Aircraft

A Japan Airlines Boeing 747-400. This is a wide-bodied long-haul **aircraft** An **aircraft** is any machine capable of atmospheric flight.

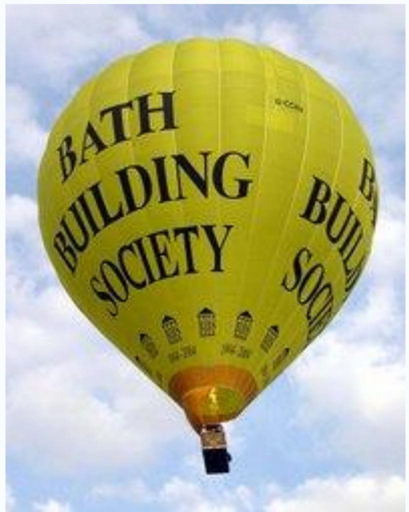
Categories and classification

Aircraft fall into two broad categories:

Heavier than air

- Heavier than air **aerodynes**, including autogyros, helicopters and variants, and conventional **fixed-wing aircraft**: ***aeroplanes*** in Commonwealth English (excluding Canada), ***airplanes*** in North American English. Fixed-wing aircraft generally use an internal-combustion engine in the form of a piston engine (with a propeller) or a turbine engine (jet or turboprop), to provide thrust that moves the craft forward through the air. The movement of air over the airfoil produces lift that causes the aircraft to fly. Exceptions are gliders which have no engines and gain their thrust, initially, from winches or tugs and then from gravity and thermal currents. For a glider to maintain its forward speed it must descend in relation to the air (but not necessarily in relation to the ground). Helicopters and autogyros use a spinning rotor (a *rotary wing*) to provide lift; helicopters also use the rotor to provide thrust. The abbreviation VTOL is applied to aircraft other than helicopters that can take off or land vertically. STOL stands for Short Take Off and Landing. Mainly used internationally.

Lighter than air



A hot air balloon takes off from Royal Victoria Park, Bath, England

- Lighter than air **aerostats**: hot air balloons and airships. Aerostats use buoyancy to float in the air in much the same manner as ships float on the water. In particular, these aircraft use a relatively low density gas such as helium, hydrogen or heated air, to displace the air around the craft. The distinction between a balloon and an airship is that an airship has some means of controlling both its forward motion and steering itself, while balloons are carried along with the wind.

There are several ways to classify aircraft. Below, we describe classifications by design, propulsion and usage.

By design

A first division by design among aircraft is between lighter-than-air, **aerostat**, and heavier-than-air aircraft, **aerodyne**.

Examples of lighter-than-air aircraft include non-steerable balloons, such as hot air balloons and gas balloons, and airships (sometimes called dirigible balloons) such as blimps (that have non-rigid construction) and rigid airships that have a rigid frame. The most successful type of rigid airship was the Zeppelin, although there were some accidents such as the Hindenburg Zeppelin which was destroyed in a fire at Lakehurst, NJ, in 1937.

In heavier-than-air aircraft, there are two ways to produce lift: aerodynamic lift and engine lift. In the case of aerodynamic lift, the aircraft is kept in the air by wings or rotors (see aerodynamics). With engine lift, the aircraft defeats gravity by use of vertical thrust greater than its weight.

Examples of engine lift aircraft are rockets, and VTOL aircraft such as the Hawker-Siddeley Harrier.

Among aerodynamically lifted aircraft, most fall in the category of fixed-wing aircraft, where horizontal airfoils produce lift, by profiting from airflow patterns determined by Bernoulli's equation and, to some extent, the Coanda effect.

The forerunner of these type of aircraft is the kite. Kites depend upon the tension between the cord which anchors it to the ground and the force of the wind currents. Much aerodynamic work was done with kites until test aircraft, wind tunnels and now computer modelling programs became available.

In a "conventional" configuration, the lift surfaces are placed in front of a control surface or tailplane. The other configuration is the canard where small horizontal control surfaces are placed forward of the wings, near the nose of the aircraft. Canards are becoming more common as supersonic aerodynamics grows more mature and because the forward surface contributes lift during straight-and-level flight.

The number of lift surfaces varied in the pre-1950 period, as biplanes (two wings) and triplanes (three wings) were numerous in the early days of aviation. Subsequently most aircraft are monoplanes. This is principally an improvement in structures and not aerodynamics.

Other possibilities include the delta-wing, where lift and horizontal control surfaces are often combined, and the flying wing, where there is no separate vertical control surface (e.g. the B-2 Spirit).

A variable geometry ('swing-wing') has also been employed in a few examples of combat aircraft (the F-111, Panavia Tornado, F-14 Tomcat and B-1 Lancer, among others).

The lifting body configuration is where the body itself produce lift. So far the only significant practical application of the lifting body is in the Space Shuttle, but many aircraft generate lift from nothing other than wings alone.

A second category of aerodynamically lifted aircraft are the rotary-wing aircraft. Here, the lift is provided by rotating aerofoils or rotors. The best-known examples are the helicopter, the autogyro and the tiltrotor aircraft (such as the V-22 Osprey). Some craft have reaction-powered rotors with gas jets at the tips but most have one or more lift rotors powered from engine-driven shafts.

A further category might encompass the wing-in-ground-effect types, for example the Russian ekranoplan also nicknamed the "Caspian Sea Monster" and hovercraft; most of the latter employing a skirt and achieving limited ground or water clearance to reduce friction and achieve speeds above those achieved by boats of similar weight.

A recent innovation is a completely new class of aircraft, the fan wing. This uses a fixed wing with a forced airflow produced by cylindrical fans mounted above. It is (2005) in development in the United Kingdom.

And finally the flapping-wing ornithopter is a category of its own. These designs may have potential but are not yet practical.

By propulsion

A turboprop-engined DeHavilland Twin Otter adapted as a floatplane

Some types of aircraft, such as the balloon or glider, do not have any propulsion. Balloons drift with the wind, though normally the pilot can control the altitude either by heating the air or by releasing ballast, giving some directional control (since the wind direction changes with altitude). For gliders, takeoff takes place from a high location, or the aircraft is pulled into the air by a ground-based winch or vehicle, or towed aloft by a powered "tug" aircraft. Airships combine a balloon's buoyancy with some kind of propulsion, usually propeller driven.

Until World War II, the internal combustion piston engine was virtually the only type of propulsion used for powered aircraft. (See also: Aircraft engine.) The piston engine is still used in the majority of aircraft produced, since it is efficient at the lower altitudes used by small aircraft, but the radial engine (with the cylinders arranged in a circle around the crankshaft) has largely given way to the horizontally-opposed engine (with the cylinders lined up on two sides of the crankshaft). Water cooled V engines, as used in automobiles, were common in high speed aircraft, until they were replaced by jet and turbine power. Piston engines typically operate using avgas or regular gasoline, though some new ones are being designed to operate on diesel or jet fuel. Piston engines normally become less efficient above 7,000-8,000 ft (2100-2400 m) above sea level because there is less oxygen available for combustion; to solve that problem, some piston engines have mechanically powered compressors (blowers) or turbine-powered turbochargers or turbonormalizers that compress the air before feeding it into the engine; these piston engines can often operate efficiently at 20,000 ft (6100 m) above sea level or higher, altitudes that require the use of supplemental oxygen or cabin pressurisation. During the forties and especially following the 1973 energy crisis, development work was done on propellers with swept tips or even scimitar-shaped blades for use in high-speed commercial and military transports.

Pressurised aircraft, however, are more likely to use the turbine engine, since it is naturally efficient at higher altitudes and can operate above 40,000 ft. Helicopters also typically use turbine engines. In addition to turbine engines like the turboprop and turbojet, other types of high-altitude, high-performance engines have included the ramjet and the pulse jet. Rocket aircraft have occasionally been experimented with. They are restricted to rather specialised niches, such as spaceflight, where no oxygen is available for combustion (rockets carry their own oxygen).

By usage

The major distinction in aircraft usage is between military aviation, which includes all uses of aircraft for military purposes (such as combat, patrolling, search and rescue, reconnaissance, transport, and training), and civil aviation, which includes all uses of aircraft for non-military purposes.

Military aircraft

A prototype of Hindustan Aeronautics' Light Combat Aircraft.

Combat aircraft like fighters or bombers represent only a minority of the category. Many civil aircraft have been produced in separate models for military use, such as the civil Douglas DC-3 airliner, which became the military C-47/C-53/R4D transport in the U.S. military and the Dakota in Britain and the Commonwealth. Even the little fabric-covered two-seater Piper J3 Cub had a military version, the L-4 liaison, observation and trainer aircraft. In the past, gliders and balloons have also been used as military aircraft; for example, balloons were used for observation during the American Civil War and World War I, and cargo gliders were used during World War II to land intruding German troops in many European countries in the 1940/42 period, while Allied troops used them in Europe after D-Day .

Combat aircraft themselves, though used a handful of times for reconnaissance and surveillance during the Italo-Turkish War, did not come into widespread use until the Balkan War when first air-dropped bomb was invented and widely used by Bulgarian air force against Turkey. During World War I many types of aircraft were adapted for attacking the ground or enemy vehicles/ships/guns/aircraft, and the first aircraft designed as bombers were born. In order to prevent the enemy from bombing, fighter aircraft were developed to intercept and shoot down enemy aircraft. Tankers were developed after World War II to refuel other aircraft in mid-air, thus increasing their operational range. By the time of the Vietnam War, helicopters had come into widespread military use, especially for transporting and supporting ground troops.

Civil aviation

Bell 206B JetRanger III **helicopter**

Civil aviation includes both scheduled airline flights and general aviation, a catch-all covering other kinds of private and commercial use. The vast majority of flights flown around the world each day belong to the general aviation category, ranging from recreational balloon flying to civilian flight training to business trips to firefighting to medevac flights to cargo transportation on freight aircraft.

Within general aviation, the major distinction is between private flights (where the pilot is not paid for time or expenses) and commercial flights (where the pilot is paid by a customer or employer). Private pilots use aircraft primarily for personal travel, business travel, or recreation. Usually these private pilots own their own aircraft and take out loans from banks or specialized lenders to purchase them. Commercial general aviation pilots use aircraft for a wide range of tasks, such as flight training, pipeline surveying, passenger and freight transport, policing, crop dusting, and medical transport (medevac). Piston-powered propeller aircraft (single-engine or twin-engine) are especially common for both private and commercial general aviation, but even private pilots occasionally own and operate helicopters like the Bell JetRanger or turboprops like the Beechcraft King Air. Business jets are typically flown by commercial pilots, although there is a new generation of small jets arriving soon for private pilots.

Related topics

- List of aircraft by category
- List of aircraft by date and usage category
- List of civil aircraft
- List of helicopter models
- List of military aircraft
- List of World War II jet aircraft
- List of aircraft engines
- List of aircraft engine manufacturers (alphabetical)

- Aerial refuelling
- Aeronautics
- Aircraft carrier
- Aircraft spotting
- Airline call signs
- Airliner
- Air safety

- Aviation
- Contrail
- First flying machine
- Flight controls
- Flight instruments
- Gliding
- Lifting body
- List of early flying machines
- Model aircraft
- Mobile phones on aircraft
- Spacecraft propulsion
- Spacecraft
- Steam aircraft
- Successful aircraft types
- Undercarriage
- Wright brothers
- List of aviation, aerospace and aeronautical terms

History

- Smithsonian Air and Space Museum - Excellent online collection with a particular focus on history of aircraft and spacecraft
- Virtual Museum
- Prehistory of Powered Flight
- The Evolution of Modern Aircraft (NASA)
- Check-Six - Information on historic aircraft crashes including the X-15 and Flying Wing
- Aircraft community

Information

- Aircraft-Info.net
- Airliners.net
- HomebuiltAircraft.com- Information Portal about Homebuilt Aircraft
- Airforces
- Series of Photo Essays on British Aviation
- Pictures of Aircraft published on Usenet
- PAF Procedures and Information, Wallpapers, Picture Gallery, Updated News

Fixed-wing aircraft

An American Airlines Boeing 767, an example of a fixed-wing aircraft

Fixed-wing aircraft is a term used to refer to what are more commonly known as **airplanes** in North American English and **aeroplanes** in Commonwealth English. An airplane is a heavier-than-air aircraft where movement of the wings in relation to the aircraft is not used to generate lift. All aircraft wings flex, and some aircraft have wings that can tilt, sweep back or fold, but if none of these movements are used to generate lift, the wing is considered to be a "fixed-wing."

Fixed-wing aircraft include a large range of craft designed for many purposes from small trainers and recreational airplanes to large airliners and military cargo aircraft. Some aircraft use fixed wings to provide lift only part of the time and may or may not be referred to as fixed-wing. Airplanes have no ability to drive on the ground for extended time periods.

The term also embraces a minority of aircraft with folding wings that are intended to fold when on the ground. This is usually in order to to ease stowage or facilitate transport on, for example, a vehicle trailer or the powered lift connecting the hangar deck of an aircraft carrier to its flight deck. It also embraces an even smaller number of aircraft, such as the General Dynamics F-111 Aardvark, Grumman F-14 Tomcat and the Panavia Tornado, which can vary the sweep angle of their wings during flight. In the early days of their development, these were termed "variable geometry" aircraft. When the wings of these aircraft are fully swept, usually for high speed cruise, the trailing edges of their wings abut the leading edges of their tailplanes, giving an impression of a single delta wing if viewed from above or below. There are also rare examples of aircraft which can vary the angle of incidence of their wings in flight, such the F-8 Crusader, which are also considered to be "fixed-wing".

Two characteristics common to all the airplanes are the necessity of constant air flow over the wings for lifting of the aircraft, and an open area free of obstacles where they can, with sufficient space, take off or land. The majority of airplanes, however, also need an airport with enough infrastructure to receive adequate maintenance, restocking, refueling and for the loading and unloading of crew, cargo and/or passengers, when these are present in sufficient amounts. While the vast majority of airplanes land and take off on land, some are capable of take off and landing on ice, snow and calm water.

The airplane is currently the fastest method of civil and military transport on the planet. Commercial jet airplanes can reach up to 875 km/h, and cover one fourth of the terrestrial sphere in a matter of hours, and single-engine airplanes are easily capable of reaching 175 km/h or more at cruise speed. Supersonic airplanes, currently only military, research and a few private aircraft, can reach speeds that sometime surpass the speed of the sound.

Types of fixed-wing aircraft

Propeller aircraft

1971 Cessna 172

Propeller airplanes make use of combustion engines, that in turn, turn a propeller, which creates the necessary force for the movement of the aircraft. They are relatively quiet, but they fly at lower speeds, and have lower load capacity compared to similar sized jet powered aircraft. However, they are significantly cheaper and much more economic than jets, and is the generally the best option for people who need to use an airplane in a smaller company to transport a few passengers and/or small amounts of cargo. They are also the aircraft of choice for pilots who wish to own their own aircraft.

Jet aircraft

KLM Fokker 70 lands at Bristol International Airport, England

Jet airplanes make use of turbines for the creation of the necessary force for the movement of the aircraft. Jet airplanes generally have turbine engines that are much more powerful than a reciprocating engine. As consequence, they have greater weight capacity and faster flight speeds than propeller driven aircraft. One drawback, however is the great amount of sound created for a turbine; this makes jet airplanes a source of noise pollution.

Huge widebodies ("wide bodies"), such as the Airbus A340 and Boeing 777, can carry hundreds of passengers and several tons of cargo, and are able to travel for distances of up to 13 thousand kilometers - a little more than one quarter of the circumference of the Earth.

Jet airplanes possess high cruising speeds (700 to 900 km/h) and relatively high speeds for take-off and landing (150 to 250 km/h). Due to the high speeds needed for takeoff and landing, the jet airplane makes great use of flaps and leading edge devices for the control of lift and speed, and has engine reversers (or thrust reverses) (to direct the airflow frontward) on most engines for slowing down the aircraft upon landing to supplement the brakes.

Super sonic aircraft


F/A-22 Raptor in flight

Super sonic airplanes, such as military fighters and bombers, the Concorde, also known as the SST (SuperSonic Transport) and others, make use of special turbines (often utilizing afterburners), that generate the huge amounts of power for flight faster than the speed of the sound. Moreover, the design of the supersonic airplane has substantial differences from the design of sub-sonic airplanes, in order to make the transition to supersonic flight smoother and to make supersonic flight more efficient.

Flight at super-sonic speed creates much more sound pollution than flight at sub-sonic speeds, due to the phenomena of sonic booms. This limits super-sonic flights to areas of minimal population density or open ocean. When they approach an area of heavier population density, super-sonic airplanes are obliged to fly at sub-sonic speed.

Due to the high costs, limited areas of use and low demand there are no longer any super-sonic aircraft in use by any major airline, and the last Concorde flight was November 26, 2003. It appears that supersonic aircraft will remain in use almost exclusively by militaries around the world for the foreseeable future.

Rocket-powered aircraft


The X-15 in flight


Bell X-1A in flight

Experimental rocket powered aircraft were developed by the Germans as early as World War II, although they were never mass produced by any power during that war. The first fixed wing aircraft to break the sound barrier was the rocket powered Bell X-1. The later North American X-15 was another important rocket plane, that broke many speed and altitude records and laid much of the groundwork for later aircraft and spacecraft design. Rocket airplanes are not in common usage today, although rocket-assisted takeoffs are somewhat common for military aircraft. SpaceShipOne is the most famous current rocket airplane that is the testbed for developing a commercial sub-orbital passenger service.

Ramjet aircraft


The X-43A, shortly after booster ignition


USAF SR-71 trainer

Ramjet (and the Scramjet variant) aircraft are mostly in the experimental stage. The D-21 Tagboard was an unmanned Mach 3+ reconnaissance drone that was put into production in 1969 for spying, but due to the poor level of success and the development of better spy satellites, it was cancelled in 1971. The SR-71's Pratt & Whitney J58 engines act as ramjets at high-speeds (Mach 3.2). The last SR-71 flight was in October 1999. The Boeing X-43 is an experimental scramjet with a world speed record for a jet-powered aircraft - Mach 9.6, or nearly 7,000 mph. The X-43A set the record on Nov. 16, 2004.

History

The dream of flight goes back, for Man, to the days of pre-history. Many legends, beliefs and myths of antiquity involve flight, such as the legend of Icarus. Leonardo of the Vinci, among others visionary inventors, drew an airplane, in the 15th century. With the first flight made by man (Francois Pilatre de Rozier and Francois d'Arlandes) in an aircraft lighter than air, a balloon, the biggest challenge became to create other craft, capable of controlled flight.

Years of research by many eager people who dreamed of flight produced very slow, but continuous, progress. On August 28 of 1883, John J. Montgomery became the first person to make a controlled flight in a glider. Other aviators who had made similar flights at that time were Otto Lilienthal, Percy Pilcher and Octave Chanute. Sir George Cayley, the inventor of the science of aerodynamics, was building and flying models of fixed wing aircraft as early as 1803, and he built a successful passenger-carrying glider in 1853, but it is known the first practical self-powered aeroplanes were designed and constructed by Clément Ader. On October 9, 1890, Ader attempted to fly the Éole, which succeeded in taking off and flying a distance of approximately 50 meters before witnesses. In August 1892 the Avion II flew for a distance of 200 metres, and on October 14, 1897, Avion III flew a distance of more than 300 metres.

On August 28, 1903 in Hanover, the German Karl Jatho made his first flight. The Wright Brothers made their first successful test flights in December 17, 1903 and by 1904 Flyer III was capable of fully-controllable stable flight for substantial periods. Strictly, its wings were not completely fixed, as it depended for stability on a flexing mechanism named wing warping. This was soon superseded by the competitive development of ailerons, attached to an otherwise rigid wing.

In some countries today, particularly Brazil, Santos-Dumont is considered to be the "Father of Aviation", because of the official and of public character of the *14-bis* flight and/or technical points such as the plane's integral landing gear and its ability to take off on open ground.

The *14 Bis*, was the first to take off, fly, and land without the use of catapults, high winds, or other external assistance. Most Brazilians, and many other admirers of Alberto Santos-Dumont consider him, instead of the Wright Brothers, to be the true inventor of the airplane, although the very concept of the invention of the first flying machine has substantial ambiguity.

Wars in Europe, in particular, the First World War, served as initial tests for the use of the airplane as a weapon. First seen by generals and commanders as a "toy", the airplane proved to be a machine of war capable of causing serious casualties to enemy lines. In the first war, great aces appeared, of which the greatest was the German Red Baron. On the side of the allies, the ace with the biggest amount of downed aircraft was René Fonck, of France.

After the First World War, airplanes gained innumerable technological advances. Charles Lindbergh became the first person to cross the Atlantic Ocean in solo flight nonstop, on May 20, 1927. The first commercial flights took place between the United States and Canada, in 1919. The turbine or the jet engine was in development in the 1930's, military jet airplanes began operating in the 1940's.

Airplanes played a primary role in the Second World War, having a presence, either major or minor, in all the known major battles of the war, especially in the Attack on Pearl Harbor, the battles of the Pacific and D-Day. They were also an essential part of several of the new military strategies of the time period, such as the German Blitzkrieg or the American and Japanese Aircraft carriers.

In October of 1947, Chuck Yeager, in the Bell X-1, was the first person to exceed the speed of sound. The Boeing X-43 is an experimental scramjet with a world speed record for a jet-powered aircraft - Mach 9.6, or nearly 7,000 mph.

Airplanes, in a civil military role, continued to feed and supply Berlin in 1948, when access to railroads and roads to the city, completely surrounded by Eastern Germany, were blocked, by order of the Soviet Union.

The first commercial jet, the de Havilland Comet, was introduced in 1952, and the first successful commercial jet, the Boeing 707, is still in use 50 years later. Boeing 707 would develop into the later in Boeing 737. The Boeing 727 was another widely used passenger airplane, and the Boeing 747, was the biggest commercial airplane in the world up to 2005, when it was surpassed by the Airbus A380.

Designing and constructing an airplane

Small airplanes can be designed and constructed at home, by aviators who possess sufficient knowledge in the areas of engineering, physics and aerodynamics. Other aviators with less knowledge make their airplanes using complete kits, with pre-manufactured parts, and assemble the aircraft themselves.

While there are thousands of "amateur-built" airplanes flying around the world, they are still a small minority. Given their complexity, most airplanes are constructed by companies with the objective of producing them in quantity for customers. The design and planning process, including safety tests, can last up to four years for small turboprops, and up to 12 years for airplanes with the capacity of the A380.

During this process, the objectives and design specifications of the aircraft are established. First. the construction company uses a great number of drawings and equations, simulations, wind tunnel tests and experience to predict the behavior of the aircraft. Generally, computers are used by companies to draw, plan and do initial simulations of the airplane. Small models and mockups of all or certain parts of the airplane are then tested in wind tunnels to verify the aerodynamics of the aircraft.

When the airplane has made it through this process, the company typically constructs a limited number of these aircraft for testing on the ground. Special attention is given to the engines (or turbines) and to the wings.

After passing the above-designated process, representatives from an aviation governing agency often make a first flight. When the behavior of the aircraft does not present suspicion of imperfections, the flight-tests continue until the airplane has fulfilled all the necessary requirements. Then, the governing public agency of aviation of the country authorizes the company to begin production of the aircraft en masse.

In the United States, this agency is the Federal Aviation Administration (FAA), and in the European Union, Joint Aviation Authorities (JAA). These two are the agencies of regulation of most important aircraft of the world. In Canada, the prescribed the public agency in charge and authorizing the mass production of aircraft is the Department of Transport.

In the case of the international trade of airplanes, a license of the public agency of aviation or transports of the country where the aircraft is also to be used is necessary. For example, aircraft from Airbus need to be certified by the FAA to be flown in the United States and vice versa, aircraft of Boeing need to be approved by the JAA to be flown in the European Union.

Industrialized production

There are relatively few companies that produce airplanes on a large scale. However, the production of an airplane for one company is a process that actually involves dozens, or even hundreds, of other companies and plants, that produce the parts that go into the aircraft. For example, one company can be responsible for the production of the landing gear, while another one is responsible for the radar. The production of such parts is not limited to the same city or country; in the case of large aircraft manufacturing companies, such parts can come from all over of the world.

After being manufactured, the parts are sent to the main plant of the aircraft company, where the production line is located. The different parts are assembled with the others, eventually, producing the aircraft. In the case of large airplanes, lines of production are dedicated to the assembly of certain parts of the aircraft can exist, especially the wings and the fuselage.

When complete, an airplane goes through a set of rigorous inspection, to search for imperfections and defects, and after being approved by the inspectors, the airplane is tested by a pilot, in a flight test, in order to assure that the controls of the aircraft are in working properly. With this final test, the airplane is ready to receive the "final touchups" (internal configuration, painting, etc), and is then ready to be sent to the customer.

Safety

Statistics show that the risk of an air accident is very small. One is more likely to have an accident going to the airport in a car than have one during your flight. Many people have a fear of flying because the risk of death in an aircraft accident, if there is one, is extremely high. Furthermore, car crashes rarely feature outside local news whereas air crashes are reported internationally, making the risk seem greater.

The majority of aircraft accidents occur due to human error, that is, an error of the pilot(s) or control tower. After human error, mechanical failure is the biggest cause of air accidents, which sometimes also can involve a human component (ie: negligence of the airline in carrying out proper maintenance). Adverse weather is the third largest cause of accidents. Icing of wings, downbursts and low visibility are often major contributors to weather related crashes.

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Glider

Gliders are heavier-than-air aircraft primarily intended for un-powered flight.

A DG808 over the Lac de Serre Ponçon in the French Alps

Terminology

The term "glider" is broadly used to refer to all types of unpowered aircraft - from older low performance gliders that have only a limited ability to gain altitude to modern high performance gliders capable of flying thousands of kilometers in a single day. The term is also used to refer to motorgliders of various types (see below). The term "sailplane" is of more recent vintage and implies higher performance - at least sufficient for the glider to climb in rising air. (See the article on gliding for more complete information about the sport of soaring.) The term "pure glider" (or equivalently, but less commonly "pure sailplane") may be used to distinguish an unpowered glider from a motorglider, without implying any differential in gliding or soaring performance.

History

In ancient China, manned kites were used for military reconnaissance. The first glider seems to have been designed in 500BC by Lu Pan a contemporary of Confucius, although this was more of a toy than a genuine aircraft. Some records mention manned gliders in China by 500 AD, although the veracity of these accounts is not clear.

The first heavier-than-air (i.e. non balloon) aircraft to be flown in Europe, Sir George Cayley's *Coachman Carrier* (1853), was a pure glider. Otto Lilienthal, Percy Pilcher and the Wright Brothers are other pioneers who built gliders to develop aviation. After the First World War gliders were built in Germany for sporting purposes and this is the main use of gliders today throughout the world. However, gliders were developed by a number of countries for military use, particularly during World War II. A glider was even built secretly by POWs as a potential escape method at Colditz Castle near the end of the war in 1944. (See article: Military gliders)

The Orbiter vehicles or "space shuttles", which glide to earth at the end of each spaceflight, are also gliders.

Sailplanes

Typical Modern Sailplane Cockpit (N101RP "67R")

Sailplanes are specifically intended for the sport of gliding. Their design enables them to use energy from the atmosphere to "soar"; they can climb as well as descend. For more about soaring, see the *gliding*, *hang gliding* and *paragliding* articles.

Launch methods

The two most common methods of launching gliders are by aerotow and by winch. When aerotowed, the glider is towed behind a powered aircraft using a rope about 60 meters long. The sailplane's pilot releases the rope after reaching the required altitude, but the rope can also be released by the towplane in an emergency. Winch launching uses a powerful stationary engine located on the ground at the far end of the launch area. The glider is attached to one end of 800-1200 metres of wire cable and the winch then rapidly winds it in. More rarely, automobiles are used to pull gliders into the air or gliders are launched from sloping ground or cliffs. For more about these and other methods (see *gliding*).

Staying aloft without an engine

Flights of five hours (and much longer) by sailplanes are common. These flights are possible because glider pilots seek out rising air masses (lift) that has been created by one or more of several naturally occurring weather phenomena.

THERMALS: The most commonly used source of lift is created by the sun's energy heating the ground which in turn heats the air above it. This warm air rises in columns known as thermals. Soaring pilots quickly become aware of visual indications of thermals such as: cumulus clouds, cloud streets, dust devils and haze domes. Also, nearly every glider contains an instrument known as a variometer (a very sensitive vertical speed indicator) which shows visually (and often audibly) the presense of lift and sink. Having located a thermal, a glider pilot will circle within the area of rising air to gain height. In the case of a cloud street thermals can line up with the wind creating rows of thermals and respectively sinking air. A pilot can use a cloud street to fly long straightline distances by remaining in the row of rising air.

RIDGE LIFT: Another form of lift is formed when the wind meets a mountain, cliff or hill. The air mass is deflected up the windward face of the mountain forming lift and sailplanes can climb in this rising air by flying along these features. This is commonly referred to as "ridge running" and has been used to set record distance flights along the Appalachians in the USA and the Andes Mountains in South America.

MOUNTAIN WAVE: The third main type of lift used by glider pilots occurs downwind of the mountains because the airflow can generate standing waves with alternating areas of lift and sink.

CONVERGENCE: Another form of lift results from the convergence of air masses, as with a sea-breeze front.

More exotic forms of lift are the polar vortexes which the Perlan Project hopes to use to soar to great altitudes [1]. A rare phenomenon known as Morning Glory has also been used by sailplane pilots in Australia [2].

Sailplane design

Early gliders had no cockpit and the pilot sat on a small seat located just ahead of the wing. These were known as "primary gliders" and they were usually launched from the tops of hills, though they are also capable of short hops across the ground while being towed behind a vehicle. To enable sailplanes to soar more effectively than primary gliders, the designs minimised drag. Sailplanes now have very smooth, narrow fuselages and very long, narrow wings with a high aspect ratio.

The early gliders were made mainly of wood with metal fastenings, stays and control cables. Later fuselages made of fabric-covered steel tube were married to wood and fabric wings for lightness and strength. New materials such as carbon-fiber, glass-fiber and Kevlar have since been used with computer-aided design to increase performance. The first glider to use glass-fiber extensively was the Akaflieg Stuttgart Phönix which first flew in 1957. This material is still used because of its high strength to weight ratio and its ability to give a smooth exterior finish to reduce drag. Drag has also been minimised by more aerodynamic shapes and retractable undercarriages.

With each generation of materials and with the improvements in aerodynamics, the performance of gliders has increased. One measure of performance is the glide ratio. A ratio of 17:1 means that in smooth air a sailplane can travel forward 17 meters while only losing 1 meter of altitude. Comparing some typical gliders that might be found in the fleet of a gliding club - the Grunau Baby from the 1930s had a glide ratio of just 17:1, the glass-fiber Libelle of the 1960s increased that to 39:1, and nowadays flapped 18 meter gliders such as the ASG29 have a glide ratio of over 50:1. The latest open-class sailplanes with spans of 26 meters can exceed ratios of 60:1 and maintain this efficiency over a wide range of air-speeds.

Due to the critical role that aerodynamic efficiency plays in the performance of a sailplane, sailplanes often have state of the art aerodynamic features seldom found in other aircraft. A modern racing sailplane will have a specially designed low-drag laminar flow airfoil and a wing produced in a mold with a wing surface that is smooth to within a few thousandths of an inch. Vertical winglets at the ends of the wings are computer designed to decrease drag and improve handling performance. Special aerodynamic seals are used at the ailerons, rudder and elevator to prevent the flow of air through control surface gaps. Turbulator devices in the form of a zig-zag tape or multiple blow holes positioned in a spanwise line along the wing are used to trip laminar flow air into turbulent flow at a desired location on the wing. This flow control prevents the formation of laminar flow bubbles and ensures the absolute minimum drag. Bug wipers may be installed to wipe the wings while in flight and remove insects that may disturb the smooth flow of air over the wing.

Modern gliders are also designed to carry jettisonable water ballast. This is advantageous if the lift is likely to be strong, and may also be used to adjust the glider's centre of gravity. Although heavier gliders have a slight disadvantage climbing in rising air, the same glide angle is achieved at a higher velocity. While this is an advantage in strong conditions when the gliders spend only little time climbing in thermals, the pilot can jettison the water ballast before it becomes a disadvantage because of weaker thermal conditions. To avoid undue stress on the airframe, gliders must jettison the water ballast before landing.

Classes of glider

For competitions several classes of glider have been defined by the FAI. They are:

- Standard Class (No flaps, 15m wing-span, water ballast allowed)
- 15 metre Class (Flaps allowed, 15m wing-span, water ballast allowed)
- 18 metre Class (Flaps allowed, 18m wing-span, water ballast allowed)
- Open Class (No restrictions)
- Two Seater Class (maximum wing-span of 20 metres)
- Club Class (This class allows a wide range of older small gliders with different performance and so the scores have to be adjusted by handicapping. Water ballast is not allowed).
- World Class (The International Gliding Commission which is part of the FAI and an associated body called Organisation Scientifique et Technique du Vol à Voile (OSTIV) announced a competition in 1989 for a low-cost sailplane, which had moderate performance, was easy to assemble and to handle, and was safe for low hours pilots to fly. The winning design was announced in 1993 as the Warsaw Polytechnic PW-5. This allows competitions be run with only one type of glider.

Major manufacturers of gliders

- DG Flugzeugbau GmbH
- Schempp-Hirth GmbH
- Alexander Schleicher GmbH & Co
- Rolladen-Schneider Flugzeugbau GmbH (taken over by DG Flugzeugbau)

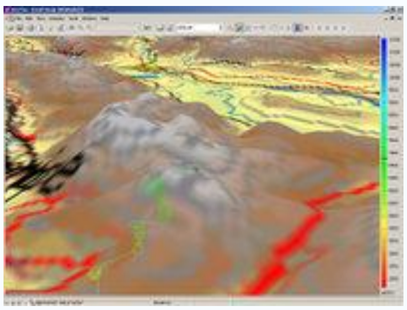
See also the full list of glider manufacturers, past and present, and the list of gliders.

Instrumentation and other technical aids

Gliders are equipped with an altimeter, compass and an air-speed indicator, and often with a radio, though in some countries the radio is not compulsory. In European countries with crowded airspace there are also proposals that all gliders should fly with anti-collision devices such as transponders but this is still uncertain.

Much more than in other types of aviation, glider pilots depend on an instrument known as a variometer (a very sensitive vertical climb indicator), which measures the climb or sink rate of the plane. This enables the pilot to detect rising and sinking air. Both mechanical and electronic 'varios' are usually fitted to a glider. The electronic variometers produce a beeping noise of variable amplitude and frequency depending on the strength of the lift, so that the pilot can concentrate on watching for other traffic, on navigating and on the weather. (Refer to the *variometer* article for more information). Rising air is announced to the pilot as a rising tone which the pilot may choose to react to by turning the sailplane to circle in the lift. Alternately descents are announced with different tone and the pilot will typically accelerate to escape the sink as soon as possible. The same instrument will often also suggest an ideal speed when flying straight after allowing for factors such as water ballast, headwinds/tailwinds and insects on the leading edges of the wings.

Sailplane variometers are often fitted with devices such as the "MacCready Ring" to indicate the optimal speed to fly for given conditions. These devices are based on the mathematical theory developed by Paul MacCready. MacCready theory solves the problem of how fast a pilot should cruise in between thermals, given both the average lift the pilot expects in the next thermal climb, as well as the amount of lift or sink he encounters in cruise mode.



SeeYou(C) Soaring Software - Click to enlarge

Soaring flight computers, in combination with PDAs and specialized soaring software, have been specifically designed for sailplane use. Using GPS technology these tools are able to:

- Provide the glider's position in 3 dimensions by a moving map display
- Alert the pilot to nearby airspace restrictions
- Indicate contest task position along with managing required course direction and distance
- Show airports within gliding distance (ignoring sink/lift)
- Calculate and display information to help in remaining aloft
- Determine wind direction and speed at current altitude
- Show historical lift information
- Create a secure GPS log of the flight, required for contest flying

...and a host of other soaring related data.

The flight computer's GPS log may be replayed on specialized computer software to analyse past flights, including watching one or more gliders fly together in a two or three dimension *3-D* view. The 3-D representation is shown here with a typical topographical background showing map details such as roads, cities and airports. The glider ("CD") has just executed a series of tight thermalling turns in the Austrian Alps. Other backgrounds might be a satellite image or an FAA sectional map.

Glider markings

To distinguish gliders in flight, large numbers/letters are sometimes put on the fin and wings. Because these numbers were once needed by ground-based observers in competitions, these are known as "competition numbers". They are in addition to the glider's registration and are assigned by national gliding associations. They are useful in radio communications between gliders and so they are often the glider's call-sign.

Modern gliders are mainly white but some have bright patches painted on them in an attempt to improve their visibility to other aircraft.

Aerobatic gliders

A modern aerobatic glider

Another - less widespread - form of gliding is aerobatics. In this type of competition, the pilot fly a program of maneuvers (such as inverted flight, loop, roll, and various combinations). Each maneuver has a rating called the "K-Factor." This number of points is given if the maneuver is flown perfectly, otherwise a number of points is subtracted. The winner is the pilot with the highest sum of points in each skill based category.

Schleicher ASH26 self-launching glider

Motor gliders

Scheibe SF25C - a typical old-style touring motorglider

Some sailplanes ("self-launching motor gliders") are equipped with propellers that retract into the fuselage. The motor is powerful enough to allow these gliders to launch independently. Recently electric self-launchers such as the Antares have been developed. Others ("self-sustaining motor gliders," also referred to as "turbo" or "sustainer" gliders) are equipped with motors just powerful enough to allow the glider to climb slowly but they must be launched like unpowered gliders. A third type, termed touring motorglider, has a conventional layout with a motor and propellor on the front of the aircraft.

The most important point in favor of powered gliders (retractable engine high-performance types) is that it helps pilots to avoid outlandings. Outlandings, while they are not necessarily dangerous, can be an expensive and time-consuming nuisance for competitive pilots who need to be back home at a set time. Another consideration is that a retrieve crew is needed on stand-by. However the sense of achievement in completing a difficult cross-country is lessened if an engine has been available.

Some people argue that an engine makes the aircraft safer, because the pilot can avoid storms, and can go on to an airstrip to land. An opposing view is that motor gliders are against the spirit of the sport, and, more importantly, that they sometimes give pilots a false sense of security. Even in a motor glider, it is important never to be out of gliding range of a 'landable' area.

More recently, pilot licensing terms have changed in Europe. Powered gliders are now categorized into gliders with retractable propellers/engines, which can be flown with an ordinary glider pilot license (GPL), and touring motor gliders (TMG), which require a specific license extension to the standard GPL. In the United Kingdom, where gliding is regulated by the British Gliding Association, pilots of self-sustaining gliders, like those of pure gliders, do not have to be licensed with the United Kingdom Civil Aviation Authority.

In the United States, a private glider pilot certificate allows the pilot to fly unpowered gliders, self-launching motor gliders (including touring motor gliders and gliders with retractable engines or propellors) and sustainer motor gliders. An instructor must provide instruction and sign the logbook of the pilot to authorize the launch method, which may be by airplane towing, ground launch (winches, bungee, auto tow, etc.) or, in the case of a suitable motor glider, by self-launching.

Other meanings

- In Conway's Game of Life a glider is a certain small structure that moves indefinitely in a direction. In cellular automata in general, such features are known as spaceships
- A comfortable swinging padded seat with a back, usable by more than one person, and typically used on a porch or veranda, is also called a *glider*.
- Glider PRO by Casady & Greene, a game for the Apple Macintosh.

See also

- gliding
- glider pilot license (GPL)
- Gimli Glider
- Hang Glider
- Paraglider
- Underwater gliders

Conventional airplanes

Conventional airplanes -- from small planes such as the Bumble Bee II and Cessna 140 to a gigantic Antonov 225 -- consist of a longitudinal fuselage, one or more wings to provide the majority of lift, a tailplane for stability, and a one or more vertical surfaces at the tail for stability.

Fixed parts

- Each wing is a single wing structure integrated into the fuselage of the aircraft. Sometimes, the half of a wing on either side of the fuselage is referred to as a wing, e.g. left wing and right wing. Most airplanes are monoplanes having one wing structure for providing lift. Biplanes (two wings) or triplanes (three wings) were popular in the past, and some are still made for special purposes like aerobatics. Fuel is often stored in tanks in the wing.
- In smaller aircraft, fuel is sometimes stored in the fuselage (or main body).
- An engine (or engines): Also known as powerplants, engines serve to propel the aircraft on the ground and the air. Airplanes use a wide variety of engines, including turbine, reciprocating, and radial engines. The engines are usually located under or on the wings or attached to the fuselage. A few aircraft have engines attached to the vertical or horizontal stabilizer.
- The tailplane is a small wing that provides positive or negative lift to stabilize the aircraft in flight. Most often it is configured to provide negative lift. It may be a fixed horizontal stabilizer with a movable elevator or a stabilator that rotates on a shaft to change the angle of incidence.
- The vertical stabilizer is a small vertical wing that is usually attached to the rear of the fuselage. Some aircraft have two vertical stabilizers attached to the horizontal stabilizer or boom structures. A rudder is attached to the vertical stabilizer.

Mobile parts

- Ailerons are located on the wing of the aircraft. They always act at the same time, but in inverse directions, so that the airplane can be turned along its longitudinal axis. This movement is called roll. Because roll changes the direction of lift of the wings, it is the primary method of changing the direction of travel.
- The elevators are located on the horizontal stabilizer to control the rotation around the lateral axis called pitch. The elevator and horizontal stabilizer may be combined into a stabilator.
- On delta-wing aircraft the ailerons and elevators are combined together to perform the same actions and are called elevons.
- The rudder is located on the vertical stabilizer and controls movement around the vertical axis called yaw.
- The landing gear allow the airplane to take off and land. They usually retract during flight to reduce drag; however, on smaller aircraft the gear are often fixed parts. Some aircraft are equipped with special landing gear, such as pontoons or skis, to allow them to land on various surfaces.
- The flaps change the profile of the wing of the airplane, maximizing lift and control of the speed of the aircraft in air, particularly in operations of low speed - especially important in landing and take-off.

Other common parts of aircraft include trim tabs, air brakes, spoilers, winglets and canards.

Unconventional aircraft have been built in a variety of forms. For example: lifting body, canard, V-tail and flying wing.

Complex airplane

A **complex** **airplane** as defined by the United States Federal Aviation Administration is an airplane that has all of:

- A retractable landing gear (land airplane only; a seaplane is not required to have this)
- A controllable pitch propeller (also called a constant speed propeller)
- Movable or adjustable flaps.

Undercarriage

Main and nosewheel undercarriage of a Qatar Airways Airbus A330

Wing and fuselage undercarriages on a Boeing 747, shortly before landing

The dual tandem landing gear of a B-52 Stratofortress

The **undercarriage** or **landing gear** is equipment which supports an aircraft when it is not flying. The assembly usually has wheels and some sort of shock absorber apparatus, but sometimes skis for snow or floats for water, and skids or pontoons (helicopters). To decrease drag in flight, the undercarriages on many aircraft, particularly large modern ones, retract behind doors which close flush with the fuselage.

A design for retractable landing gear was first seen as far back as 1876 in plans for an amphibious monoplane designed by Frenchmen Alphonse Pénaud and Paul Gauchot . Aircraft with at least partially retractable landing gear did not appear until 1917, and it wasn't until the late 1920s and early 1930s when such aircraft became common. By then, aircraft performance was improved to the point where the aerodynamic advantage of retractable undercarriage justified the added complexity and weight.

Wheeled undercarriages come in two main types: either *taildragger*, where there are two main wheels towards the front of the aircraft and a single, much smaller, wheel or skid at the rear; or *tricycle undercarriage* where there are two main wheels (or wheel assemblies) under the wings and a third smaller wheel in the nose. Most modern airplanes have tricycle undercarriages or variants thereof. Taildraggers are considered harder to land and take off, and usually require special training. Sometimes a small tail wheel or skid is added to aircraft with tricycle undercarriage, in case the tail strikes the ground during take-off. The Concorde, for instance, had a retractable tail "bumper" wheel.

As aircraft grow larger, they employ more wheels to cope with the increasing weights. The Airbus A340-500 has an additional four-wheel undercarriage bogie on the fuselage centreline. The Boeing 747 has five sets of wheels, a nose-wheel assembly and four sets of four-wheel bogies. A set is located under each wing, and two inner sets are located in the fuselage, a little rearward of the outer bogies. Tricycle undercarriage aircraft are usually steered by the leading wheel(s) when taxiing. The Boeing 747 is also partially steered by the two inner bogies which guide the body of the aircraft left when the nose wheels are moving the front of the 747 to the right, much as four-wheel steering works on a car.

Some planes use wheels only for take off and drop them afterwards to gain the improved streamlining without the complexity, weight and space requirements of a retraction mechanism. In this case, landing is achieved on skids or similar simple devices. Historical examples include the Messerschmitt Me 163 and the Messerschmitt Me 321.

Hawker Harrier GR7 (ZG472) showing the two mainwheels in line astern under the fuselage and the smaller wheel near the tip of each wing.

Other examples of unusual undercarriage configuration include the Hawker-Siddeley Harrier, which has two mainwheels in line astern under the fuselage (called a bicycle or *tandem* layout) and a smaller wheel near the tip of each wing (moved further inboard on second generation Harriers). A multiple tandem layout was used on some military jet aircraft during the 1950s such as the Lockheed U-2, Myasishchev M-4, Yakovlev Yak-25, Yak-28 and the Boeing B-47 because it allows room for a large internal bomb bay between the main wheels. A variation of the multi tandem layout is also used on the B-52 Stratofortress which has four main wheel bogies underneath the fuselage and a small outrigger wheel supporting each wing-tip. The B-52's landing gear is also unique in the way all four pairs of main wheels can be steered. This allows the landing gear to line up with the runway and thus makes crosswind landings easier (using a technique called *crab landing*).

Undercarriage malfunction can directly result in ground loop.

Flap (aircraft)

Three-slotted trailing-edge **flaps** on a Boeing 747 fully extended for landing at Heathrow airport, London.

Flaps are hinged surfaces on the trailing edge of an airplane wing which, when deployed, increase the lift (and drag) of a wing by changing the camber of the airfoil. They are usually used while landing to allow the aircraft to fly more slowly and to steepen the approach to the landing site.

Types include:

- Plain flap - rotates on a simple hinge.
- Split flap - upper and lower surfaces are separate, the lower surface operates like a plain flap, but the upper surface stays immobile or moves only slightly.
- Fowler flap - slides backwards before hinging downwards, thereby increasing both camber and chord, creating a larger wing surface better tuned for lower speeds.
- Slotted flap - systems made up of several individual Fowler flaps, which combine to form a single, much more powerful, flap.
- Blown flaps - systems that blow engine air over the upper surface of the flap at certain angles to improve lift characteristics.

Slats are similar to flaps - they are on the leading edge of the wing.

Air brake (aircraft)

This KLM cityhopper Fokker 70 still has its spoilers/airbrakes deployed (the cream-coloured panels) after landing at Bristol International Airport, England.

In aeronautics **air brakes** are a type of flight control used on aircraft to reduce speed during landing.

Air brakes differ from spoilers in that air brakes are designed to increase drag while making little change to lift, spoilers greatly reduce lift while making little change to drag.

Often, both characteristics are desirable - most airliners for example feature combined spoiler and airbrake controls. On landing, the deployment of these spoilers causes a dramatic loss of lift and hence the weight of the aircraft is transferred from the wings to the undercarriage, allowing the wheels to be mechanically braked with much less chance of skidding. In addition, the form drag created by the spoilers directly assists the braking effect. Reverse thrust is also used to help slow the aircraft on landing.

One interesting airbrake design is the deceleron, a special kind of aileron that functions normally in flight but can split in half such that the top half goes up as the bottom half goes down to brake. This technique was first used on the F-89 Scorpion and has since been used by Northrop on several aircraft, including the B-2 Spirit.

Airfoil

An aerofoil section is nicely displayed at the tip of this Denney Kitfox aircraft (G-FOXC), built in 1991

An **aerofoil** (in British English, or **airfoil** in American English,) is the shape of a wing or blade (of a propeller or ship's screw or sail) as seen in cross-section. It is passed through a fluid in order to provide either lift or downforce, depending on its application. Subsonic-flight aerofoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, and often with camber.

Lift and Drag curves for a typical aerofoil

To understand lift itself, see lift. As well as the wing, an aircraft's horizontal and vertical stabilizers are aerofoils as well. Aerofoils are also found in propellors, fans, compressors and turbines. Sails are also aerofoils, and the underwater fins of sailboats, such as centerboards are similar in cross-section and operate on the same principles as aerofoils. Swimming and flying creatures and even many plants and sessile organisms employ aerofoils; common examples being bird wings, the bodies of fishes, and the shape of sand dollars .

An inverted aerofoil will create a downward pressure on an automobile or other motor vehicle, improving its traction and keeping it on the ground. The term "lift" can mean a force generated in any direction in any medium. Any thin object with a positive angle of attack, such as a flat plate or the deck of a bridge, will generate lift. Aerofoils though are more efficient, generating lift with the least drag and maintaining lift at higher angle of attack. A lift and drag curve obtained in wind tunnel testing is shown on the right.

Aerofoil design is a major facet of aerodynamics. Various aerofoils serve different flight regimes. A supercritical aerofoil, with its low camber, reduces transonic drag divergence, while a symmetric aerofoil may better suit frequent inverted flight. Supersonic aerofoils are much more angular in shape and can have a very sharp leading edge. Moveable high-lift devices, flaps and slats are fitted to aerofoils on most aircraft. New aerofoil design techniques continue to develop.

Various systems have been devised to describe and characterise aerofoils — the most common and prevalent is the NACA system. Before this, various ad-hoc systems were used. An example of a general purpose aerofoil that finds wide application, and predates the NACA system is the Clark-Y.

Winglet

Winglets on a Privatair Boeing Business Jet

The winglets of a Learjet 60 business jet

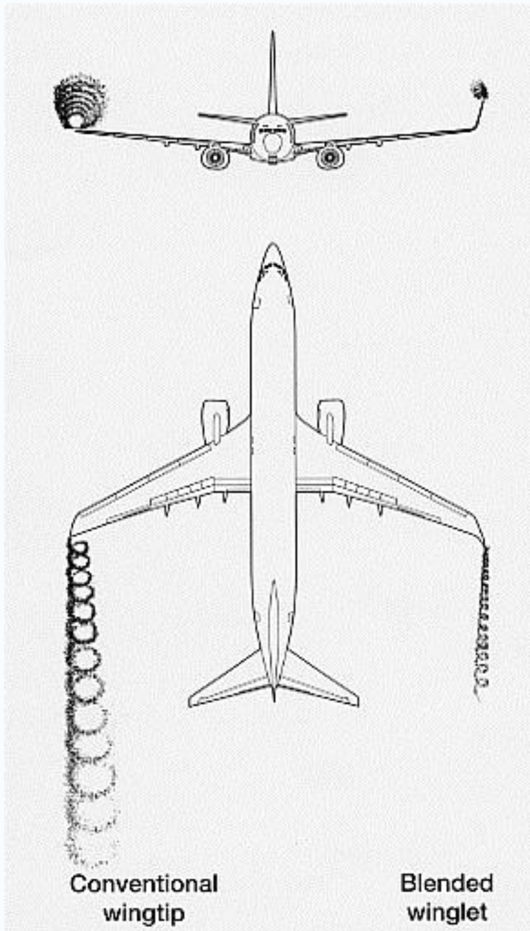
A **winglet** is a device used to improve the efficiency of aircraft by lowering the lift-induced drag caused by wingtip vortices. The winglet is a vertical or angled extension at the tips of each wing.

Winglets work by increasing the effective aspect ratio of a wing without adding greatly to the structural stress and hence necessary weight of its structure - an extension of wing span would also permit lowering of induced drag, though it would cause parasitic drag and would require boosting the strength of the wing and hence its weight - there would come a point at which no overall useful saving would be made. A winglet helps to solve this by effectively increasing the aspect ratio without adding to the span.

The exact upward angle (called *cant*) of the winglet, and its inward angle (or *toe*) is critical for correct performance, and is determined for each aircraft application. The vortex which rotates around from below the wing strikes the angled surface of the winglet, generating a small lift force that angles forwards relative to the direction of flight - thus the energy in the vortex contributes to thrust rather than drag as it normally would. This is analogous to a sailing boat sailing very close to the wind. This small contribution can be very worthwhile on long distance flights.

Some types of aircraft, especially airliners, have winglets, for example the Airbus A340, and the Boeing 747-400. Other designs such as the Boeing 777 omit them, because the gain available is very small and would make the aircraft just too large for a standard airport gate. The designers of the 777 considered folding wingtips to accommodate winglets, but in the end, customers decided that the extra complexity of the wing did not justify it. Recently, blended winglets have been offered as an aftermarket retrofit for Boeing 737 and 757 aircraft by Aviation Partners Inc., allowing these aircraft improved performance and efficiency characteristics.

Some airlines have taken advantage of the fact that winglets are visible to many passengers onboard through the airplane's windows. One example is Southwest Airlines, which advertises its website address on the interior side of winglets on its 737-700s.



Aspect ratio (wing)

The low aspect ratio wing of a Piper PA-28 Cherokee

In aerodynamics, the **aspect ratio** is an airplane's wing's span divided by its standard mean chord (SMC). It can be calculated more easily, however as span squared divided by wing area: $AR = \frac{b^2}{S}.$

Informally, a "high" aspect ratio indicates long, narrow wings, whereas a "low" aspect ratio indicates short, stubby wings.

Aspect ratio is a powerful indicator of the general performance of a wing. Wingtip vortices greatly deteriorate the performance of a wing, and by reducing the amount of wing tip area, making it skinny or pointed for instance, you reduce the amount of energy lost to this process, and increase the lift generated by the wing. This is why high performance gliders have very long, skinny wings; with no engine power, they must be as efficient as possible in every respect in order to stay aloft.

High aspect-ratio wings reduce the amount of induced drag relative to the amount of lift produced.

Why don't all aircraft have high aspect-ratio wings? There are several reasons:

- **Structural**: the deflection along a high aspect-ratio wing tends to be much higher than for one of low aspect ratio, thus the stresses and consequent risk of fatigue failures are higher - particularly with swept-wing designs.
- **Maneuverability**: a high aspect-ratio wing will have a lower roll rate than one of low aspect ratio, due to higher drag and greater moment of inertia, thus rendering them unsuitable for fighter aircraft.
- **Stability** - low aspect ratio wings tend to be more naturally stable than high-aspect ratios. This confers handling advantages, especially at slow speeds.
- **Practicality** - low aspect ratios have a greater useful internal volume, which can be used to house the fuel tanks, retractable landing gear and other systems.

The high aspect ratio wing of a USAF B52 bomber

It is interesting to note that as with many discoveries in science and engineering, nature got there first. Most birds have wings with a high aspect ratio, and with tapered or elliptical tips. This is particularly noticeable on soaring birds such as the albatross and eagle. In addition, the V-formation (echelon) often seen in flights of geese, ducks and other migratory birds can be considered to act as a single swept wing with a very high aspect ratio - the vortices shed by the lead bird are smoothly transferred to the next and so on. This confers a huge efficiency advantage to the flight as a whole - perhaps as much as a 100% improvement compared to a single bird in flight. Note that the usual common explanation of the V-formation - that following birds are "shielded" from air resistance by the bird in front - may be misleading. While birds do "take turns" at being the lead bird, it is probably to give those at the tips a rest - they are the ones that will experience the most drag when the vortices are finally shed. However, the full explanation of this behaviour is still the subject of research and debate; scientists still do not claim to have fully understood the phenomenon.

Fuselage

The fuselage can be short, and seemingly unaerodynamic, as in this Christen Eagle 2

In an aircraft, the **fuselage** is the main body section that holds crew and passengers or cargo. In single engine aircraft it will usually contain an engine, athough in some amphibious aircraft the single engine is mounted on a pylon attached to the fuselage. The fuselage also serves to position control and stabilization surfaces in specific relationships to lifting .

Fuselages are constructed using three types of structures:

- A box truss structure. The structural elements resemble those of a bridge, with emphasis on using linked trianglular elements. The aerodyamic shape is completed by additional elements called formers and stringers and is then covered with fabric and painted. Most early aircraft used this technique with wood and wire trusses and this type of structure is still in use in many lightweight aircraft using welded steel tube trusses. This method is especially suitable for amateur built aircraft kits, where a complete welded truss structure is delivered with the fitting of other components, covering, and finishing completed by the user, as it ensures that a robust, uniform load bearing structure is within the completed aircraft.

The Vans RV-7 fuselage is slender for high speed flight

- A monocoque shell. In this, the exterior surface of the **fuselage** is also the primary structure. A typical early form of this was built using moulded plywood, where the layers of plywood are formed over a "plug" or within a mold, A later form of this structure uses fiberglass cloth impregnated with polyester or epoxy resin. A simple form of this used in some amateur built aircraft uses rigid expanded foam plastic with a fiberglass covering, eliminating the necessity of fabricating molds, but requiring more effort in finishing. An example of a moulded plywood aircraft is the De Havilland Mosquito light fighter/bomber of World War II. The use of molded fiberglass using negative molds (which give a nearly finished product) is prevalent in the series production of many modern sailplanes.

- Semi-monocoqe. This is the preferred method of constructing an all aluminum **fuselage**. First, a series of formers in the shape of the fuselage cross sections are held in position on a rigid fixture. These formers are then joined with lightweight longitudinal elements called stringers. These are in turn covered with a skin of sheet aluminum, attached by riveting or by bonding with special adhesives. The fixture is then disassembled and removed from the fuseleage, which is then fitted out with wiring, controls, and interior equipment such as seats and luggage bins. Most modern large aircraft are built using this technique, but use several large sections constructed in this fashion which are then joined with fasteners to form the complete **fuselage**. As the accuracy of the final product is determined largely by the costly fixture, this form is suitable for series production, where a large number of identical aircraft are to be produced. Early examples of this type include the Douglas Aircraft DC-2 and DC-3 civil aircraft and the Boeing B-17 Flying Fortress.


The forward double-deck fuselage of a South African Airways Boeing 747-400

V-tail

The V-tail of a Belgian Air Force Fouga Magister

In aircraft, a **V-tail** (sometimes called a "butterfly tail") is an unconventional arrangement of the tail control surfaces that replaces the traditional fin and horizontal surfaces with two surfaces set in a V-shaped configuration when viewed from the front or rear of the aircraft. The rear of each surface is hinged, and these movable sections (sometimes called "ruddervators") combine the tasks of the elevators and rudder. The arrangement was invented by Polish engineer Jerzy Rudlicki in 1930, and first tested on a modified Hanriot H-28 trainer in 1931.

The V-tail has not been a popular choice for aircraft manufacturers. The most popular V-tailed aircraft in mass production was the Beechcraft Bonanza Model 35, often known as the *V-tail Bonanza* or simply *V-Tail*. Another distinctive example is the F-117 Nighthawk stealth fighter, the French Fouga Magister trainer, and the Northrop YF-23 Black Widow II.

Advantages

With fewer surfaces than a conventional tail, the V-tail is lighter and produces less drag. The air flowing over the tail surfaces is also likely to be less turbulent. A V-tail tends to reflect radar at an angle that reduces the return signal, making the aircraft harder to detect. This is an advantage for military aircraft.

A V-tailed light aircraft: the Robin ATL L

Disadvantages

Combining the pitch and yaw controls is difficult and requires a more complex control system. The V-tail arrangement also places greater stress on the rear fuselage when pitching and yawing.

In the mid-1980s, the Federal Aviation Administration grounded the Beechcraft Bonanza due to to safety concerns. While the Bonanza met the initial certification requirements, it had a history of fatal mid-air breakups during extreme stress, at a rate exceeding the accepted norm. The type was deemed airworthy and restrictions removed after Beechcraft issued a structural modification as an Airworthiness Directive.

Tiltrotor

The Bell-Boeing V-22, an example of a **tiltrotor** aircraft

A **tiltrotor** aircraft combines the vertical lift capability of a helicopter with the speed of a turboprop aeroplane.

As the name implies, it uses tiltable (rotating) propellers, or *proprotors*, for lift and propulsion. For vertical flight the proprotors are angled to direct their thrust downwards, providing lift. In this mode of operation the craft is essentially identical to a helicopter. As the craft gains speed, the proprotors are slowly tilted forward, eventually becoming perpendicular to the ground. In this mode the wing provides the lift, and the wing's greater efficiency helps the tiltrotor achieve its high speed. In this mode, the craft is essentially a turboprop aircraft.

In vertical flight, the tiltrotor uses controls very similar to a twin or tandem-rotor helicopter. Yaw is controlled by tilting its rotors in opposite directions. Roll is provided through differential power or thrust. Pitch is provided through rotor cyclic or nacelle tilt. Vertical motion is controlled with conventional rotor blade pitch and either a conventional helicopter collective control lever (as in the Bell-Agusta BA-609) or a unique control similar to a fixed wing engine control called a thrust control lever (TCL) (as in the Bell-Boeing V-22 Osprey).

The tiltrotor's advantage is significantly greater speed than a helicopter. In a helicopter the maximum forward speed is defined by the speed that the rotor turns at; at some point the helicopter will be moving forward at the same speed as the backwards-moving side of the rotor is spinning, so that side of the rotor sees zero or negative airspeed, and begins to stall. This limits modern helicopters to cruise speeds of about 150 knots (277 km/h.) However, with the tiltrotor this problem is avoided, because the proprotors are perpendicular to the motion in the high-speed portions of the flight regime (and thus never suffering this reverse flow condition), meaning that the tiltrotor has relatively high maximum speed - over 300 knots (560 km/h) has been demonstrated in the two types of tiltrotors flown so far, and cruise speeds of 250 knots (460 km/h) are achieved.

This speed is achieved somewhat at the expense of payload. The two production tiltrotors flown so far have about half the payload of a helicopter with the same power and empty weight. As a result of this reduced payload, a tiltrotor does not exceed the transport efficiency (speed times payload) of a helicopter (reference 1). Additionally, the tiltrotor propulsion system is more complex than a conventional helicopter due to the large, articulated nacelles and the added wing; however, the improved cruise efficiency and speed improvement over helicopters is significant in certain uses. Speed and, more importantly, the benefit to overall response time is the principal virtue sought by the military forces that are using the tiltrotor. Tiltrotors are inherently less noisy in forward flight (airplane mode) than helicopters. This, combined with their increased speed, is expected to improve their utility in populated areas for commercial uses and reduce the threat of detection for military uses. Tiltrotors, however, are typically as loud as equally sized helicopters in hovering flight.

The advantages of the V/STOL capability of tiltrotors, particularly to the military, are still being evaluated. However, it is clear that for some military missions, such as rapid troop insertion/extraction and long range combat rescue, the tactical advantage of speed might well be worth the reduced payload capability. Tiltrotors also provide substantially greater cruise altitude capability than helicopters. Tiltrotors can easily reach 20,000 ft or more whereas helicopters typically do not exceed 10,000 ft altitude. This feature will mean that some uses that have been commonly considered only for fixed-wing aircraft can now be supported with tiltrotors without need of a runway. A drawback however is that a tiltrotor suffers considerably reduced payload when taking off from high altitude. Based on the approved flight manuals for each, the 50,000 lb class (22,600kg) V-22 Osprey carries the same payload as the 22,000 lb class (9,950kg) UH-60L Black Hawk helicopter when both operate from a landing zone at 10,000 feet above sea level.

Tiltrotor proprotors require all the fundamental parts of a twin rotor helicopter. They also have a full set of airplane controls, and they have a tilt mechanism that rotates the lifting rotors (while carrying flight loads). This means that the cost of a tiltrotor is typically 50 to 100% more than a helicopter of the same power and empty weight. For example, one V-22 Osprey is reported to cost more than $80 million without including development costs.

Several designs of such aircraft have been built, starting with the introduction of large turbine engines in the late 1950s. Two particularly successful designs were the Canadair CL-84 *Dynavert* tiltwing and the LTV XC-142 tiltwing. Both aircraft were technical successes, but neither entered production due to other issues. Another design philosophy was that instead of turning the wing, engine pods, or propeller shafts to horizontal and vertical, the entire aircraft could do the same. This resulted in the Ryan X-13 tailsitter, which never went into production. It was a ZLTO VTOL aircraft.

However, Bell Helicopter has been dominant in tiltrotor development with major designs from almost every decade back to the 1950s. They are currently partnered with Boeing on the first production tiltrotor aircraft, the jointly developed and manufactured, Bell-Boeing V-22 Osprey. Bell is developing commercial tiltrotors like the Bell-Agusta BA-609. Bell-Boeing is studying larger Quad Tilt Rotor military models for possible application to the US Army's Joint Heavy Lift program.

List of tiltrotorcraft

- V-22 Osprey
- Bell/Agusta BA609
- XV-15
- XV-3

Tiltwing

A **tiltwing** aircraft is similar to the tiltrotor V-22 Osprey. Whereas a tilt rotor rotates the prop from axial to dorsal, a tiltwing rotates the entire wing, not just the nacelles (as in the V-22) or prop and shaft. They are typically fully capable of VTOL operations.

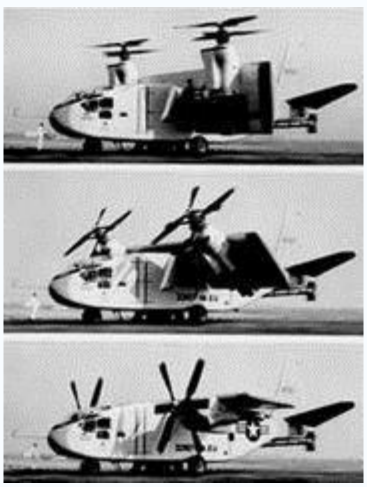
An advantage of tilt wing over tilt rotor is that when the rotors tilt up, the wings rotate so that they do not block the downward air.

Also, the rotation point is on the body of the aircraft instead of the wing tips. This means you do not have to send a shaft all the way down the wing length to cause the rotation, saving weight and complexity.

The Canadair CL-84 *Dynavert* was a successful tiltwing design that never went into production.

Hiller X-18

The **X-18** was an experimental cargo transport aircraft designed to be the first testbed for tiltwing and STOVL (short take off and vertical landing) technology.



The Hiller X-18, roatating its tiltwings

Ground testing the X-18 tiltwing

The X-18 showing its elaborate engine configuration


The X-18 with partially rotated tiltwings

Development

Design work started in 1955 by Stanley Hiller Jr and Hiller Aircraft Corporation received a manufacturing contract and funding from the U.S. Air Force to build the only X-18 ever produced.

To speed up construction and conserve money the plane was constructed from scavenged parts including a Chase C-122 Avitruc fuselage and the turboprops came from the Lockheed XFV-1 and Convair XFY-1 Pogo experimental airplanes program. The tri-bladed counter-rotating propellers were a giant 16 ft (4.8 m) 4.8 m across. The Westinghouse turbojet engine had its exhaust diverted upwards and downwards at the tail to give the plane pitch control at low speeds.

Service history

The first test flight wasn't until November 24, 1959, ultimately recording 20 flights out of Edwards AFB. A number of problems plagued the X-18 including being susceptible to wind gusts when the wing rotated, acting like a sail. In addition the turboprop engines were not cross-linked, so the failure of one engine meant the airplane would crash.

On the 20th and final flight in July 1961, the X-18 had a propeller pitch control problem when attempting to hover at 10,000 ft and went into a spin. The crew regained control and landed but the X-18 never flew again, however ground testing of the tiltwing concepts continued. Eventually a test stand that the plane was mounted on failed and the plane was severely damaged in the fall. The program was cancelled January 18, 1964 and the X-18 was cut up for scrap.

[Specifications (X-18)

General characteristics

- **Crew:** 2-3
- **Capacity:**
- **Length:** 63 ft 0 in (19.2 m)
- **Wingspan:** 48 ft 0 in (14.6 m)
- **Height:** 24 ft 7 in (7.5 m)
- **Wing area:** ft^2 m^2
- **Empty:** 26,786 lb (12,150 kg)
- **Loaded:** lb (kg)
- **Maximum takeoff:** 33,000 lb (14,850 kg)
- **Powerplant:**
  - 2x Allison T40-A-14 turboprop, 5,500 hp (4,100 kW) each
  - 1x Westinghouse J34 turbojet for pitch control, 3,400 lbf (15.2 kN) thrust

Performance

- **Maximum speed:** 253 mph (407 km/h)
- **Range:** miles (km)
- **Service ceiling:** 35,300 ft (10,800 m)
- **Rate of climb:** ft/min (m/min)
- **Wing loading:** lb/ft² (kg/m²)
- **Power/mass:**

Aerobatics

The Frecce Tricolori aerobatics team of the Italian Air Force, flying at the Royal International Air Tattoo, Fairford,

In the early days of flying, pilots realised that their aircraft could be used as part of a flying circus to entertain people or impress others by performing **aerobatics**. Maneuvers that had no practical purpose were flown for artistic reasons or to draw gasps from onlookers. In due course some of these maneuvers were found to allow aircraft to gain tactical advantage during aerial combat or "dog fights" between fighter aircraft. The word presumably derives from the term used by human gymnasts - acrobatics - to describe exercises designed to impress or build muscle strength.

All aerobatic maneuvers involve rotation of the aircraft about its longtitudinal axis - rolling - or the pitch axis - looping. Some complex maneuvers - such as a spin - also require that the aircraft be displaced around a vertical axis, known as yaw. Maneuvers are often compounded which demands a higher level of skill from the pilot, but greatly increases the spectacle of an aerobatic flight sequence.

Formation aerobatics are usually flown by teams of up to sixteen aircraft, although economic considerations mean that most teams habitually fly between four and ten aircraft. Some are state funded to reflect pride in the armed forces whilst others are commercially sponsored. Coloured smoke trails may be emitted to emphasise the patterns flown and/or the colours of a national flag. Usually each team will use aircraft similar to one another finished in a special and dramatic colour scheme, thus emphasising their entertainment function.

Famous teams include the Turkish Stars (Türk Yıldızları), Brazil Air Force Demonstration Squadron (Esquadrilha da Fumaça), Black Arrows, Blue Angels, Diables Rouges, Frecce Tricolori, Halcones, Patrouille de France, Patrouille Suisse, Red Arrows, Red Pelicans, Rothmans, Silver Falcons, Roulettes, Royal Jordanian Falcons, the USAF Thunderbirds, Snowbirds, the Patrulla Aguila from Spain and the Yellowjacks.

Teams often fly V-formations - they can't fly directly behind another aircraft, or they'd get caught in the wake vortices or engine exhaust. Aircraft will always fly slightly below the aircraft in front, if they have to follow exactly in line.

The UK Utterly Butterly display team perform an aerobatic maneuvre with their Boeing Stearmans, at an air display in England.

Aerobatic aircraft usually fall into two categories - specialist aerobatic, and aerobatic capable. Specialist designs such as the Pitts Special, the Extra 200 and 300, and the Sukhoi Su-29 aim for ultimate aerobatic performance. This comes at the expense of general purpose use such as touring, or ease of non aerobatic handling such as landing. At a more basic level, *aerobatic capable* aircraft can be dual purpose - equipped to carrying passengers and luggage, easy to land, as well as being capable of basic aerobatic figures.

Aerobatics is taught to military fighter pilots as a means of developing precise flying skills and for tactical use in combat.

Aerobatics is also practiced as a sport. Some pilots fly solely for recreation, whilst a smaller number (about 600-800 in the USA) choose to compete in aerobatic competitions. US Competitions start at 'Primary ' level and proceed in complexity through Sportsman, Intermediate and Advanced, with 'Unlimited' being the top competition level. Unlimited pilots perform much more complex figures and sustain higher g levels (+/- 10g's). A sample competition sequence is described here, along with a good description of how it should be flown.

Aerobatic maneuvers flown in a jet powered aircraft are limited in scope as they cannot take advantage of the gyroscopic forces that a propellor driven aircraft can exploit. Jet powered aircraft also tend to fly much faster which increases the size of the figures and the length of time which the pilot has to withstand increased g-forces. Jet aerobatic teams often fly in formations which further restricts the maneuvers that can be safely flown.

All aerobatic maneuvers demand proper training and regular practice to avoid accidents. Fortunately such accidents are rare but can result in fatalities; safety regulations are such that there has not been an airshow spectator fatality in the USA since the 1950s. Low-level aerobatics are extremely demanding and airshow pilots must demonstrate their ability before being allowed to gradually reduce the height at which they may fly their show.


Red Arrows Hawks in Concorde formation

Aerobatics are most likely to be seen at a public airshow.

a considerable amount of complexity, and also reduces weight to some degree.

In addition the radial is far more resistant to damage; if the block cracks on an inline that entire cylinder bank will lose power, but the same situation on a radial will often only make that individual cylinder stop working.

These sorts of advantages – light weight and reliability – suggest that the radial layout is a natural fit for aircraft uses. However the radial design also has two important disadvantages. One is that any supply of compressed air (from a turbocharger or supercharger) has to be piped around the entire engine, whereas in the inline only one or two pipes are needed, each feeding an entire cylinder bank. The other disadvantage is that the frontal area of the radial is always much larger than the same displacement inline, meaning that the radial will often have greater drag. For a low-speed plane this is not very important, but for fighter aircraft and other high-speed needs, this was initially a "killer problem," but was mitigated significantly with the introduction of the NACA cowling in the late 1920s. The large frontal area combined with the durability of radial engines proved advantageous to fighter aircraft at times though, particularly those in the attack role where the engine would act as an additional layer of armor for the pilot.

The debate about the merits of the radial vs. the inline continued throughout the 1930's, with both types seeing at least some use. The radial tended to be more popular largely due to its simplicity, and most navy air arms had dedicated themselves to the radial because of its improved reliability (very important when flying over water) and lighter weight (for carrier takeoffs).

In the mid-1930s a new generation of highly streamlined high-speed aircraft appeared, along with more powerful inline engines like the Rolls Royce Merlin and Daimler-Benz DB 601. This re-opened the debate anew, with the needs of streamlining often winning out. However the Focke-Wulf Fw-190 and the Lavochkin La-5 and La-7 showed that a radial engine fighter could compete with the best of the inlines, given a proper installation. From that point on many new designs used radials, and after the war the inlines quickly disappeared from the now-smaller aircraft market.

Originally radial engines had but one row of cylinders, but as engine sizes increased it became necessary to add extra rows. Most did not exceed two rows, but the largest radial engine ever built in quantity, the Pratt & Whitney Wasp Major, was a 28-cylinder 4-row radial engine used in many large aircraft designs in the post-World War II period.

At least two companies build modern radials today: a 110 horse power 7 cylinder and 150 horse power 9 cylinder from Australia's Rotec Engineering and Gesoco Industries Inc. offers a 360 horse power 9 cylinder.

VTOL

Vertical Take-Off and Landing (VTOL) describes airplanes that can lift off vertically. This classification includes only a very few aircraft; helicopters, autogyros, balloons and airships are not considered VTOL. Some aircraft can operate in VTOL mode in addition to others, such as CTOL (Conventional Take-off and Landing). Others can only operate by VTOL, due to the aircraft lacking landing gear that can handle horizontal motion.

In 1928, Nikola Tesla received patents for an apparatus for aerial transportation. Tesla called it the "*Flivver*". It is one of the earliest examples of VTOL aircraft. In the late 1950s and early 1960s almost all fighter aircraft designed included some VTOL features. This was a response to the worrying possibility that a first-strike against airfields by nuclear armed bombers would leave a country open to attack by following bombers. The "solution" was to use VTOL fighters that could be moved to open fields around the countryside, making them immune to widespread destruction.

In reality the costs of VTOL performance were huge, and while it turned out to be fairly easy to move the plane, moving the support equipment and fuel was not so easy. By the mid-1960s interest in VTOL had faded, perhaps due much to the widespread introduction of ICBMs as the main nuclear delivery system.

Currently there are believed to be two types of practical VTOL aircraft in operation:

- Bell Boeing V-22 Osprey "tilt-rotor" and the
- British Aerospace Harrier "Jump jet" (or its updated American-built counterpart, the Boeing AV-8B Harrier II)

An early VTOL prototype was the so-called "flying bedstead".

The Harrier is often flown in STOVL mode which enables it to carry a higher fuel or weapon load over a given distance. It was developed from the Hawker P.1127 and Kestrel. The Indian and Spanish Navies operate Sea Harriers, mainly from aircraft carriers.

The United States Marine Corps uses a license-built derivative of the Harrier. NASA has flown other VTOL craft such as the XV-15 research craft, as have the Soviet Navy and *Luftwaffe*. Sikorsky tested an aircraft dubbed the X-Wing, which took off in the manner of a helicopter. The rotors would become stationary in mid-flight, and function as wings, providing lift in addition to the static wings. Boeing X-50 is a Canard Rotor/Wing prototype

The Harrier will be replaced in the air arms of the US and UK by a STOVL variant of the F-35 Joint Strike Fighter.

In the 1960s France developped a version of the Dassault Mirage III capable of attaining Mach 1. The Dassault Mirage III - V *Balzac* (not to be confused with the Mirage 5) achieved transition from vertical to horizontal flight in March of 1966 and reached Mach 1.3 in level flight a short time later.

The Soviet Yak-38 Forger was the Soviet Navy's VTOL aircraft for their light carriers, cargoships, and capital ships. It was developed from the Yak-36 Freehand experimental aircraft. Before the Soviet Union collapsed, a supersonic VTOL aircraft was developed as the Yak-38's successor, the Yak-141, which never went into production.

The Moller Skycar is a prototype personal VTOL aircraft -- literally, a "flying car".

Aircraft designed to operate in extraterrestrial environments often utilize VTOL. An example of this type of aircraft is the LLRV. Spacecraft typically operate in environments where runways or even a suitably flat surface for skids is nonexistent.

STOL

STOL is an acronym for *Short Take-Off and Landing*, used in the aircraft industry to describe airplanes with very short runway requirements. Most STOL aircraft are bush planes, though some, like the de Havilland Dash-7, are designed for use on prepared airstrips; likewise, most STOL aircraft are taildraggers, though there are some famous exceptions like the de Havilland Twin Otter and the Peterson 260SE.

Runway length requirement is a function of the square of the minimum flying speed (stall speed), and most design effort is spent on reducing this number. For takeoff, large power/weight ratios and low drag help the plane to accelerate for flight. The landing run is minimized by strong brakes, low landing speed or spoilers (less common). Overall STOL performance is set by the length of runway needed to land or take off, whichever is longer.

Of equal importance to short ground run is the ability to clear obstacles, such as trees, on both take off and landing. For takeoff, large power/weight ratios and low drag result in a high rate of climb required to clear obstacles. For landing high drag allows the airplane to descend steeply to the runway without building excess speed resulting in a longer ground run. Drag is increased by use of flaps (devices on the wings) and by a forward slip (causing the airplane to fly somewhat sideways though the air to increase drag).

Normally, a STOL plane will have a large wing for its weight. These wings often use aerodynamic devices like flaps, slats, and vortex generators. Typically, designing an airplane for excellent STOL performance reduces maximum speed, but does not reduce payload lifting ability. The payload is critical, because many small, isolated communities rely on STOL aircraft as their only transportation link to the outside world for passengers or cargo; examples include many communities in the Canadian north and Alaska.

Most STOL planes can land either on- or off-airport. Typical off-airport landing areas include snow or ice (using skis), fields or gravel riverbanks (often using special fat, low-pressure tundra tires), and water (using floats): these areas are often extremely short and obstructed by tall trees or hills. Wheel skis and amphibious floats combine wheels with skis or floats, allowing the choice of landing on snow/water or a prepared runway. A STOLPORT is an airport designed with STOL operations in mind, normally having a short single runway. These are not common but can be found, for example, at London City Airport, London, England.

List of STOL aircraft

- Antonov An-72
- BAe 146
- Fieseler Fi 156
- de Havilland Beaver
- de Havilland Twin Otter
- de Havilland Dash-7
- Helio Courier
- Pilatus PC-6
- Piper Cub
- PZL Wilga
- Maule
- Wren 460 and Peterson 260SE
- Westland Lysander
- Zenair CH 701 STOL

CTOL

Conventional Take-off and Landing is the process whereby conventional aircraft (such as passenger aircraft) take off and land, involving the use of runways. The aircraft will taxi along the runway until its rotation speed is reached, then climb into the air. During landings, the aircraft will touch the ground while still traveling at a significant forward velocity.

Seaplanes, instead of using runways, use water.

STOVL

STOVL is an acronym for **S**hort **T**ake **O**ff and **V**ertical **L**anding.

This is the ability of some aircraft to take off from a short runway, and land vertically (i.e. with no runway). This is often accomplished on aircraft carriers through the use of "ski-jump" runways, instead of the conventional catapult system. STOVL use tends to allow aircraft to carry a larger payload as compared to during VTOL use, while still only requiring a short runway. The most famous example is probably the Hawker-Siddeley Harrier Jump Jet, which though technically a VTOL aircraft, is operationally a STOVL aircraft due to the extra weight it carries at take off for fuel and armaments. The same is true of the F-35 Joint Strike Fighter, which demonstrated VTOL capability in test flights but is operationally STOVL.

Other examples include:

- EWR VJ 101C (Germany)
- Dassault Mirage III V (France)
- Yakovlev Yak-38 (USSR)
- Yakovlev Yak-141 (USSR)

Except Yak-38, none of these has reached operational status, though the JSF is expected to enter service by 2010.

VTOHL

Vertical Take-Off Horizontal Landing describes planes that can lift off vertically but land in the traditional manner. While many VTOL aircraft can operate in this fashion, some planes must land normally after taking off vertically due to a vertical landing either being impossible (requiring a structure to orient it vertically for take off) or impractical (compexities and power requirements in descending on engine power with no horizontal velocity).

Examples include the German rocket plane, Heinkel P.1077, and Space Shuttle.

STOL

V/STOL is an acronym for **Vertical/Short Take-Off and Landing**. **V/STOL** aircraft can take-off or land vertically or on short runways. The Hawker-Siddeley Harrier is perhaps the most famous production **V/STOL** aircraft.

V/STOL has been replaced by STOVL in popularity because it reduces the amount of thrust required to lift a fully laden aircraft from the ground, and hence allows a greater load to be carried. For instance, the Harrier is incapable of taking off vertically with a full weapons and fuel load, and hence is operated as STOVL wherever possible.

STOBAR

STOBAR (**S**hort **T**ake **O**ff **B**ut **A**rrested **R**ecovery) is a system used for the launch and recovery of aircraft from the deck of an aircraft carrier, combining elements of both STOVL and CTOL. Aircraft launch under their own power using a ski-jump to assist take-off (rather than using a catapult like most carriers). However, these are conventional, rather than STOVL aircraft, and thus require arrestor wires to land on the ship. The Russian Navy aircraft carrier *Admiral Kuznetsov* is the most prominent current example of a STOBAR carrier.

When the Eurofighter was proposed for the "Future Carrier Borne Aircraft" it was envisaged that it would operate in a STOBAR configuration. The FCBA is to be deployed on the Royal Navy's next generation carriers, CVF.

JATO

BMQ-74E Chukar target drone using JATO

JATO is an acronym for *Jet Assisted Take Off*. The term is used interchangeably with the (arguably more accurate) **RATO** (for *Rocket Assisted Take Off*). It is a system for helping overloaded planes into the air by providing additional thrust in the form of small rockets. See also assisted take off

Early experiments with using rockets to boost sailplanes into the air were conducted in Germany in the 1920s, but practical JATO systems were first introduced by the RAF early in World War II. These used fairly large solid fuel rockets to shoot planes (typically the Hawker Hurricane) off a small ramp fitted to the fronts of merchant ships in order to provide some cover against German spotter planes. After firing, the rocket was released from the back of the plane to fall into the water (and sink). The pilot would later parachute from the plane, hopefully to be picked up by one of the escort vessels.

The Luftwaffe also used the technique in order to help their small bombers into the air with loads that would have made the takeoff run too long otherwise. This became especially important late in the war when the lengths of usable runways were severely curtailed due to the results of Allied bombing. Their system typically used Walter HWK 500 *Starthilfe* ("start-help") rocket engines driven by breaking down hydrogen peroxide. A parachute at the front of the motor was used to slow its fall after being released from the plane, so the system could be re-used. Other German experiments with JATO were aimed at assisting the launch of interceptor aircraft such as the Messerschmitt Me 262 so that they could reach enemy bomber formations sooner. Similar experiments were carried out in the late 1950s in the USSR, with a modified MiG-19 fighter, designated SM-30, launched from a special launcher, using rocket booster.

After World War II JATO became particularly common owing to the low slow-speed thrust of then-current jet engines. As the quality and power of the engines has grown, JATO has fallen from favour. It is still used, however, when heavily-laden aircraft need to take off from short runways.

The US Navy demonstration team, The Blue Angels, use JATO rockets to launch the C-130 'Fat Albert' in under 1500 feet.

Operation Credible Sport was a United States military operation plan in late 1980 to rescue hostages held by Iran using C-130 cargo planes modified with rocket engines to enable a very short take off and landing. The plan was cancelled.

In all of these cases the term "jet" is inaccurate and the system is more accurately called *RATO*. However *JATO* remains the most popular version, apparently due to its US origin.

The JATO Rocket Car is a famous urban legend that relates the story of a car equipped with JATO units for a lark, that is later found smashed into a mountainside. This story is often given as an example of a Darwin Award; however it appears to be apocryphal, with no basis in fact. A particularly elaborate form of this legend has been promulgated by hacker group CULT OF THE DEAD COW in the ostensibly autobiographical story "Rocket Car". This legend was convincingly debunked in 2003 on the Discovery Channel show *MythBusters*. They replicated the scene and the thrust of the JATO with some commercially-available amateur rocket motors. The car did go very fast, maybe 150 MPH, but did not go anywhere near 300 MPH, and did not become airborne. However, a nearly verbatim copy of the cDc version is detailed here, involving a car frame attached to an old mine railcar and a JATO rocket as described in the Cult of the Dead Cow version. The reader must determine whether the presence of two such accounts amounts to verification or copying.

Zero length launch

The **zero length launch system** or **zero length take-off system** was a system whereby jet fighter-interceptors were placed upon rockets attached to launch platforms. In the event of a sudden Soviet attack across the German plains that would overrun and devastate Western European airfields, a credible air defence could still be launch from the forests of Germany through strategically placed fighters that launched without a runway by rocket.