots who shot down more than five aircraft were called 'aces'. This *Fokker Dr.I* triplane was flown by German ace Manfred von Richthofen – also known as the Red Baron.

HOW PLANES FLY

An aircraft flies when the four forces of lift, weight, thrust and drag work together. This principal was the same back in 1903, when the Wright brothers undertook the first powered flight, as it is now, when modern aircraft like the 800-ton A380 commercial airliner do the seemingly impossible and roar into the skies. The way a pilot uses pitch, roll and yaw to control their plane hasn't changed either.

When the pilot moves the **rudder** (usually by pressing their feet on pedals) it causes the aircraft to 'yaw' horizontally from side to side. Pressing on the right pedal causes the rudder to turn right and the aircraft to yaw right; pressing on the left pedal cause the rudder to turn left and aircraft to yaw left.

Elevators change the aircraft's 'pitch'; that's the 'up' and 'down' movement. When the pilot lowers the elevators by pushing forward on the control stick, the plane's nose pitches down; when they raise the elevator by pulling back on the control stick, the plane's nose pitches up.

LIFT

A plane needs lift to oppose Earth's gravitational force and keep it flying. Aircraft wings (also called aerofoils) are designed to create lift. The top of each individual wing (the plane shown here is a biplane, so has two sets of wings, one above the other) is curved. This creates a larger surface area than the flatter bottom on the wing, so when air flows over it, it creates the upward force – lift – required to keep the plane airborne.

THRUST

Created by propeller or jet engines, thrust is the force that moves the aircraft forward through the air. For a plane to fly, the thrust it creates must be equal to or greater than the drag. If drag becomes greater than thrust, the plane slows down. If thrust is greater than drag, the plane speeds up.

DRAG

Drag is the opposing force to thrust. Drag slows the plane down and is caused by air acting against the aircraft. Aircraft are often designed to be **aerodynamic** in order to present the air they fly into with the smallest possible surface area. For an aircraft to fly, thrust must be equal to or greater than drag.

The **ailerons** cause the aircraft to 'roll'. When the pilot moves the control stick left, the plane rolls left and begins to turn; when they move the control stick right, the plane rolls right and begins to turn. If they hold the stick for long enough the aircraft will complete a 360° barrel roll.

WEIGHT

Weight is the opposing force acting against lift. The effect of gravity on the aircraft's weight forces it towards the ground, but with enough lift (created by the wings) the plane overcomes gravity and flies.

THE GOLDEN AGE OF FLIGHT

Worldwide enthusiasm for aviation rose sky-high during the 1920s and 30s. Many pilots wanted to make a living showing off their skills. They purchased planes and became 'barnstormers': pilots who thrilled crowds with dangerous stunts and acrobatics. Technology improved too: planes got faster, more agile, and could fly much further. All this created a breed of pilots burning with the desire to push themselves and their machines to the limit.

After a career as a pilot during the First World War (for which he won the Military Cross for gallantry), Australian Charles Kingsford Smith became a pioneering long-distance aviator. In 1928, he and his crew became the first to cross the Pacific from the USA to Australia. Smith was also the first to cross Australia, and fly non-stop from Australia to New Zealand. He went missing in 1935 while attempting to break the speed record from Australia to England.

Bessie Coleman dreamed of being a pilot but wasn't allowed to attend flying school in the USA because of her African American and Native American heritage. Undeterred, she moved to France and obtained her pilot's licence there. For the next five years, Queen Bess (as she became known) amazed crowds with her daring stunts, and campaigned passionately against racial discrimination. Tragically, she died in a plane crash in 1926 aged only 34.

Adventurous as a child, it's no surprise that American Amelia Earhart went on to become one of the most famous flyers in history. After helping found an all-female pilots club called the Ninety-Nines (still in existence today), Earhart became the first woman to fly solo across the Atlantic in 1932 – and in record time. After many other exploits, Earhart and her navigator set off on an arduous 47,000km journey to **circumnavigate** the globe. They disappeared somewhere over the Pacific.

New Zealander Jean Batten was encouraged by her mother and Charles Kingsford Smith to follow her desire to become a record-breaking pilot. After obtaining her licence in 1930, she achieved international fame for her amazing aviation exploits, including becoming the first woman to fly from England to Argentina, breaking the speed record between England and New Zealand, and becoming the first woman to fly solo from England to Australia and back again.

– AMAZING AIRCRAFT –

THE SPIRIT OF ST. LOUIS

On May 20th, 1927, at an airfield just east of New York City, 25-year-old US Air Mail pilot Charles Lindbergh climbed into his silver-skinned monoplane the *Spirit of St. Louis* and cranked up the engine. Ahead lay a rain-soaked runway. Beyond that, the grey and empty expanse of the Atlantic. Lindbergh's goal was to be the first to cross it, alone, and earn a place in aviation history – a dangerous challenge that had already claimed the lives of several other flyers. But Lindbergh was experienced, confident and courageous, so without hesitation he opened the throttle on his fuel-laden aircraft and took to the skies.

The *Spirit of St. Louis* was a heavily modified version of a mail-carrying *Ryan* M-1 aircraft. The M-1's cargo and passenger areas were replaced with fuel tanks, including one directly in front of the cockpit, entirely blocking Lindbergh's forward view. If he wanted to see ahead, he had to yaw the plane and peer through the side windows. Everything Lindbergh felt he didn't need – including the radio and parachute – was removed to make the *Spirit of St. Louis* as lightweight as possible. It had a 223hp air-cooled J-5C Wright Whirlwind engine that was designed to run flawlessly for around 9,000 hours (that's over a year) and had a special mechanism to keep its moving parts greased. All these changes, plus many more, were made in only 60 days.

Cramped inside his tiny cockpit, Lindbergh sat on a wicker seat, which was designed to be uncomfortable to help keep him awake. For 33 and a ½ hours he soared eastward over the featureless Atlantic. He faced many perils, including ice that froze up his wings, fog that obscured his vision, and violent storms he had to fly over to survive. Eventually, on May 21st and after flying 5,800km, he set down safely at Le Bourget Aerodrome, France, where he was greeted by a crowd eager to celebrate his incredible transatlantic achievement.

AIRSHIPS

Airships were the first commercial airliners. During the early 20th century, these huge gas-filled giants carried those who could afford it non-stop for thousands of kilometres. Up until then, such journeys could only be carried out by train and ship. But because airships were faster and could fly in a straight line, they covered similar distances in a matter of days. Sailing high over oceans, countries and continents, passengers enjoyed delicious food and drink, relaxed in luxurious lounges and slept in their own private cabins.

Named after pioneering German airship designer Count Ferdinand von Zeppelin, Zeppelin rigid airships were used as bombers during the First World War, and as passenger airliners in the 1920s and 30s. Zeppelins had a rigid metal frame covered in thick, waterproof cotton fabric. Inside the frame were gasbags filled with lighter-than-air hydrogen gas. Five propeller engines gave them a top speed of 128km/h and a range of around 10,000km. To gain height, water was dumped from **ballast tanks**. Passengers and crew spent their time in a 30m long 'gondola' positioned below the airship; it was unheated, so passengers sometimes wore coats, gloves and scarves to keep warm.

The rigid airship flourished in the first three decades of the 20th century: they were swift, glamorous and exciting. However, the golden age of the airship came to an abrupt end on May 6th, 1937. Running several hours late due to stormy weather, passenger airship LZ 129 *Hindenburg* approached its landing ground in New Jersey, USA, in the early evening. At 7.25pm, after dropping its mooring lines, the *Hindenburg* caught fire. Within a few seconds, the whole craft was ablaze as flames consumed the 198,000m^3 of highly combustible hydrogen gas. Thirty-five people perished. The tragedy was caught on camera and broadcast all over the world.

WAR IN THE AIR

Aircraft technology had advanced considerably by the time the Second World War broke out in 1939, and there were many types of military aeroplane designed to carry out different tasks. Unlike the First World War, where most of the fighting was done by armies on the ground, aeroplanes played a hugely significant role in deciding the outcome of the Second World War.

The most successful fighters were fast, nimble, single seaters armed with machine guns. Their job was to keep friendly skies free from invasion, and protect slower, more vulnerable bombers on their missions over enemy territory. This Japanese Mitsubishi *A6M Zero* fighter had a top speed of 533km/h and could be launched from aircraft carriers.

Both sides used bombers to target military installations such as weapon factories and airfields, as well as civilian sites like cities. Most bombers had four engines and gun turrets to defend themselves from fighters, and flew together in huge, high-flying formations. This British *Avro Lancaster* was designed to carry out missions at night.

Not all bombers were slow, four-engine, high-flying giants. Dive bombers, like this Russian *Petlyakov Pe-2*, were specially designed to hit small targets, such as tanks or ships, with pinpoint accuracy. Pilots could then use their superior speed (when compared to ordinary bombers) to escape enemy fighters.

During the Second World War, both sides used ships to transport vital supplies, and both sides used submarines to try and destroy those ships. Aircraft like this American *B-24 Liberator* anti-submarine bomber used searchlights and radar to locate German U-boats before attempting to sink them.

Transport aircraft, like this German tri-motor *Junkers Ju 52*, were vital for ferrying food, weapons and supplies. As well as being faster than trucks, aircraft can fly over obstacles like mountains, rivers and enemy forces. Cargo can then be offloaded after landing or dropped by parachute from the air.

There are few aircraft that conjure the same amount of emotion and admiration than the superlative Supermarine Spitfire. Even today, people of all ages stare up in wonder when one of the around 60 preserved and still-flying Spitfires soars overhead. The deep and throaty roar of the Merlin engine, the unmistakable silhouette of the tapered fuselage and elegant, elliptical wings, coupled with the historic role it played defending the British Isles during the Second World War ensure this fighting machine remains a true icon of the skies.

Designed by Reginald Joseph Mitchell, the chief designer at Supermarine, during the 1930s, the Spitfire was a lightweight, agile fighter plane capable of high speeds, high altitudes and high manoeuvrability. Entering service with the British Royal Air Force (RAF) in 1938, it was an almost immediate success. Pilots loved flying Spitfires because they were fast and easy to control. In the end there were 24 different Spitfire designs, called 'marks'. Some marks simply improved on previous designs. Others were created for specific purposes, including flying into enemy territory to take reconnaissance photographs, and being able to operate from aircraft carriers (this version was called the Seafire).

The Spitfire arrived just in time. Nazi dictator Adolf Hitler needed control of the skies before invading Britain, and all that stood in the way of his air force (the Luftwaffe) was the outnumbered RAF. And so, during the summer of 1940, a desperate aerial war raged over the cities, towns and countryside of southern England. For day after exhausting day young pilots from many countries (including Poland, South Africa and New Zealand) climbed into their Spitfires and Hurricanes to face wave after wave of attacking German bombers, and the highly effective Messerschmitt Bf 109 fighters that escorted them. Losses were high on both sides, but the Luftwaffe suffered most. By October, the Battle of Britain was over, leaving the UK safe from invasion and free to continue the fight against the Nazis.

UNSUNG HEROINES

The outbreak of the Second World War presented the British Royal Air Force with a problem: how to fly the thousands of newly built aircraft from factory to airbase without using the frontline pilots needed to protect the skies. The answer was the Air Transport Auxiliary (ATA). The ATA recruited pilots who had experience but were not deemed suitable for combat duties: older or less fit people, and those with disabilities.

The ATA also recruited around 170 female pilots. Initially they were restricted to flying only small trainer aircraft, but soon they were ferrying whatever needed moving: from *P51 Mustang* fighters, to super-fast *de Havilland Mosquito* strikers, to four-engine heavy bombers like the *Handley Page Halifax* and Boeing B17 *Flying Fortress*. Typically for that time, the women were paid 20% less for doing exactly the same job as their male colleagues, but in 1943 they were granted equal pay. ATA pilots, both men and women, came from all over the world, including South Africa, Canada, New Zealand, Australia, Chile, China, Russia, Poland and Siam (now Thailand). One American ATA pilot, Jacqueline Cochran, returned to the USA and founded her own similar organisation called the Women Airforce Service Pilots (WASP).

Although the ATA was not a military organisation, the hundreds of thousands of transport missions it carried out during the war were fraught with danger. None of the aircraft carried ammunition, so they were completely defenceless. Sometimes the pilots had never even seen the aircraft they were ordered to command, let alone trained in them. Instead, they were expected to refer to their Ferry Pilot's Notes – a thin book with guidance on how to fly each of the 147 aircraft types used during the war – and get on with the job of transporting them. By the time the war ended, 173 ATA pilots had lost their lives while carrying out their vital transport duties, including famous aviator Amy Johnson (the first woman to fly solo from the UK to Australia) while flying in bad weather over Kent.

AIRPORTS

There are different types of airports for planes to land, refuel, repair, load, unload and take off from again. Landing strips are usually just a single short grass runway with maybe a building or two. Aerodromes and airfields are larger, with longer, hardtop runways and more facilities for cargo and passenger services. International airports are so big and busy they're almost like mini cities. Every day they handle hundreds of flights.

Air traffic controllers sit in the control tower. Their job is to keep the flow of traffic running smoothly and prevent accidents. They use radar to monitor aircraft, and radios to inform their crews of flight paths, landing and take-off times, and crucial information such as local weather conditions.

Large airports often have several runways. Taxiways connect the runways to the gates and hangers. Runways need to be specially constructed to withstand the weight of landing airliners without cracking and buckling. Lights guide pilots at night and in fog.

Airports need a transport system that allows passengers and employees to arrive and leave as quickly and efficiently as possible. After all, no one wants to miss their flight! People can use bus, rail or **subway systems**, or drive by road and leave their vehicles in car parks.

The terminal building is where passengers begin their journey through the airport. Here they check in with their tickets, hand over their baggage to be put onboard the airliner, then make their way through security. Beyond security, as they wait for their flight to be called, passengers can pass the time in restaurants and shops.

Just before their flight, passengers are called to the correct gate. Gates are where airliners are refuelled, cleaned, restocked with food and supplies, and where they wait for passengers and their baggage to be loaded. Then it's time for take-off.

SEAPLANES

Seaplanes (sometimes called flying boats) are specialised aircraft designed to land and take off from water. Their fuselages are wide and flattened at the bottom – similar to a boat's hull – and they have floats slung under each wing to aid balance and keep them buoyant.

The *Hughes H-4 Hercules* (nicknamed the *Spruce Goose* because it was made from wood) is the largest seaplane ever built. It was designed as a long-range transport plane to carry supplies from the USA to Britain during the Second World War. However, development of this eight-engine giant was slow, and by the time it was built the war was over. *Spruce Goose* flew only once, for just over a kilometre, in 1947.

Developed during the First World War, the *Felixstowe F.2's* overall design influenced many seaplanes that followed. The *F.2* had two Rolls-Royce engines, several machine guns and could carry bombs. Its job during the war was to patrol the North Sea looking out for enemy submarines, aircraft and airships.

Seaplanes were popular during the 1930s as commercial airliners. There were not many airports in those days – but that didn't affect seaplanes like this *Short Empire* because they could land on lakes, rivers or the sea instead. *Short Empires* were also converted into a military aircraft called the *Short Sunderland*.

Floatplanes are a type of seaplane that uses elongated floats (usually a pair, but sometimes one) fixed under their fuselage to give them buoyancy. They are typically smaller than traditional seaplanes. This *de Havilland Canada DHC-3 Otter* is a STOL (short take-off and landing) floatplane that's been in use for carrying passengers and cargo since 1953.

Although not used as much today as during the first half of the 20th century, seaplanes are still useful for reaching remote locations or places without airfields – as long as there's a body of water big enough for them to land and take off from. Introduced in 1994, this *Canadair CL-415* was designed for aerial firefighting and search-and-rescue operations.

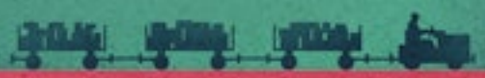
PROPELLER AIRLINERS

From the historic day in 1903 when the Wright brothers performed the first powered flights, it was clear their achievement would eventually revolutionise travel. Sure enough, it wasn't long before the first commercial airliners took to the skies.

Airline travel began in the 1920s. Advances in aviation technology made during the First World War allowed designers to build civilian aircraft capable of carrying passengers and their baggage. This *Blériot-SPAD S.46* seated four in an enclosed cabin and flew all over Europe.

Commercial travel expanded during the 1930s. Airline companies welcomed passengers aboard their planes – like this 8-seater *de Havilland DH.89 Dragon Rapide* – for both business and pleasure. However, tickets were expensive, and journeys were noisy and uncomfortable.

Introduced in 1933, the Boeing 247 was one of the first airliners made from metal instead of wood. The designers also considered passenger comfort by installing air conditioning, and sound proofing to reduce engine noise in the cabin.



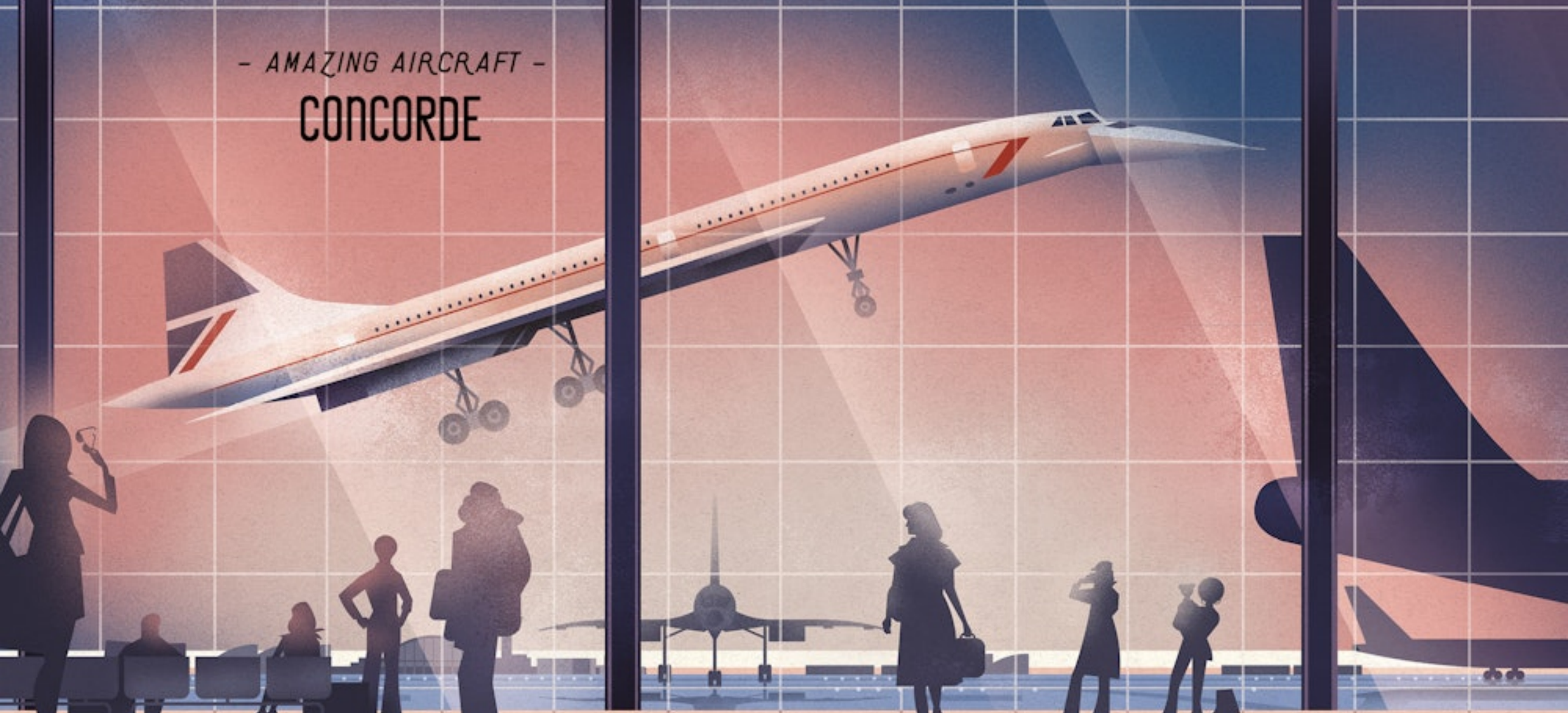
JET AIRLINERS

Jet airliners could travel further, faster and carry more passengers than those powered by propellers. This led to cheaper flights, which gave ordinary people the opportunity to travel the world in comfort and safety.

Entering service in 1952, the *de Havilland Comet* was the first jet airliner. It had an aerodynamic shape, pressurised cabin and four jet engines inside the wings. Compared to earlier propeller airliners, the Comet was quiet and comfortable to fly on.

The first 'wide-body' airliner (an aeroplane that has three rows of seats across its width) was introduced in 1970. The Boeing 747-100 quadjet could carry up to 366 passengers and had a top speed of 969km/h.

First roaring into the air in 2005, the largest airliner in the world at the moment is the wide-body Airbus A380. This quadjet giant of the skies can carry up to 853 passengers in its two decks of seats.



Bright white, narrow-bodied and shaped like a spear tip, there has never been a commercial airliner like *Concorde*. That's because it was designed to be utterly unique and ground-breaking: a passenger aircraft that could fly faster than a fighter jet, and cruise to its destination on the very edge of space. Inside, as the sky beyond the windows turned dark blue and the stars began to twinkle, passengers enjoyed multi-course meals of the finest food, relaxing in the first (and so far, only,) supersonic airliner in the world.

The design, cost and construction of this sleek and beautiful aircraft was shared between France and the UK. The name *Concorde* was chosen to reflect this cooperation because it means 'union', 'agreement' or 'harmony'. Creating a supersonic airliner ended up costing several times more than the designers expected, but the results were incredible. With a top speed of 2,179km/h (faster than a bullet fired from a rifle!) and a maximum altitude of just over 18km, *Concorde* cut the 8-hour journey time from London to New York to a mere 3 hours, 30 minutes. Its huge delta-shaped wings provided the lift, four screamingly loud afterburning turbojet engines provided the thrust, and a needle-sharp nose and narrow fuselage reduced drag.

Twenty *Concordes* were built. Each carried between 92 and 128 passengers and had a crew complement of nine (pilot, co-pilot, flight engineer and six cabin crew). Over the course of 50,000 flights between 1976 and 2003, *Concordes* ferried a total of around 2.5 million passengers all over the world. However, the huge cost of keeping these technological marvels flying meant they never made a profit and, after a tragic accident (the only one in 27 years' service) during take-off in July 2000, *Concorde* was forced into early retirement.

LIGHT AIRCRAFT

Light aircraft are small, lightweight and simple to fly. Most have a single engine and can be piloted by one person. Coming in many different designs, they can carry out a range of tasks, including passenger and cargo transport, aerial photography and filming, ground observation, towing advertising banners and pilot training.

Bush aeroplanes are a type of light aircraft that are designed to reach places that other planes cannot. They are capable of landing and taking-off from short runways, or places that are uneven, such as fields, deserts or frozen tundra. This *Champion Scout* is rugged, easy to maintain, repair and fly, and has large wheels for rough touchdowns.

Turboprops (named after the turboprop engines that power them) are typically faster, bigger and more powerful than conventional propellor-driven light aircraft. This twin-engine *Beechcraft King Air 350i* can be used as a comfortable passenger transport, an air ambulance and by the military for aerial patrols and surveillance.

Some light aircraft are designed to perform aerobatics at air shows. Stunts include loops, rolls, stall turns, and sometimes involve multiple aircraft flying close together in perfect unison while carrying out complex manoeuvres. This *Pitts Special* biplane has been in production since 1944 and dominated aerobatic competitions for many years.

Ultralight aircraft (also called microlights) are usually privately owned and used for short-distance recreational sightseeing. They are much cheaper to buy and operate than conventional light aircraft. This *Pegasus Quantum* has a delta-shaped wing with a two-seat open cockpit fixed below. Its propeller engine is fitted at the rear.

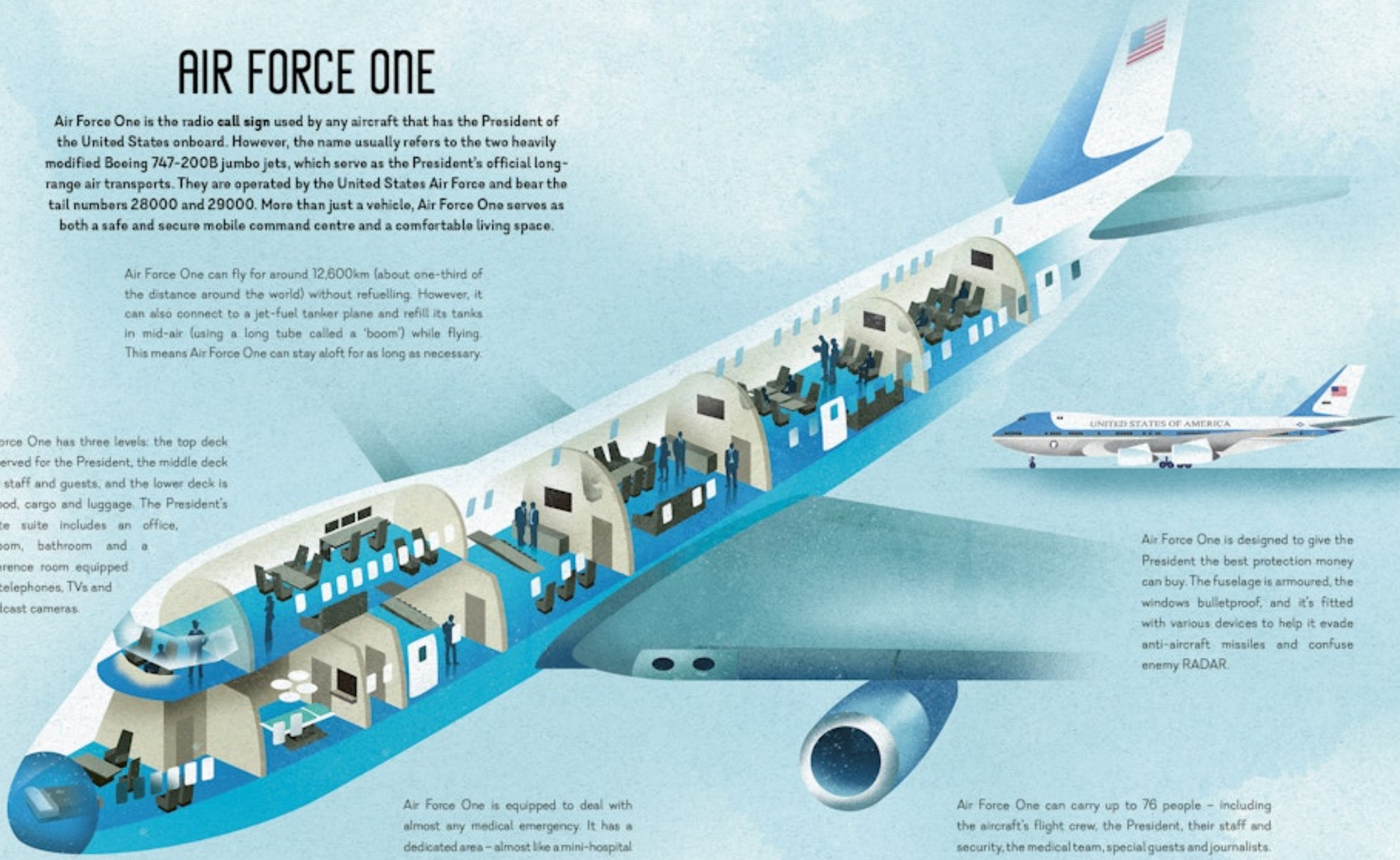
With around 44,000 made since production began in 1956, the American *Cessna 172 Skyhawk* is the most produced aircraft in history. Popular all over the world and still being made today, the high-wing, single-engine *Skyhawk* seats four, and has three non-retractable wheels.

AIR FORCE ONE

Air Force One is the radio call sign used by any aircraft that has the President of the United States onboard. However, the name usually refers to the two heavily modified Boeing 747-200B jumbo jets, which serve as the President's official long-range air transports. They are operated by the United States Air Force and bear the tail numbers 28000 and 29000. More than just a vehicle, Air Force One serves as both a safe and secure mobile command centre and a comfortable living space.

Air Force One can fly for around 12,600km (about one-third of the distance around the world) without refuelling. However, it can also connect to a jet-fuel tanker plane and refill its tanks in mid-air (using a long tube called a 'boom') while flying. This means Air Force One can stay aloft for as long as necessary.

Air Force One has three levels: the top deck is reserved for the President, the middle deck is for staff and guests, and the lower deck is for food, cargo and luggage. The President's private suite includes an office, bedroom, bathroom and a conference room equipped with telephones, TVs and broadcast cameras.



Air Force One is designed to give the President the best protection money can buy. The fuselage is armoured, the windows bulletproof, and it's fitted with various devices to help it evade anti-aircraft missiles and confuse enemy RADAR.

Air Force One is equipped to deal with almost any medical emergency. It has a dedicated area – almost like a mini-hospital – with an operating table, medical supplies, a fridge full of blood matching that of the President, and a permanently on-hand doctor and nurse.

Air Force One can carry up to 76 people – including the aircraft's flight crew, the President, their staff and security, the medical team, special guests and journalists. All these people are fed from two kitchens (or 'galleys').

JETS AND ROCKETS

Propeller engines have been in use ever since the Wright Brothers first fixed one to their *Flyer*. However, there are limits to how fast and high propeller aircraft can fly, and how much weight they can carry. Work to create more powerful jet and rocket engines began in the 1920s, but it wasn't until the Second World War, when each side was striving to gain technological advantages, that they became truly practical.

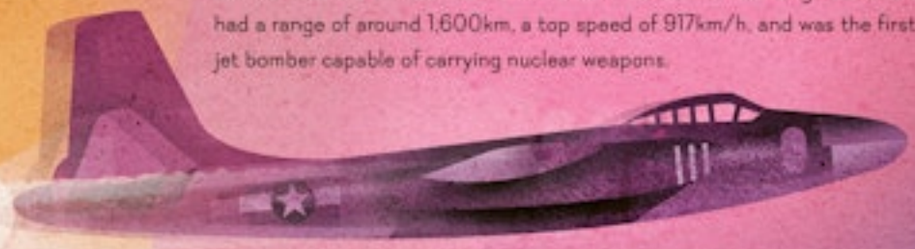
Introduced in 1944, the *Messerschmitt Me 163 Komet* was the only rocket-propelled fighter ever made. Armed with two cannons, capable of extreme speeds (over 1,000km/h) and filled with highly volatile rocket fuel that was prone to explode, the *Komet* was as dangerous for the pilot flying it as those it fought against. Although not a successful fighter, the Komet's rocket technology proved useful after the war in the development of space rockets.

Powered by two ground-breaking turbojet engines, the *Gloster Meteor* was Britain's first jet fighter. First flown in 1943, the *Meteor* had a top speed of around 991km/h. Nearly 4,000 were built before being replaced by the swept-wing *Hawker Hunter*.

The *F-86 Sabre* was the USA's first swept-wing jet fighter. Swept wings (meaning wings angled towards the rear of the aircraft) create less drag (see page 14), which allows them to fly faster and more smoothly. First flown in 1947, 9,860 *Sabres* were built, making it one of the most-produced jet fighters in history.

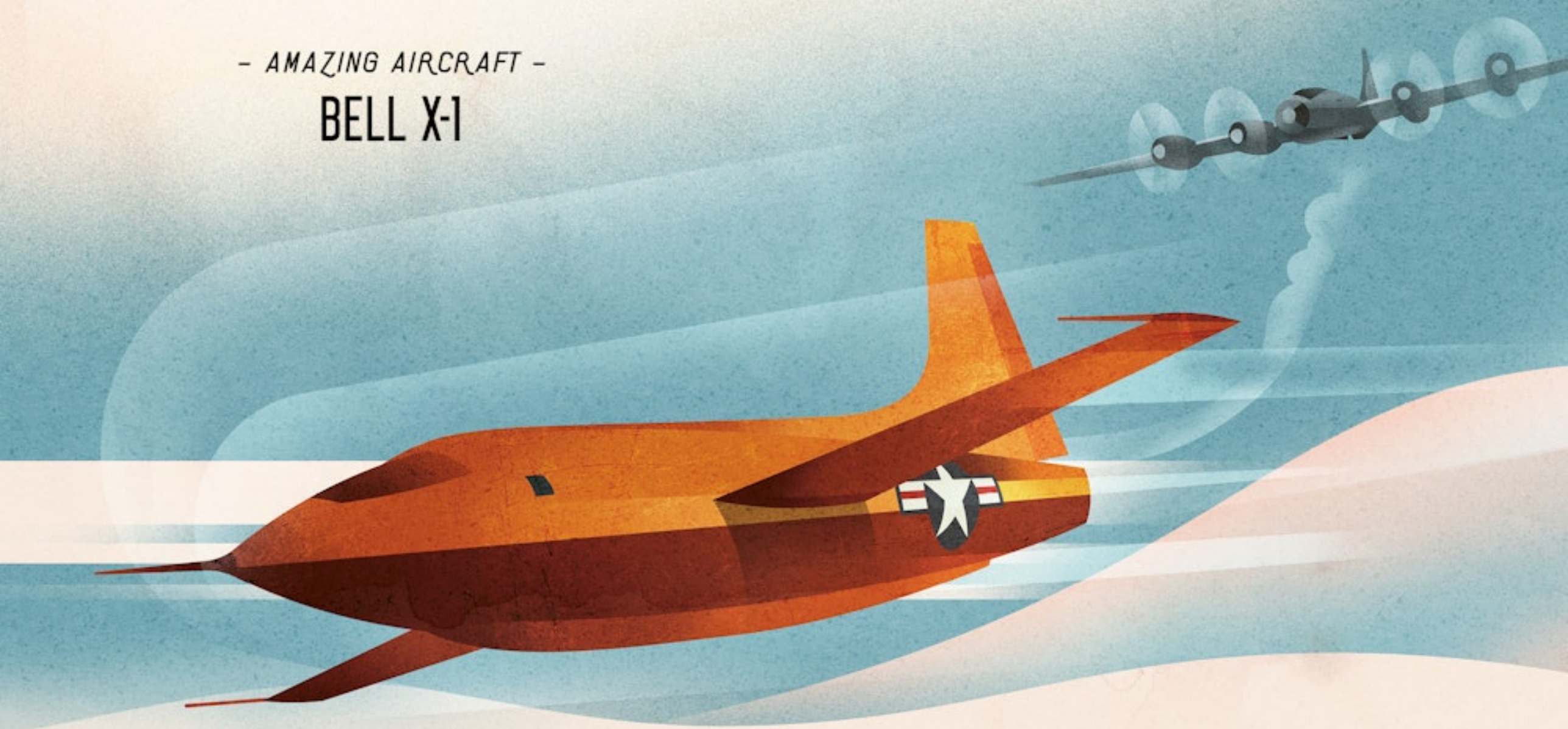
The very first operational jet fighter was the German *Messerschmitt Me 262*. Introduced into combat in 1944 and manufactured using highly advanced technology and materials for the time, the *Me 262* was designed to dominate the skies of Europe with a top speed of around 870km/h.

The American *B-45 Tornado* was one of the very first jet bombers. Entering service with the United States Air Force in 1948, this four-engine aircraft had a range of around 1,600km, a top speed of 917km/h, and was the first jet bomber capable of carrying nuclear weapons.



– AMAZING AIRCRAFT –

BELL X-1



On October 14th, 1947, an American *B-29 Superfortress* took off and climbed high over the sands of the Mojave Desert in California. Strapped under the fuselage was another much smaller aircraft. The Bell Aircraft Company called it the *X-1*. Captain Charles 'Chuck' Yeager, the test pilot in the cockpit, called it 'Glamorous Glennis' in honour of his wife. And because of its speed and streamlined shape, the designers called it the 'bullet with wings'. At a height of 7,000m, the *X-1* was drop-launched and blasted its way into the history books.

As an experimental research aircraft, the *Bell X-1* was designed to be the first piloted vehicle to exceed the speed at which sound travels: 1,225km/h, also called Mach 1. Using his years of piloting experience, Yeager ignited the *X-1*'s XLR11 rocket engine, climbed higher still to 13,000m, levelled the aircraft out and increased speed to a never-before-reached 1,127km/h. Finally, with his fuel (a highly explosive mixture of liquid oxygen and ethyl alcohol) expended, he glided safely to the ground as the first pilot to have reached supersonic speeds in level flight.

The *Bell X-1* (and every supersonic aircraft that followed in its speedy wake) had to be specially designed to cope with the mechanical stresses caused by breaking the sound barrier. When an aircraft reaches speeds close to Mach 1, it experiences a sharp rise in drag. This rise in drag is created by sound waves (produced by the aircraft) building up in front of it. When the aircraft exceeds the speed of sound, it punches through these sound waves, causing a loud noise called a sonic boom. The *Bell X-1*'s successful flight marked the first chapter in the age of supersonic aviation.

WEIRD PLANES

Thousands of aeroplanes have been invented since the *Wright Flyer*. Many were average; some were highly successful, and a few were so strange and experimental it must have taken nerves of steel to fly them. None of the aircraft on these two pages made it into production.

The *De Lackner HZ-1 Aerocycle* was designed as a vehicle so easy to fly even untrained operators could handle it. The pilot stood above spinning rotor blades and controlled the vehicle's direction by shifting their weight – just like riding a skateboard. However, it proved hard to control and the project was abandoned in 1956.

Looking more like a space rocket that an aeroplane, the *Convair XFY Pogo* was meant to be a fast-response fighter. It was designed to take off vertically from ships without runways, see off attackers with its machine guns, and return. However, landing was extremely difficult because the pilot had to do so while looking over their shoulder.

The increasing range of bomber aircraft during the 1940s meant that escorting fighter planes could not travel far enough to chaperone them all the way to their targets. One proposed solution was the *McDonnell XF-85 Goblin*. The idea was that the turbojet powered *Goblin* would travel inside a bomber, ready to be launched if they came under attack.

Designed in Germany in 1944, the *Focke-Wulf Triebflügel* (which means 'thrust-wing hunter') was similar in concept to the later *XFY Pogo*. Wingless, and a kind of mix between a helicopter and an aeroplane, it launched straight up in the air using thrust (see page 14) provided by a huge propeller behind the cockpit.

The *Hafner Rotabuggy* was a jeep with a helicopter blade attached. This design was supposed to enable the British army to airdrop jeeps onto the battlefield. Surprisingly, these flying jeeps worked during testing, with one managing to cruise for about 10 minutes at 105km/h. However, the introduction of a glider that could carry jeeps made further development of the *Rotabuggy* pointless.

- AMAZING AIRCRAFT -

SR-71A BLACKBIRD

At the height of the Cold War, the American President ordered a revolutionary aircraft be designed. He wanted something so fast and invisible to radar that it would literally be impossible to shoot down. In 1966, the engineers at aerospace company Lockheed unveiled their response to the President's demand: the *SR-71A Blackbird* spy plane.

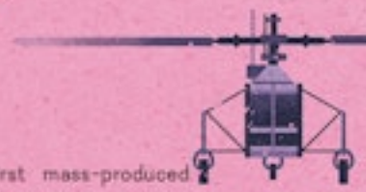
Although *Blackbird* was a military aircraft, it was not a fighting machine. Its main purpose was to fly high over enemy territory, using cameras to capture images of important locations, such as naval bases and missile installations, then bring the information back home for analysis. *Blackbird*'s surveillance equipment was so sophisticated it could photograph 160,934km² of land per hour, and the images were clear enough to identify objects on the ground that were only the size of a shoe.

Blackbird had several advantages over anyone who wanted to shoot it down. Firstly, it was a stealth plane. The special materials it was made from, its narrow shape and the sharp leading edges on its wings meant it was hard for radar to pick it up: the ideal mission was when the enemy hadn't even realised *Blackbird* was right over their heads! Secondly, its incredible speed. If a missile was fired at *Blackbird*, the pilot simply opened the throttle and was long gone before the missile arrived. Over 1,000 surface-to-air missiles (SAMs) were fired at *Blackbirds*, without a single hit being scored. Despite being nearly 60 years old, *Blackbird* still holds many world records, including the highest (25,929m) and fastest (3,530km/h) manned aircraft, making it a true icon of style, speed and technology.

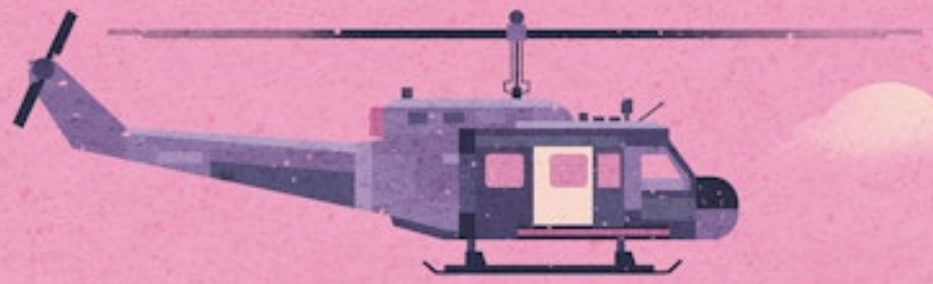
HELICOPTERS

The helicopter's ability to hover, move in any direction, and take off and land vertically make it an especially useful aircraft. The whirling horizontal rotor blade located on top creates the lift, and the tail rotor keeps the fuselage stable.

After decades of development by many inventors (who created strange and unstable prototypes), the first truly functional helicopter first flew in 1936. The double-rotor, single-seater German *Focke-Wulf Fw 61* proved such vehicles could fly stably and safely, and the age of the helicopter began.



The *Sikorsky R-4 Hoverfly* was the first mass-produced helicopter. As well as setting up the standard one-horizontal, one-vertical rotor blade design that most helicopters use today, it also performed the first helicopter ship deck landing in 1944.



First produced in 1959 and still used today, the *Bell UH-1 'Huey'* is one of the most successful helicopters in history, with over 16,000 produced. With a top speed of 217km/h, they are used to transport people and cargo (including in war zones) and carry out rescue operations; they have been fitted with water tanks to help douse forest fires.

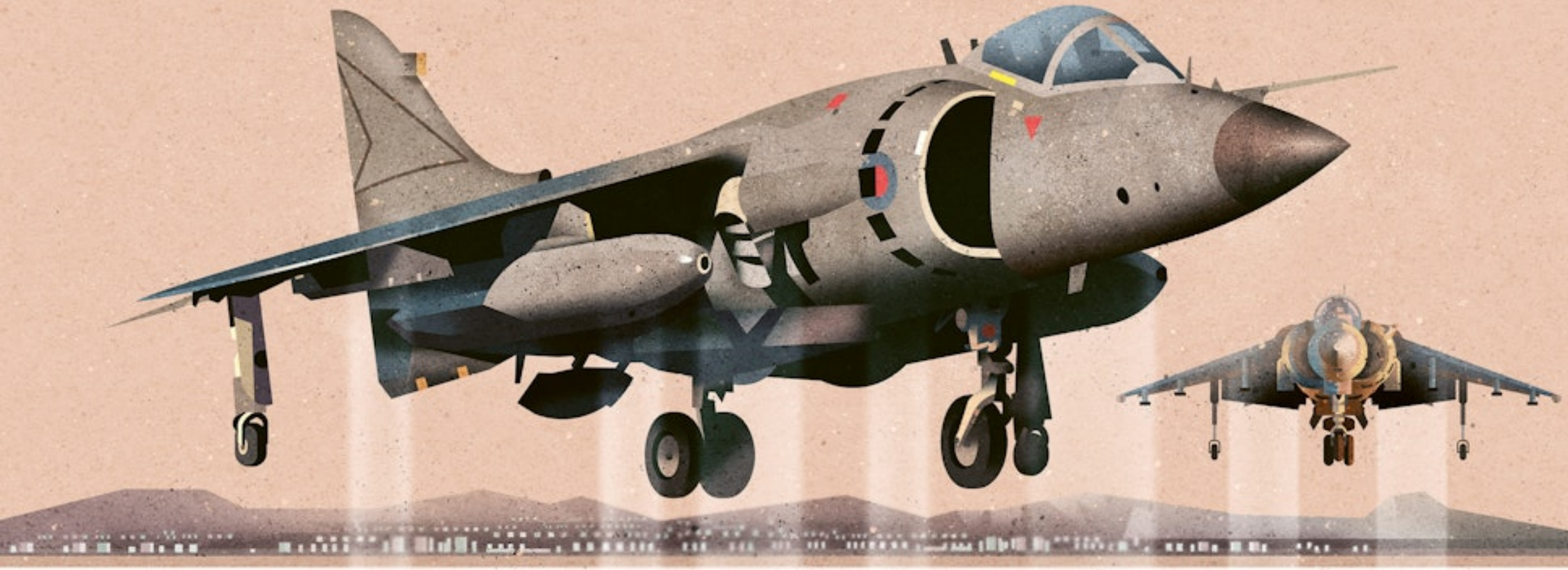
Helicopters like this *Westland WS-61 Sea King* are useful for carrying out search-and-rescue operations. Their ability to fly slowly or hover in a stationary position makes looking for people lost in remote areas or floating in the sea much easier. Once found, they can be winched onboard and flown to safety.

One of the most recognisable civilian helicopters is the *Bell 206 JetRanger*. Not only are they used as a small passenger transport, media companies also use them to make traffic reports and film newsworthy or sporting events. Police also use them to search for and pursue suspects, or observe disaster and accident sites.

Some helicopters are designed for military purposes. First flown in 1965, this *Bell AH-1 Cobra* was the first-ever attack helicopter. Swift, sleek and agile, the *Cobra* has no cargo bay or passenger compartment. Instead, it has a pilot (in the rear seat) and a gunner (in the front seat), protected by armour.

– AMAZING AIRCRAFT –

HARRIER JUMP JET



Named after a bird of prey that can hover while hunting, the *Hawker Siddeley Harrier*, or *'Jump Jet'* is a truly ground-breaking aircraft. It combines the speed, range and agility of a fighter jet with the unique flying capabilities of a helicopter. It first took to the air in 1966 (after many years of experiments and test flights) to become the first Vertical/Short Take-Off and Landing (V/STOL) aeroplane.

Unlike conventional fighter aircraft, the *Harrier*'s ability to take off horizontally from short runways that don't need to be paved (or vertically if not fully loaded with fuel and weapons) and land vertically means it can operate virtually anywhere. *Harriers* can land in car parks, on roads or in forest clearings. They can then be hidden under camouflage nets, refuelled and re-armed in only 30 minutes by the ground crew, and take off again. Later designs were adapted to operate from ships with short runways and (sometimes) ramps to help the *Harrier* become airborne.

The *Harrier*'s V/STOL ability comes from its Pegasus jet engine and four rotatable thruster nozzles. When the nozzles point down, the thrust created by the engine lifts the *Harrier* and allows it to hover; when they face backwards the *Harrier* flies forwards like a conventional jet. Smaller thrusters called 'puffer ducts' on the nose, tail and each wingtip allow the pilot to manoeuvre the plane while hovering. Compared to other jets, the *Harrier* is difficult to fly (especially when hovering), and even a small mistake could lead to a catastrophic accident.

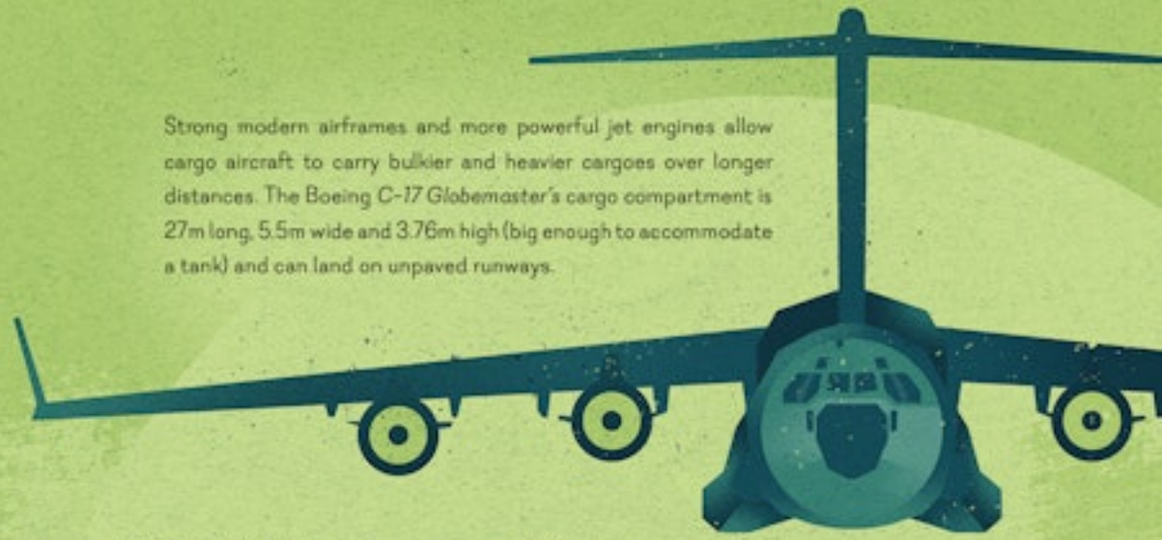
CARGO AIRCRAFT

Aeroplanes have been used to transport goods almost from the time they were first invented. Early planes couldn't carry much cargo, but they were useful for transporting letters and small parcels much faster than by ship or automobile. As technology advanced, manufacturers began designing aircraft that specialised in carrying heavier and bulkier loads.

Some early cargo aircraft were built by converting existing passenger airliners. This was done because airliners shared some of the attributes needed by cargo aircraft: they can fly long distances and have plenty of room in the fuselage. Used extensively from the 1940s, this American *Douglas C-47 Skytrain* was developed from the *Douglas DC-3* passenger airliner.

Introduced in 1956, the *Lockheed AC-130 Hercules* is one of the most successful cargo aircraft ever produced. Powered by four turboprop engines, it has a wide fuselage, a ramp at the back for loading and unloading, and can land and take off from short runways. Hercules are also used for aerial fire-fighting, and search-and-rescue operations.

Strong modern airframes and more powerful jet engines allow cargo aircraft to carry bulkier and heavier cargoes over longer distances. The Boeing *C-17 Globemaster's* cargo compartment is 27m long, 5.5m wide and 3.76m high (big enough to accommodate a tank) and can land on unpaved runways.



Helicopters like this Boeing *CH-47 Chinook* ferry cargo too. Although they usually can't carry as much as aeroplanes, cargo helicopters have other advantages: they can land and take off vertically so they don't need a runway; and they hover, meaning they can use a winch to lower or raise cargo without having to land at all.

Some cargo aircraft are constructed specially for jobs that ordinary transport vehicles can't accomplish – usually carrying extremely large or extra-heavy payloads. First flown in 1965, the *Aero Spacelines Super Guppy* has been used by NASA (National Aeronautics and Space Administration) to transport space rocket components – including sections of the *Saturn V* moon rocket.

– AMAZING AIRCRAFT –

F-35 LIGHTNING II

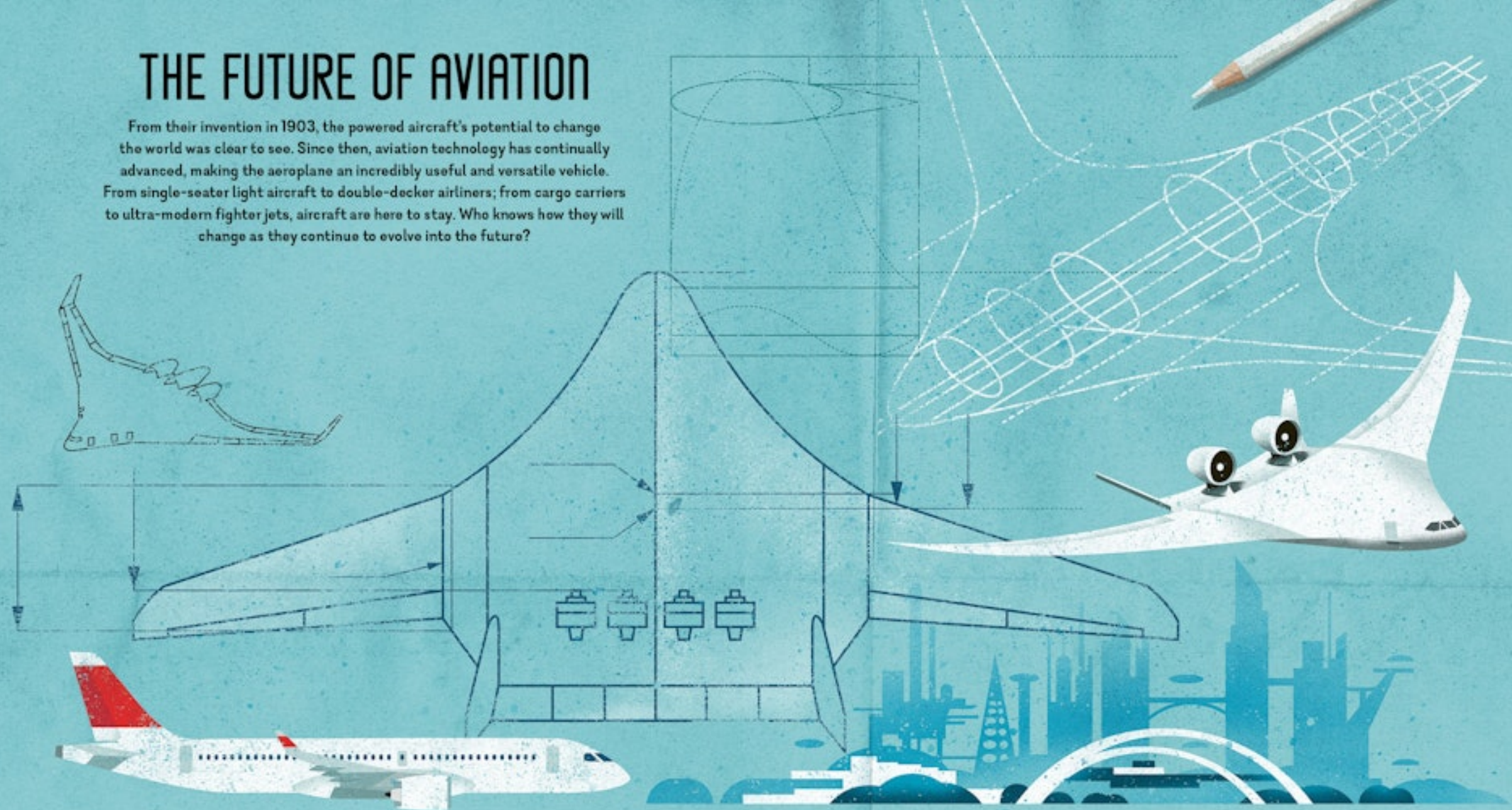
The *Lockheed Martin F-35 Lightning II* fighter flies on the cutting edge of aviation technology. First introduced in 2006 after many years of development, it's likely to remain in service until around 2070. Although the *F-35* is a fighter jet, it's not designed for the sort of close-quarters dogfights carried out by older fighters. Instead, the *F-35* is a stealth aircraft – staying invisible to enemy radar while carrying out its missions. It's also a long-range fighter, locating enemy aircraft or ground targets from hundreds of kilometres away, and long before it itself can be detected.

There are three types (called 'variants') of the *F-35 Lightning*. With a top speed of 1,960km/h, the *F-35A* is the fastest. It's a conventional take-off and landing (CTOL) aircraft, meaning it needs a full-length runway to operate from. The *F-35B* is a short take-off and landing (STOL) aircraft, meaning it only needs a short runway to get into the air and, like the *Hawker Siddeley Harrier* (see pages 50–51), can land vertically. The *F-35C* is designed to operate from aircraft carriers. A steam-powered catapult launches it into the air, and an 'arrestor' hook hanging from the Lightning's rear grabs cables strung across the carrier deck to bring the aircraft to a dead stop when it lands.

The cockpit is designed to provide all the flight information the pilot needs (such as altitude, speed, fuel level and the location of other aircraft) as efficiently as possible. As well as providing night vision, there's a touchscreen display below the canopy. Pilots wear helmets equipped with a 'helmet-mounted display system', which means they can see vital flight information no matter what direction they turn their head.

THE FUTURE OF AVIATION

From their invention in 1903, the powered aircraft's potential to change the world was clear to see. Since then, aviation technology has continually advanced, making the aeroplane an incredibly useful and versatile vehicle. From single-seater light aircraft to double-decker airliners; from cargo carriers to ultra-modern fighter jets, aircraft are here to stay. Who knows how they will change as they continue to evolve into the future?



As useful as aircraft are, we know that the non-renewable fossil fuels they burn create harmful emissions that contribute to climate change. In 2019, there were around 38 million commercial passenger flights and, except during the Coronavirus pandemic (2020–2023) when many flights were grounded, flight numbers continue to rise every year. Manufacturers are constantly updating and redesigning airliners so they can carry more people and fly as fuel efficiently as possible. This *Airbus A220-300* is one of the most fuel-efficient airliners in the world.

Looking further ahead, it's possible that aeroplanes will be able to replace fossil fuels with cleaner alternatives, such as hydrogen gas or electricity. Research is also being carried out on airliners with radically different designs from the 'tube and wing' configuration of most modern passenger jets. One idea is called the 'blended wing body', which incorporates the fuselage into the wing. The advantage of this is that the whole plane produces lift (not just the wings), and so it becomes more efficient.

AVIATION TIMELINE

The introduction of powered flight and pilot-controlled aviation, and the 120 years of technological development that has occurred since, has ensured that the aeroplane is an everyday part of our lives – even if it's just seeing distant vapour trails form in the skies over our heads. The aeroplane will continue to develop and shape our world for many years to come.

AROUND 500 BCE

Kites and sky lanterns invented in ancient China.

1480s

Leonardo da Vinci designs a flying machine called an 'ornithopter'.

1793

The first people-carrying hot air balloon takes off in France.

19TH CENTURY

Many piloted gliders are invented, paving the way towards the first powered aeroplane.

1949

The first non-stop circumnavigation of Earth in an aeroplane.

1947

The first time a pilot breaks the speed limit in level flight.

1948

The first jet bomber enters service in the USA.

1952

The first jet airliner was brought into service.

1976

Concorde, the first supersonic airliner, carries its first load of passengers.

1966

The *SR-71A Blackbird*, the world's fastest aircraft, first takes to the air, as well as the *Harrier*, the first V/STOL aircraft.

1999

First non-stop circumnavigation around the world in a hot air balloon.

1903

The Wright brothers make the first powered flights in their aeroplane, the *Flyer*.

1897

The first rigid airship, later known as the Zeppelin, is built in Germany.

1914–18

The first fighter and bomber aircraft are used during the First World War, as well as the first aircraft carrier.

1944

The first jet and rocket powered fighters enter service in Germany.

1939–45

The Second World War is the first major conflict where the aeroplane plays a major role in the outcome.

1936

The first helicopter whirls into the air.

1920–30s

The Golden Age of Flight, when many records were broken and the first commercial airline companies were formed.

2005

The world's largest passenger airliner, the *Airbus A380*, takes its first flight.

2010

Solar Impulse 1, a solar-powered aircraft, completes its first 24-hour flight, staying afloat at night by using solar energy captured during the day.

2021

Ingenuity, a helicopter designed by NASA, completes its first flight on Mars, marking the first, powered controlled flight on another planet.

RECORD BREAKERS

Aviation technology, be it for aeroplanes or helicopters, continues to evolve at a high pace. Designers all over the world are constantly pushing the boundaries to create ever faster, bigger and better flying vehicles. Here are a some of the most amazing aviation world records.

HEAVIEST AIRCRAFT

640 tonnes / *Antonov An-225 Mriya* / Cargo aircraft / Russian

HEAVIEST PROPELLER AIRCRAFT

250 tonnes / *Antonov An-22* / Cargo aircraft / Russian

HEAVIEST HELICOPTER

28 tonnes / *Mil Mi-26* / Transport helicopter / Russian

FASTEST AIRCRAFT

3,500km/h / Lockheed *SR-71A Blackbird* / Reconnaissance aircraft / American

FASTEST HELICOPTER

400.9km/h / *Westland Lynx* / Multi-purpose helicopter / British

BUSIEST AIRPORT

3110,531,300 passengers in 2019 / Hartsfield-Jackson Atlanta International, USA

LARGEST AIRPORT BY AREA

776km² / King Fahd International, Saudi Arabia

FIRST CIRCUMNAVIGATION IN A SOLAR POWERED AIRCRAFT

42,438km / 23.25 days of flight time / *Solar Impulse II* / 2015-16

FIRST NON-STOP CIRCUMNAVIGATION

1949 / 94 hours and 1 minute / Boeing *B-50 "Lucky Lady II"*

GLOSSARY

AEROBATICS

Complex aerial manoeuvres and routines designed to entertain audiences on the ground. Can include loops, rolls, turns and tailslides.

AERODYNAMIC

Aircraft designed to be less affected by drag. Aerodynamic aircraft often have a smooth, narrow or rounded construction so air flows more easily over them.

AILERON

A hinged horizontal flap on the trailing edge of an aircraft's wing. Adjusting them causes the aircraft to roll/turn.

AVIATOR

Another word for 'pilot' or 'flyer'.

BALLAST TANK

The water-filled compartment in an airship. Water is jettisoned to lighten the load and cause the airship to rise into the air.

CALL SIGN

The name of an aircraft used when communicating via radio.

CAMOUFLAGE

The method of using particular colours, patterns or materials to make something hard to see.

CARGO

Goods carried on a ship, aircraft, train, or any kind of vehicle.

CIRCUMNAVIGATE

To travel all the way around something, such as Earth.

CIVILIAN

A person who is not a member of the police force, navy, fire brigade or the armed services.

COLD WAR

1947–1991. A time of great distrust between Western democratic countries headed by the USA, and Eastern communist countries headed by the USSR.

COMBUSTIBLE

Something that catches fire easily.

COMMERCIAL AIRLINER

An aircraft that transports fee-paying passengers.

DROP-LAUNCHED

The method of launching a small aircraft from the inside, or from the underside, of a larger aircraft, while in mid-air.

ELEVATORS

Hinged flaps on an aircraft's tail, used to gain or reduce altitude.

FUSELAGE

The main section – or 'body' of an aircraft – where crew and passengers sit, and luggage is stored.

LEADING EDGE

The parts of an aircraft that face into the wind while flying forwards, such as the front of the wings.

POLYMATH

A person who is an expert in more than one field of study.

PROTOTYPE

An early experimental model of a device or vehicle on which later mass-produced versions are based.

RADAR

Radio Detection And Ranging. A system that uses radio waves to locate objects too far away to see.

RECONNAISSANCE MISSION

Also known as 'scouting', these missions involve surveying an area to obtain military information.

SUBMARINE

A vehicle designed to travel underwater.

SUBWAY SYSTEM

A public transport railway network that uses underground stations and tunnels.

SUPERSONIC

An aircraft that can travel faster than the speed of sound: 1,235km/h.

THROTTLE

A device that pilots use to regulate how much power they feed to the engines. More throttle means more speed. Similar in use to a car's accelerator.

U-BOAT

The name given to German submarines during the First and Second World Wars. 'U-boot' in German is the shortened version of Unterseeboot ('under-sea-boat').

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